DESIGN,CONSTRUCTIONANDCOMPARATIVETHERMALANALYSISOF SOLAR DRYERS FOR DRYING CASSAVA USING DIRECT SUN DRYING, INDIRECT AND GREENHOUSE METHODS

PREPAREDBY

HANAFI ROFIAT OPEYEMI
HND/23/SLT/FT/0028

SUBMITTEDTOTHE

DEPARTMENTOFSCIENCELABORATORYTECHNOLOGY(PHYSICSAND ELECTRONICSUNIT),INSTITUTEOFAPPLIEDSCIENCES,KWARASTATE POLYTEHNIC, ILORIN

INPARTIALFULFILMENTFORTHEAWARDOFHIGHERNATIONAL DIPLOMA (HND) IN SCIENCE LABORTORY TECHNOLOGY

SUPERVISED BY:

DR.OLAORE K.O.

2024/2025 SESSION

CERTIFICATION

This is to certify that this project work has been written by **HANAFI ROFIAT OPEYEMI** with matric numbers **HND/23/SLT/FT/0028** and has been read and approved as meeting the parts of the requirements for the award of Higher National Diploma (HND) in Science Laboratory technology Department (Physics and Electronics Unit), Institute of Applied Sciences, Kwara State Polytechnic.

________________________________ ____________________

DR.OLAOREK.O. **DATE**

(ProjectSupervisor)

________________________________ ____________________

MRSALAHU BASHIR **DATE**

(Headof Unit)

________________________________ ____________________

DR.USMANA. **DATE**

(Headof Department)

________________________________ ____________________

EXTERNALEXAMINER **DATE**

DEDICATION

ThisworkisdedicatedtoAlmightyGod,forhisgrace,mercyandguidanceovermebefore, during and after the completion of my academic pursuit. All Glory to God and me Supervisor(**Dr.OlaoreK.O.**)alsotomyparent,andfriendswhohasneverfailedtogive us financialandmoralsupportforallourneedsduringthetimewedevelopedoursystems a nd for teaching me that even thelargest task can beaccomplishedifit is doneonest ep as a time.

ACKNOWLEDGEMENT

I express oursinceregratitudeto God Almightyforthesuccess ofthis project. I also express my sincere gratitude to my parents, my siblings and friends for supporting me through the cause of this project. My gratitude to **Dr. Olaore K.O.** for his time and supportingin monitoringand supervisingour through this project. Thank you for shaping this project and enhancing my learning experience.

Futhermore, my special thanks goes to the Head of Department of Science Laboratory Technology **Dr. Usman A.** and my Head of Physics and Electronics Unit **Mr. Salahu Bashir** for been there for me all in time.

MayGodblessand keepyouall(amen).

TABLE OFCONTENT

LISTOFTABLES

Table4.7:TabulatedreadingsforDryingRate&MoistureContent(Day1) Tab

le4.8:TabulatedreadingsforDryingRate&MoistureContent(Day2)

LISTOF FIGURES

2.6: Supporting Frames Fig.3.1.

2.7:TheAbsorberPlates

Figure 4.8.1 Variation of drying rate against time(day 2) F

igure4.8.2Variationofmoisturecontentagainsttime(day2)

ABSTRACT

This study presents the development and evaluation of innovative solar drying systems designed to utilize solar energy for the effective drying of agricultural products, particularly cassava (Manihot esculenta Crantz), thereby minimizing post-harvest losses inNigeria.Traditionalsundryingtechniquesfacesignificantchallenges,includingdirect exposure to varying weather conditions, susceptibility to pests and rodents, inadequate monitoring facilities, and the prohibitive costs associated with mechanical drying technologies. To address these challenges, two distinct solar drying systems, an indirect solar dryer and a greenhouse solar dryer, were conceptualized, fabricated, and assessed for their drying performance. The design of both dryers employed locally sourced materials, ensuring cost-effectiveness and suitability for rural applications. The indirect solar dryer was constructed with dimensions of 1.23m × 0.57m × 0.21m for the solar collector and a drying chamber measuring 0.85m × 0.525m. In contrast, the greenhouse solar dryer was larger, with dimensions of 1.545m × 1.045m × 1m. This configuration includedaraisedconvectionheadandacollectorplatewithdimensionsof1.49m×1.02 mtoenhanceaircirculationanddryingefficiency.Theprimaryobjectiveofthisresearch was to determine the most effective drying methodology, focusing on key performance parameters such as solar radiation incident on the collector, ambient and chamber temperatures, humidity levels, moisture content of the dried product, and overall drying rates. The drying process was systematically implemented, starting at 8:00 AM and concluding at 4:00 PM each day, over three consecutive days. Results from the drying experimentsindicatedthatthegreenhousesolardryersignificantlydecreasedthe moisture content of cassava from an initial value of approximately 79% to a final value of 5%. Meanwhile,theindirectsolardryershowedacomparablereduction,decreasingmoisture from81%to6%.Incontrast,opensundrying, despiteachievinga reductionfrom95%to 5% over two days, demonstrated considerable quality degradation and risk of contamination due to environmental exposure. The greenhouse dryer recorded peak chamber temperatures reaching 53.6°C, while the indirect solar dryer achieved even highertemperaturesofupto86.1°Cinthecollector.Thesetemperaturesweresubstantially abovetheambientrangeof25.2°Cto39.2°C,showcasingtheenhancedheatingcapability ofthesolardryingsystems.Thefindingsofthisstudyhighlight theefficacyofsolardrying technologies as viable, high-quality alternatives for dehydrating agricultural products, particularlyinregionswheresignificantpost-harvestlo

ssesoccur.Theadvantagesofboth the indirect and greenhouse solar dryers offer promising solutions tailored to local conditionsandresources.Futureresearchisencouragedtofocusonoptimizingthese *drying processes for improved efficiency and product quality across diverse clim atic environments, thereby supporting sustainable agricultural practices and food security initiatives.*

CHAPTERONE

INTRODUCTION

BackgroundoftheStudy

Agriculture comprises a significant portion of the economies in most African nati ons, employing 80-90% of the workforce. Despite this extensive involvement in agr iculture, foodproductioncontinuestofallshortofmeetingthecountry'sdemands.Acru cialfactor contributing to this shortfall is the inadequate preservation and storage systems, resulting in substantial food losses and a pronounced decline in food su pply. The challenges posed bycropfailuresandconsiderableseasonalfluctuationsin foodavailabilitycanbemitigated through effective food conservation techniques, s uch as drying. Sun drying is notablythe predominant method utilized for food pres ervation across numerous African countries, attributed to the region's high levels o f solar irradiance prevailing for most of the year. However,traditionalsun dryingme thodssuchas spreadingcropsonmats,trays,orpaved surfaces and exposingthem to sunlight and windhave inherent drawbacks. These include the potential for conta mination from dust and insects, enzymatic degradation, and microbial infections, which can adversely affect food quality (Ekechukwu and Norton 1999). Furtherm ore, the traditional process is labor-intensive and time-consuming, requiring crops to be covered at night and during inclement weather, while also necessitating con stant vigilance to protect against domestic animals. Inadequate and inconsistent drying results in further crop deterioration during storage, particularly problematic in humid tropical areas where certain crops must be dried during the rainy season. Tosecureareliablefoodsupplyfortheburgeoningpopulationandenablefarmers to pro duce high-quality, marketable products, the development of efficient and cost- eff ective drying methods is essential. Research indicates that even small-scale, oil-fir ed batchdryersarenotfeasibleformostfarmersduetofinancialconstraintsandlimited access to energy required for their operation. The high-temperature dryers employed in industrialized nations are economically viable primarily on large plantations or within extensivecommercialenterprises.Consequently,theintroductionoflow-cost,locally manufacturedsolardryerspresentsaviablealternativetosignificantlyreducepost-harvest losses.Producinghigh-qualitymarketablegoodsnotonlyenhancesproductvaluebutalso offersfarmersanopportunitytoimprovetheireconomiccircumstances.However,thehigh initial investment associated with solar dryers remains a formidable obstacle for widespread adoption, given the limited income among rural populations in developing regions (Forson *et al* 2007). The drying process is critical for the preservation of various materials,asitfacilitatestheevaporationofwaterorsolvents,therebyreducingweightand volume while enhancing product stability and quality. Drying relies on two principal mechanismsofenergytransfer:heattransfer,whichelevatesthetemperatureoftheproduct to facilitate evaporation, and mass transfer, which enables moisture to migrate from the product'sinteriortoitssurfaceandsubsequently intothesurroundingair.Thermalenergy, which governs the temperature within a drying system, can be explored within the realm of thermodynamics, focusing on energy transformations in closed systems. This concept encompasses several definitions, includingenergyat a particulate level, heat transfer, and internalenergyorenthalpy.Withinruralcontexts,sundryingremainsacommonplace yet laborious method that risks compromising product quality due to exposure to environmental contaminants. While alternatives like hot air drying can yield superior results, they typically demand significant energy inputs and financial investment, accounting for a considerable portion of industrial energy consumption in developed nations. Solar energy, however, offers a vast and largely untapped potential for drying applications, although challenges in energy capture and storage remain. Historically, sun drying has been widely practiced; however, the industrial demand for more controlled drying processes has surged in 21st-century agriculture, emphasizing the need to maintain product quality(Khouya *et al* 2017).

To improve drying efficiency and product quality, solar dryers have been develope d and promoted as sustainable alternatives to traditional methods. These system s utilize solar radiation,afreelyavailableandrenewableenergysource,todrycropsina morecontrolled andhygienicenvironment.Therearethreemajortypesofsolardryers:o pensun(direct exposure),indirectsolardryers,andgreenhousesolardryers.Eachoffersvaryinglevelso f efficiency, cost, and technical complexity.

Open sun drying exposes agricultural products to environmental elements such a s dust, wind, insects, and rainfall, leading to contamination, nutrient loss, and une ven drying (Olayanju et al., 2019). Inconsistent weather conditions further prolong drying times and increase the risk of microbial spoilage. Solar drying technologies have emerged as efficient, sustainable, and hygienic alternatives to traditional op en drying (Esper&Muhlbauer, 1996; Janjai, 2012). These technologies harness sol ar radiation more effectively by controlling the heat transfer process in semi-enclo sed environments. They not only improve drying speed but also help retain nutriti onal quality, prevent contamination, and enhance the visual and sensory attribute s of food products (Bala&Mondol, 2001).

Among the types of solar dryers, direct, indirect, and greenhouse dryers have recei ved considerable attention. Each system offers unique structural and operational benefits that affect drying performance and product quality (Forson et al., 2007).

Direct solar dryers allow sunlight to directly contact the food material within a clo sed transparentbox,leadingtohighdryingtemperaturesbutexposingproductstopoten tialUV degradation.Indirectsolardryers,incontrast,channelheatedairfromasolarcolle ctorinto a separate drying chamber, which protects the product from direct light, al lows better temperature regulation, and reduces the risk of oxidative damage (Tiw ari et al., 2016).

Greenhouse solar dryers take advantage of the greenhouse effect, using transpare nt materials to trap solar radiation within a larger enclosure. These systems comb ine the advantages of both direct and indirect drying while offering better airflow and thermal retention(Sharmaetal.,2009).Theirdesignallowsforbulkdryingofhigh-moisturecrops underrelativelystablethermal conditions, even duringintermittent solar radiation. Dueto their semi-permanent structure and high thermal efficiency, greenhouse dryers are increasingly adopted for drying perishable produce such as tomatoes, cassava, okra, and pepper (El-Sebaii&Shalaby, 2012; Khouya et al., 2017).

Cassava(ManihotesculentaCrantz)standsoutasahighlyvaluedagriculturalcommodity, accounting for approximately 40% of the dietary intake in many developing countries across Africa, Latin America, and Asia (FAO, 2019). The roots of cassava possess a dry matter content of about 30-40%, primarily composed of starch, sugar, and vitamin C, making it integral for animal feed and industrial raw materials. Cassava is predominantly cultivated in the lowland tropical regions along the equatorial belt, bounded by latitudes 30°Nand30°S,andthrivesatelevationsbelow2000m, withannualrainfallrangingfrom 200 to 2000 mm (RMRDC, 2004). Notably, Nigeria is the world's largest producer of cassava,contributingover70%oftotalproductionin WestAfricaandapproximately40% of global output (Deepak and Behura 2025). Cassava chips, which are irregularly sliced driedpiecesofcassava,typicallymeasureno morethan5-6cminlength(Ky*etal.*2021), while cassava flour represents the most common form in which dried cassava roots are marketed, with exporting countries predominantly producing it.

The drying process for cassava is not merely a preservation technique; it is a crucial step intransformingcassavaintosafe,storable,andtransportableforms.Poordryingpractices can lead to mold growth, cyanide retention, and economic loss. Furthermore, inefficient dryingcontributestogreenhousegasemissions,asfarmerssometimesresorttofuelwood- based methods during the rainy season(Mahmoud *et al 2019*).

In response to these challenges, this project seeks to contribute practical and sustainable solutionsbyfocusingonthedesignandconstructionofanindirectsolardryer,specifically tailored to cassava drying in local conditions. It further conducts a comp arative thermal analysis between:

- theconstructedindirectsolar dryer,
- anexistinggreenhousesolardryer, and

- theconventionalopensundryingmethod.

The study involves the measurement of solar radiation, drying chamber temperature, ambient temperature, and cassava weight loss over time. These data sets are used to calculatedryingrates,moistureloss,andthermalperformance,providingan objectivebasis for comparing the effectiveness of each drying method(Mohammed *et al* 2020).

Beyonditstechnicalobjectives,thisresearchalignswithbroaderglobalgoals:

- It supports climate-resilient agriculturebypromotingclean energysolutions.
- ItcontributestoGoal2(ZeroHunger),Goal7(AffordableandCleanEnergy),and Goal 12 (Responsible Consumption and Production) of the United Nations Sustainable Development Goals (SDGs).
- It empowers rural farmers with accessible technologies that improve product quality, reduce waste, and enhance income.

The project also draws on key principles of physics, especially in thermodynamics (heat andenergytransfer),fluiddynamics(airflowthroughthedryingsystem),andsolar energy engineering. By applying these concepts to real-world agricultural problems, the study bridges theoretical knowledge and practical innovation.

In summary, the development and analysis of solar dryers in this project aim to advance low-cost,sustainable,andefficientmethodsforcassavapreservationtherebyhelpingrural communities adapt to modern agricultural demands while preserving traditional crops through science-backed solutions.

ProblemStatement

Cassava(ManihotesculentaCrantz),thoughhighlyvaluableandwidelyconsumed,remains one of the most perishable staple crops in Nigeria and across sub-Saharan Africa. Within 48–72 hours after harvest, cassava roots begin to deteriorate rapidly due to microbial activity, enzymatic breakdown, and moisture loss. As a result, a si

gnificant portion of the harvested cassavaislostbeforeitcan beprocessed,stored, o
r soldwhich then contributes