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Original Scientific Paper

# DESIGN AND FABRICATION OF AN ON-FARM MULTIPURPOSE CABINET DRYER

# PROJEKTOVANJE I IZRADA FARMSKE MULTIPRAKTIČNE ŠARŽNE SUŠARE

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## ABSTRACT

*The design and fabrication of an on-farm multipurpose cabinet dryer were carried out to address the drying needs of small and medium-scale farmers by providing an efficient, mobile, and sustainable solution for post-harvest processing. The dryer operates with a required air volume of 31.8 m³/min, powered by a blower with a speed of 36,083 rpm, a pressure coefficient of 0.65, and a flow coefficient of 0.69, requiring 162 kW of power input. Heat transfer calculations indicated conduction heat transfer of 21,600 W/m.K, convection at 5.8 x $10^5$ W/m².K, and radiation at 1.85 x $10^{21}$ W/m², with an overall heat transfer coefficient of 1.85 x $10^{21}$ W/m².K. The energy source for the dryer is solid fuel, and the design incorporates a lagged drying chamber to minimize heat loss. A fan is mounted on top of the chamber for regulated exhaust of humid air, while solar power operates the fans for energy efficiency. Mobility is enhanced through two wheels, and the blower is connected to the heat exchanger through a frustum-shaped vacuum to ensure even air distribution. Key considerations included the availability of materials, cost, and durability, resulting in an efficient, cost-effective, and sustainable drying solution suitable for on-farm and off-farm operations. This dryer is expected to significantly improve crop drying processes, enhance productivity, and reduce post-harvest losses.*

***Keywords-*** *On-farm drying, cabinet dryer, solid fuel energy, mobile dryer, solar-powered fans*

## APSTRAKT

*Dizajn i izrada višenamenskog sušača za farmu realizovani su kako bi se zadovoljile potrebe sušenja malih i srednjih poljoprivrednika, pružajući efikasno, mobilno i održivo rešenje za preradu nakon berbe. Sušač radi sa potrebnim protokom vazduha od 31,8 m³/min, pokretan je ventilatorom sa brzinom od 36.083 obrtaja u minuti, koeficijentom pritiska od 0,65 i koeficijentom protoka od 0,69, zahtevajući 162 kW ulazne snage. Proračuni prenosa toplote ukazuju na provodni prenos toplote od 21.600 W/m.K, konvekciju od 5,8 x $10^5$ W/m².K i zračenje od 1,85 x $10^{21}$ W/m², sa ukupnim koeficijentom prenosa toplote od 1,85 x $10^{21}$ W/m².K. Izvor energije za sušač je čvrsto gorivo, a dizajn uključuje izolovanu komoru za sušenje kako bi se minimiz gubici toplote. Ventilator je postavljen na vrhu komore za regulisano izduvavanje vlažnog vazduha, dok solarna energija pokreće ventilatore radi energetske efikasnosti. Mobilnost je poboljšana pomoću dva točka, a ventilator je povezan sa razmenjivačem toplote kroz vakuum u obliku frustuma kako bi se obezbedila ravnomerna distribucija vazduha. Ključna razmatranja uključivala su dostupnost materijala, cenu i dugotrajnost, što je rezultiralo efikasnim, isplativim i održivim rešenjem za sušenje, pogodnim za rad na farmi i van nje. Ovaj sušač se očekuje da značajno poboljša procese sušenja useva, poveća produktivnost i smanji gubitke nakon berbe.*

***Ključne reči:*** *Sušenje na farmi, kabinet sušač, energija čvrstog goriva, mobilni sušač, ventilatori na solarnu energiju*

## INTRODUCTION

One of the first ways to preserve food was by drying it. Even before there were any written records, primitive societies used to dry meat and fish in the sun. As a method of food preservation, food drying is still significant today. Long periods of time can pass without dried foods degrading in storage (Rahman, 2010). This is mostly since germs that cause food to deteriorate, and spoil cannot grow and proliferate without adequate water, and many of the enzymes that inadvertently alter the chemical composition of food cannot function without it (Jay et al., 2005). Although drying often occurs in conjunction with other procedures, preservation is the main motivation for drying. For example, heat expands gasses during bread baking, changes the structure of the protein and starch, and dries the loaf. Unwanted moisture losses can also occur during the curing of cheese or during the freezing or fresh storage of meat. Countless other moist food products can also lose moisture when they are held in the air (Rahman, 2020).

Foods are said to be dried when the water has been removed. The latent heat of vaporization must be provided to vaporize the water that is present in the food, which is how drying is often performed (Khurmi and Gupta, 2011). Hence, the unit operation of drying is influenced by two key process-controlling factors: moving water or water vapor through the food item and subsequently away from it, as well as transferring heat to produce the necessary latent heat of vaporization. Rajput (2011) asserts that this temperature determines the amount of energy required to evaporate the water at any given temperature. The latent heat of vaporization, if it comes from a liquid, or the latent heat of sublimation, if it comes from a solid, is the amount of energy needed per kilogram of water. Since steam and water vapor are the same thing, the latent heat listed in the steam table can be used to calculate the amount of heat energy needed to evaporate water under any set of circumstances.

The potential (temperature) differential and the properties of the transfer system, as shown by the heat-transfer coefficient, both affect the rate of heat transfer. A temperature differential creates the driving force for the movement of heat energy in heat transfer. The mass moves due to the same driving force that a partial pressure or concentration difference gives (Faghri et al., 2010). The rate of mass transfer is affected by the potential (pressure or concentration) differential as well as the properties of the transfer system, which are represented by a mass-transfer coefficient.

Both natural and artificial drying techniques are used in the drying process. According to Stephen and Emmanuel (2009), the natural drying method basically entails letting the threshed product air dry in either the sun or the shade. The grain is spread out in thin layers on a dry floor and left to air (in either the sun or the shade) for a maximum of 10 to 15 days in order to achieve the required moisture content. The grain needs to be stirred often to promote even drying, particularly if it is exposed to direct sunlight. The other artificial technique involves subjecting the grain to a forced ventilation of air that has been heated to a specific temperature in special devices known as "dryers."

Solid fuels have been widely used as a source of energy for centuries, playing a crucial role in heating, cooking, and industrial processes. However, the choice of solid fuel can have significant implications for energy efficiency, environmental impact, and sustainability (Dinesha et al., 2019).

A potential research gap in this topic could be the exploring and optimization of energy-efficient drying methods and technologies within the context of on-farm applications. This could investigate how different drying techniques, such as solar, alternative heat source, hybrid systems, can be integrated into the design of the cabinet dryer to enhance its performance and reduce energy consumption while maintaining drying quality across various agricultural products.

This study is based on both the study and development of the multipurpose agricultural on-farm cabinet dryer, using solid fuels as source of heat and a solar electrical battery for the blower and aspirator.

## Nomenclature:

| | | |
|---|---|---|
| Absolute temperatures of the surfaces | $T_1$ and $T_2$ | K or °R |
| Acceleration due to gravity | g | m/s$^2$ |
| Air density | $\rho$ | Kg/m$^3$ |
| Airflow rate | Q | M$^3$/s |
| Cross-sectional area | A | m² or ft² |
| Diameter of impeller | d | M |
| Emissivity of the surface | ε | Dimensionless |
| Flow coefficient | $\emptyset$ | Dimensionless |
| Head change | h | m |
| Heat load | Q | W or Btu/hr |
| Heat transfer rate | Q | W or Btu/hr |
| Load | t | sec |
| Mass | m | Kg |
| Power | P | W=J/s |
| Pressure coefficient | $\varphi$ | Dimensionless |
| Specific heat capacity | C | J/kg°C |
| Specific speed | Ns | Dimensionless |
| Speed of motor | $\omega$ | rpm |
| Static pressure | $P_s$ | Pa = N/m$^2$ |
| Stefan-Boltzmann constant | σ | 5.67 x 10$^8$ W/ (m$^2$K$^4$) |
| Temperature difference | ΔT | K or °F |
| Thermal conductivity of the material | k | W/mK or Btu/(hr·ft·°F) |
| Thickness of the material | d | m or ft |
| Volume | V | M$^3$ |
| Width of the impeller | w | M |
| Efficiency | $\eta$ | Dimensionless |

# MATERIALS AND METHODS

### Description of the dryer

The multipurpose purpose cabinet dryer operates under a forced flow of air and a counter flow also. The constructed dryer is equipped with square shaped heat exchangers as shown in figure 1 (6). The heat exchangers help to transfer heat by conduction to the material to be dried through the frustum shaped diffuser in figure 1 (4). A blower as shown in figure 1 (7) is attached to the heat exchanger for a general diffusion of the heat which is sent to the material to be dried by conduction. The drying unit is made of stainless to prevent corrosion and contamination. After heat must have been well circulated, the excess heat is extracted by the aspirator or fan to prevent condensation. This process repeats its cycle till drying occurs.

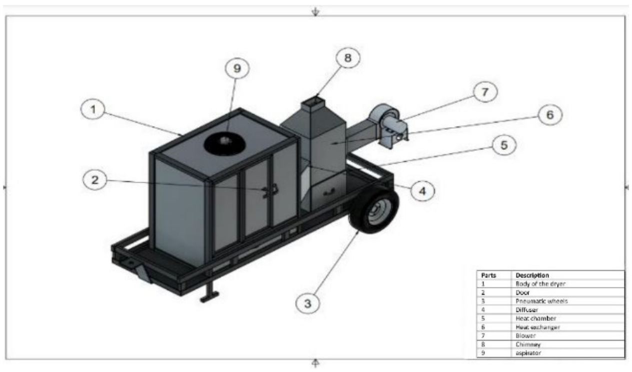


*Fig. 1. Isometric view of the designed multipurpose cabinet dryer*

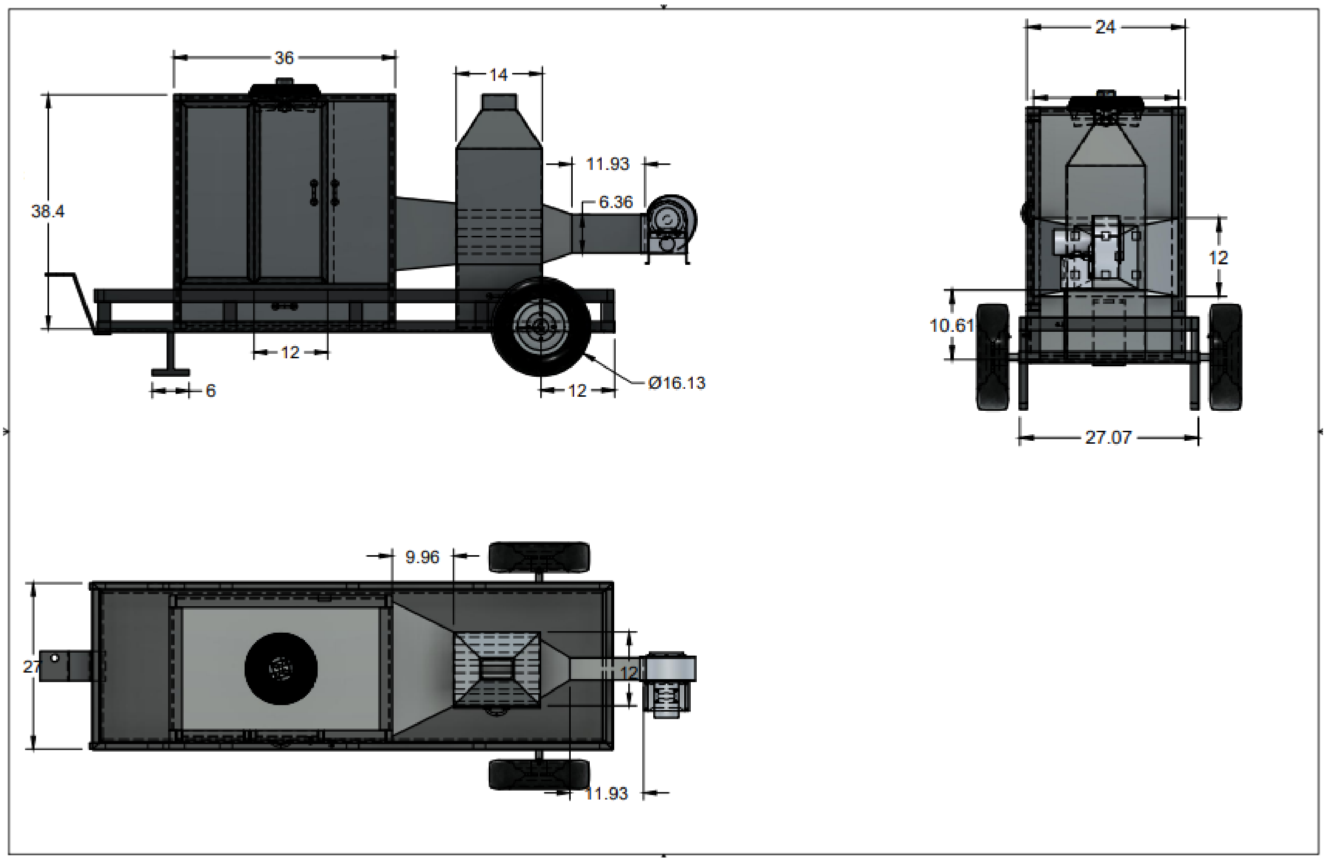


*Fig. 2. Orthographic view of the designed multipurpose cabinet dryer*

1. **Body of the dryer:** The body of the drying chamber which is measured 3ft x 2ft x 3.12ft in length, width and height respectively. It is made from stainless steel due to its resistance to corrosion and contamination, whereas the outer part of the drying chamber is made from 2mm mild steel. In between the stainless and mild steel, a 2mm fiber glass material is used to lag the dryer to prevent heat loss. The drying chamber has a hollow frustum shape allowing for the even distribution of air in the drying chamber. The heat exchanger is attached to the frustum.
2. **Door:** The door measures a total of 2ft by 20in and the door is divided in two for flexible opening at the center measuring a total of 10in each. The outer part of the door is made from mild steel while the inner part of the door is made of stainless steel 2mm each. Fiber glass lagging of 1 inch was incorporated in between the mild steel and stainless steel of the door. The door has a handle made from 1 x 1in angle bar of 4in length with properly curved edges to prevent injury. The door uses a total of four hinges, positioned in twos on each equally sectioned division of the door. The hinge measures 3in in distance from the top and bottom of the door which is incorporated on both sides. From the door, the materials to be dried in introduced into the drying chamber.
3. **Pneumatic Wheels:** The dryer uses a pair of wheels which are made from rubber and have a diameter of 13in and 6in rim. The wheels aid mobility.
4. **Diffuser:** The diffuser has a hollow frustum shape allowing for the even distribution of air in the drying chamber.
5. **Heating Chamber:** It is made from a mild steel. It is measured 14in ×12in × 5in. It is in a form a tray where the solid fuel will be placed. The bottom part of the tray is drilled to ensure the inlet of oxygen during combustion.
6. **Heat Exchanger:** The heat exchanger is from 1 x 2in square pipe having a length of 23in. The pipes are positioned in a stack bond method having mild steels 10 x 12in apart vertically and horizontally and lagged 1inch around. The heat exchange is enclosed in a box measured (14×12×20) in.
7. **The Blower:** the blower having a horse power of 0.25hp and having 230VAC, 450V, 0.4A, 50/60hz is attached to one end the heat exchanger to incorporate the forced flow of air into the drying chamber.
8. **The chimney:** It is measured (4×2×1) in and is made from mild steel. It said the escape of exhaust cases.
9. **Fan.** The centrifugal fans are used and placed at the top of the drying chamber to prevent condensation back to the drying material.
10. **The Chassis and Tow Hitch:** The chassis and tow hitch are made from 2 x 2in square pipes. The chases after construction measures 4ft x 3ft in length and breadth respectively.

### Theoretical design consideration

The following was considered during the design.

The energy required for the drying should be generated from solid fuels.

The drying chamber should be lagged to prevent heat loss and is designed to be operated by one person.

A fan is placed at the middle top on the dryer and aid the quick and regulated escape of humid air.

The power requirement for the fans will be solar powered. The two wheels of the dryer are to enable the mobility of the dryer to ease on-farm and off-farm drying.

The available quantity and cost of prospective construction materials were taken into consideration.

The tyres are positioned away from the heat exchangers to prevent damage.

The blower is attached to the heat exchanger through a frustum shaped vacuum for the even distribution of air to the heated tubes (heat exchangers).

### Design of the blower

Centrifugal blower is commonly used in threshers. A centrifugal blower has a moving impeller that consists of a central shaft with a positioned set of blades 90º to the air outlet and spin the air outwards to the outlet (by deflection and centrifugal force). The blower impeller and housing are the most important parts of the blower components (Hicks, T. G., 2006).

Impeller diameter and width of the blower may be computed for a given set of statis pressure and airflow rate as shown below:

a) *Computation of Specific Speed*

$$Ns = \frac{\omega\sqrt{Q}}{{P_s}^{0.75}} \quad (1)$$

Where, Ns = Specific speed
$\omega$ = speed of motor, rpm
Q = Airflow rate
cfm and $P_s$ = Static pressure, inches in water gauge

b) *Computation of Flow and Pressure Coefficient*

Using the graph of specific speed against static efficiency of various impellers to determine the type of air moving unit which would operate at high efficiency, at or near peak efficiency at the calculated specific speed. Other factors such as relative cost, size and shape of space available and characteristics of the airflow path are used to make final selection if more than one type of air moving unit has good efficiency.

c) *Computation of the Impeller Diameter*

$$d = \frac{1}{\omega}\left(\frac{2.35*10^8*Ps}{\emptyset}\right)^{\frac{1}{2}} \quad (2)$$

Where: d = diameter of impeller and
$\varphi$ = pressure coefficient

d) *Computation of the Width*

$$w = \frac{175Q}{\emptyset*\omega*d^2} \quad (3)$$

Where: $\emptyset$ = flow coefficient
w = width of the impeller (Singh, 2000).

e) Determination of the Power Output of the Blower

The power output (P) to the blower is given as:

$$P = \rho Qgh \quad (4)$$

Where: $\rho$= Air density
g = Acceleration due to gravity
h = Head change.

### Design of the heat exchanger

The heat exchanger was constructed from a 1 x 2in square pipe having a length of 23in. The pipes are positioned in a stack bond method having mild steels 10 x 12in apart vertically and horizontally and lagged 1in around. The bottom of pipe has a tray where the solid fuel is placed, and the top has an outlet for the escape of exhaust fumes. The heat source in the machine is generated from solid fuels. Analyzing the heat transfer mechanism include:

a) *Conduction*

Conduction refers to heat transfer through a solid material without the movement of the material itself. It follows Fourier's law of heat conduction:

$$Q = -k * A * (\Delta T / d) \quad (5)$$

Where: Q = heat transfer rate (W or Btu/hr)
k = thermal conductivity of the material (W/mK or Btu/(hr·ft·°F))
A = cross-sectional area through which heat flows (m² or ft²)
ΔT = temperature difference across the material (K or °F)
d = thickness of the material (m or ft)

b) *Convection*

Convection involves the transfer of heat through a fluid (liquid or gas) by the movement of the fluid itself. The heat transfer rate due to convection can be calculated using Newton's Law of Cooling for forced convection:

$$Q = h\ A\ \Delta T \quad (6)$$

Where: Q = heat transfer rate (W or Btu/hr)
h = convective heat transfer coefficient (W/(m²K) or Btu/(hr·ft²·°F))
A = surface area through which heat flows (m² or ft²)
ΔT = temperature difference between the surface and the surrounding fluid (K or °F)

c) *Radiation*

Radiation is the transfer of heat through electromagnetic waves. The Stefan-Boltzmann Law describes the radiative heat transfer rate between a surface and its surroundings:

$$Q = \varepsilon * \sigma * A * (T_1^4 - T_2^4) \quad (7)$$

Where: Q = radiative heat transfer rate (W or Btu/hr)
ε = emissivity of the surface (dimensionless)
σ = Stefan-Boltzmann constant (5.67 x $10^8$ W/ (m²K⁴))
A = surface area (m² or ft²)
$T_1$ and $T_2$ = absolute temperatures of the surfaces (K or °R)

Overall heat transfer coefficient, U

$$Q = UA\Delta T \text{(this equation serves as the definition of U)} \quad (8)$$
$$= UA(T_{b1} - T_{b2}).$$

Where A = area of heat transfer (not always unambiguous)
$\Delta T$ = driving temperature difference
(Khurmi, R. S., & Gupta, J. K. 2011; Faghri et al., 2010)

### Design of the heating chamber

The design and specifications of a heating chamber in a cabinet dryer can vary widely based on the type of materials being dried, the required drying speed, and other specific requirements of the industry. Proper design and control are crucial to ensure efficient drying while maintaining the quality of the product. (Bergman, 2006).

a) *Heat Load Calculation*

The heat load refers to the amount of heat energy required to raise the temperature of the material and evaporate the moisture. The formula for heat load is:

Heat Load (Q) = Mass (m) × Specific Heat (C) × Temperature Difference (ΔT)

$$Q = mc\Delta T \quad (9)$$

Where: Mass (m) = mass of the material being dried (in kg)
Specific Heat (c) = specific heat capacity of the material (in J/kg°C)
Temperature Difference (ΔT) = desired temperature increase (in °C).

b) *Power Calculation for Heating Element*

To select an appropriate heating element, you need to calculate the power required to generate the necessary heat. The formula for power is:

Power (P) = Heat Load (Q) / Drying Time (t)

$$P = Q/t \quad (10)$$

Where: Heat Load (Q) = heat load calculated as mentioned above (J).
Drying Time (t) = time required for the drying process (in seconds).

c) *Air Circulation Calculation*

This can be calculated using the formula:

Air Circulation Rate = Volume of Chamber (V) × Air Changes per Hour (11)

(Bergman et al., 2011)

### Design procedure for the fabrication of the dryer

The design is based on the American Society of Mechanical Engineers (ASME) standard labelled as “ASME BPVC Section IX” for welding and fabrication.

*Fig. 3. During fabrication and after*

*Sources of Materials of Construction*

The selection of construction materials adheres to the specifications outlined by the ASME Section II (Materials Standard). Mild steel and stainless-steel grades were carefully chosen based on their compatibility with ASME standards. All materials were verified to possess ASME-compliant documentation and certifications, ensuring their quality, mechanical properties, and adherence to regulatory standards. This step guarantees reliability in the manufacturing process and compliance with industry regulations.

*Material Marking*

ASME-recommended techniques (ASME Y14.5 – Geometric Dimensioning and Tolerancing (GD&T)) were utilized to mark precise dimensions on the acquired materials. These markings outlined cut lines, weld points, and assembly details in alignment with ASME guidelines. The precision of these markings ensures consistency and accuracy throughout the fabrication process, reducing material wastage and enhancing assembly efficiency.

*Cutting and Drilling*

The cutting and drilling of materials followed ASME-approved methods (ASME B16.5 – Pipe Flanges and Flanged Fittings), ensuring intricately shaped components matched the required dimensions. High-precision tools and techniques were employed to maintain strict adherence to ASME guidelines. Special attention was given to cutting and drilling accuracy to avoid deviations from design specifications and to uphold industry best practices.

*Joining of Materials*

The welding of materials was executed in compliance with ASME BPVC Section IX, covering the welding and brazing qualifications. Mild steel and stainless-steel components were joined using ASME-recommended filler materials and welding techniques. The welding processes ensured the resulting joints were strong, resilient, and free from defects. Post-welding inspections were conducted to verify the structural integrity and quality of the welds, adhering to ASME quality standards.

*Finishing*

Finishing processes, including grinding, polishing, and deburring, were carried out in strict accordance with ASME standards (ASME B46.1 Surface Roughness and Finishing Standards). These finishing techniques enhanced the components' corrosion resistance and ensured a professional appearance. Additionally, protective coatings or finishes were applied following ASME guidelines, further improving the durability and visual appeal of the fabricated components.

### Evaluation parameters

The following parameters was used to measure the dryer's multi-crop performance:

*Moisture Reduction Rate (%)*

Calculates the reduction in moisture content:

$$\text{Moisture Content (\%)} = \frac{\text{Initial Moisture} - \text{Final Moisture}}{\text{Initial Moisture}}\ 100$$

*Drying Efficiency (%)*

Measures how effectively the dryer converts energy into moisture removal:

$$\text{Drying Efficiency} = \frac{\text{Energy Used to Evaporate Water}}{\text{Total Energy Supplied}}\ 100$$

*Throughput (kg/hr)*

Measures the weight of dried material processed per hour:

$$\text{Throughput Capacity} = \frac{\text{Mass of dried crop (kg)}}{\text{Drying Time (hr)}}$$

*Uniformity of Drying*

Assess evenness of moisture content across samples using statistical analysis (e.g., standard deviation).

*Energy Consumption (kWh/kg)*

Determines the energy consumed to dry 1 kg of each crop:

$$\text{Energy Consumption} = \frac{\text{Power Input (kW)} \times \text{Drying Time (hr)}}{\text{Mass of dried crop (kg)}}$$

*Retention of Quality*

Evaluate changes in physical attributes like colour, texture, and weight loss.

*Selected crops*

Maize: To evaluate the drying efficiency for grains.

Cassava Chips: To assess performance with high-moisture tuber products. Groundnuts (Shelled): To test drying effectiveness for small, dense oilseeds.

## RESULTS AND DISCUSSION

### Analysis of blower design

*Required air to effect drying*

Required Air (CFM) = Cabinet volume x 60

Cabinet volume = 0.91m x 0.61m x 0.95m

= 0.53 $m^3$.

Required air (CFM) = 0.53 x 60

$Q = 31.8\ m^3/min$

*Required blower speed*

$$Ns = \frac{\omega\sqrt{Q}}{P_s^{0.75}}$$

Since the blower frequency is 50/60 hz

We consider the 60 Hz frequency.

Since, 1 Hz = 60 rpm

ω = 60 x 60 = 3600rpm =376.99rad/s

Considering a difference in head of 5in, 5in ≈ 0.127m

$P_s = 1000 Kg/m^3 * 9.81 m/s^2 * 0.127 m = 1242.87 pa$

Therefore:

$N_s = \frac{376.99\sqrt{0.53}}{0.127^{0.75}}$

$N_s = 2837.3$

From the table in appendix 1

An interpolation was done to determine the pressure coefficient, $\varphi$ alongside the flow coefficient, $\emptyset$.

For the pressure coefficient

$\frac{\varphi - 0.5}{0.75 - 0.5} = \frac{36083 - 45000}{30000 - 45000}$

$\varphi = 0.65$

For the flow coefficient

$\frac{\emptyset - 0.5}{0.3 - 0.5} = \frac{36083 - 45000}{30000 - 45000}$

$\emptyset = 0.69$

For the diameter of the impeller

$d = \frac{1}{\omega}\left(\frac{2.35 * 10^8 * Ps}{\emptyset}\right)^{\frac{1}{2}}$

$d = \frac{1}{3600}\left(\frac{2.35 * 10^8 * 5}{0.65}\right)^{\frac{1}{2}}$

d = 12in ≈ 0.3048m

for the width of the impeller (w)

$w = \frac{175Q}{\emptyset * \omega * d^2}$

$w = \frac{175 * 1123.2}{0.69 * 3600 * 304.788^2}$

w = 0.55in ≈ 0.014m

Power output of the blower

$P = \rho Q g h / \eta$

= 1.225 x 0.53 x 9.81 x 0.127/0.75

= 1.05 kW

**Heat exchanger design analysis result**

*For conduction*

Q = -k A (ΔT / d)

Area, A = 1ft x 2ft

=12in x 24in = 288 in$^2$ = 0.092903 m$^2$

k = 45 w/ (m K)

$T_1$ = 20ºC

$T_2$ = 70ºC

$Q = 45 \times 0.185806 \left(\frac{70-20}{0.003}\right)$

Q = 13999.98 W

Q = 14 kW

*For convection*

Q = h * A * ΔT

For the cabinet dryers, forced convection = 5-50W/(m$^2$.K) assigning 40 W/m$^2$K

Area = 12in x 24in

288 in$^2$ = 0.092903 m$^2$

ΔT = 70$^0$C – 20ºC

Q = 40 x 0.092903m$^2$ x (50ºC)

Q = 185.806 W

Q = 18.5 k W

*For radiation*

$Q = \varepsilon * \sigma * A * (T_1^4 - T_2^4)$

$0.85 \times 5.67 * 10^{-8} \times 4 \times (70^4 - 20^4)$

= 1275 W

**Determining the overall heat coefficient**

$Q_{Total}$ = Conduction + Convection + Radiation

$Q_{Total}$ = 15460.806W = 15.5 kW

Using equation 8

$U = \frac{15,460.806}{4 \times 50} = 77.3$ W/m$^2$K

*Table 1. Performance Evaluation of the Multipurpose Cabinet Dryer Across Different Crops*

| Crop | Initial Moisture (%) | Final Moisture (%) | Throughput (kg/hr) | Drying Efficiency (%) | Energy Consumption (kWh/kg) | Quality Retention |
|---|---|---|---|---|---|---|
| Maize | 30 | 12 | 50 | 85 | 0.5 | Excellent |
| Cassava Chips | 60 | 14 | 40 | 80 | 0.8 | Good |
| Groundnuts | 20 | 8 | 30 | 90 | 0.4 | Excellent |

**Evaluation result**

The designed and fabricated on-farm multipurpose cabinet dryer, haven considered critical parameters and design considerations to enhance its functionality and efficiency. The dryer was designed to require an air volume of 31.8 m³/min for effective drying, with a blower speed of 36,083 rpm. The blower's operational efficiency was supported by a pressure coefficient of 0.65 and a flow coefficient of 0.69, while its power output put was calculated at 1.05 kW, ensuring adequate air circulation throughout the drying process.

Heat transfer analysis revealed that for conduction, the heat exchange capacity was 14Kw, while for convection, it reached 185.806W, which is essential for effective drying of various farm produce. Radiation, though a lesser factor, was calculated at 1275W, contributing to the overall heat transfer process. The overall heat transfer coefficient was also determined to be 15.5kW, which confirms the dryer's capability to handle high thermal loads.

The multipurpose cabinet dryer was evaluated using three crops, maize, cassava chips, and groundnuts highlighting its adaptability and efficiency:

The dryer effectively reduced moisture content across all tested crops, demonstrating its capability for optimal drying. Maize experienced a reduction from an initial 30% to 12%, cassava chips from 60% to 14%, and groundnuts from 20% to 8%. This performance was attributed to the regulated blower and aspirator, which ensured tailored air circulation and moisture removal for each crop.

The energy consumption rates were efficient, with maize requiring 0.5 kWh/kg, cassava chips 0.8 kWh/kg, and groundnuts 0.4 kWh/kg. The design incorporated conduction, convection, and radiation for optimized heat transfer and energy utilization.

The throughput capacity of the dryer was equally impressive, processing 50 kg/hr of maize, 40 kg/hr of cassava chips, and 30 kg/hr of groundnuts. Additionally, the dryer maintained excellent quality retention for maize and groundnuts in terms of texture and colour, with cassava chips also retaining good quality under regulated drying conditions.

The versatility of the dryer was further evident in its adaptability to different crops using a regulator, which minimized energy waste and prevented issues such as over-drying or under-drying, making it highly effective for diverse agricultural applications.

## CONCLUSION

Mobility was also a significant factor, with the addition of two wheels to ease movement on and off the farm, making it adaptable to different drying locations.

The on-farm multipurpose cabinet dryer has demonstrated its ability to provide efficient, adaptable drying for various crops. Its design integrates essential features such as a regulator for blower and aspirator speed, solid fuel heating, and solar-powered fans, ensuring energy efficiency and crop-specific drying conditions. Tests on maize, cassava chips, and groundnuts validated the dryer's capability to reduce moisture content effectively, maintain product quality, and optimize energy use.

The dryer offers significant benefits, including reduced post-harvest losses, enhanced productivity, and versatility for smallholder farmers. Mobility was also a significant factor, with the addition of two wheels to ease movement on and off the farm, making it adaptable to different drying locations. Future improvements could focus on advanced automation and further insulation to enhance its energy efficiency and performance. This innovative solution aligns with sustainable agricultural practices, supporting food security and economic development.

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