COMPARATIVE STUDY OF THE CHARACTERISTICS OF OPEN SUN AND PARABOLIC SHAPED SOLAR DRIED FLUTED PUMPKIN (*Telfairia occidentalis*)

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BENIN CITY

NOVEMBER, 2025

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A PROJECT REPORT SUBMITTED TO THE DEPARTMENT OF ANIMAL SCIENCE, FACULTY OF AGRICULTURE, UNIVERSITY OF BENIN, BENIN CITY, IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE BACHELOR OF AGRICULTURE HONORS, DEGREE IN ANIMAL SCIENCE OF THE UNIVERSITY OF BENIN, BENIN CITY, NIGERIA.

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CERTIFICATION

This is to certify that this research was carried out by **Victoria GABRIEL (Miss)** in the Department of Animal Science, Faculty of Agriculture, University of Benin, Benin City, Nigeria.

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Dr. N.C. Akaeze **(Head of Department)**	**Date**

DEDICATION

This work is dedicated to God Almighty, my unyielding source of strength and inspiration. For His Graciousness throughout the course of my program in the University of Benin. And to my lovely parents Mr. & Mrs. Gabriel for their love guidance and unwavering support.

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ABSTRACT

This study investigated the comparative drying performance and product quality of fluted pumpkin (*Telfairia occidentalis)* leaves processed using traditional open sun drying (OSD) and an improved parabolic-shaped solar dryer (PSSD). Freshly harvested fluted pumpkin leaves were divided into two batches and dried under both methods to a target moisture content of 10% (wet basis). Key performance indicators measured included drying time, drying rate, and final moisture content, while sensory attributes such as colour, odour, texture, and overall acceptability were assessed using a 9-point Hedonic Scale. Results revealed that the PSSD achieved significantly faster drying (4.55 h) and higher drying rate (21.78 g/hr) compared to OSD (6.05 h and 16.22 g/hr, respectively), with the difference statistically significant ($p = 0.027$). Sensory evaluation further indicated that leaves dried with the PSSD were preferred (overall acceptability = 7.9) to those dried under open sunlight (5.9), with superior colour retention and aroma preservation ($p < 0.001$). The enhanced efficiency and product quality observed in parabolic solar drying demonstrate its potential as a sustainable, energy-efficient alternative for preserving perishable leafy vegetables in Nigeria. Adoption of this technology can substantially reduce postharvest losses, improve marketability, and promote year-round availability of nutrient-rich vegetables like fluted pumpkin.

CHAPTER ONE

1.0 INTRODUCTION

Fluted pumpkin (*Telfairia occidentalis*) is one of Nigeria's most important indigenous leafy vegetables that play central roles in both nutrition and culture (Degu *et al*., 2024). Fluted pumpkin, popularly called '*Ugwu'*, is commonly cultivated in home gardens and farms across southern Nigeria (Kayode and Kayode, 2011), and its leaves are a major component of soups and stews consumed daily by millions of households (Duling, 2019). Beyond its culinary significance, this vegetable is culturally and medicinally valued (Orole *et al*., 2020; Cho *et al*., 2020). Fluted pumpkin leaves are often used as a natural blood booster due to their rich iron content **(**Chijindu, 2024**)**.

The nutritional profile, which include high levels of vitamins, minerals, proteins, and antioxidants, make it indispensable in diets aimed at combating malnutrition and micronutrient deficiencies in Nigeria (Akpasi *et al*., 2023; Sanusi *et al*., 2022). Demand for these vegetables continues to rise, both domestically and internationally. In Nigeria, fluted pumpkin is among the most frequently purchased vegetables in urban and rural markets, but production often falls short of domestic demand due to its seasonal availability (Adeniran *et al*., 2021). These export opportunities highlight the economic potential of these vegetables beyond local consumption, with their growing recognition as part of the "ethnic food" market among African communities abroad. However, the highly perishable nature of these vegetables poses challenges for both domestic supply and export trade, as they tend to deteriorate rapidly without effective preservation methods **(**Bamishaiye, 2018**)**.

Postharvest losses remain one of the biggest obstacles to the steady supply of leafy vegetables in Nigeria. Due to their high water content, estimated at over 90%, these vegetables are extremely prone to spoilage once harvested. In Nigeria, poor handling practices, lack of cold storage, and inadequate transport infrastructure lead to significant losses, often exceeding 30% of production (Ahmed *et al*., 2023). During peak harvest seasons, when supply is abundant, farmers are often forced to sell their produce at low prices or watch them rot in markets, as facilities to extend their shelf life are limited. Such losses not only reduce farmers' income but also threaten food and nutritional security, especially in rural communities where these vegetables are primary sources of essential micronutrients. This situation underscores the urgent need for effective preservation strategies that can minimize waste and ensure that vegetables remain available throughout the year.

Drying has emerged as one of the most practical and sustainable preservation methods for leafy vegetables in Nigeria **(**Oshadumo, 2024**)**. Traditional open sun drying, which involves spreading leaves on mats, rooftops, or bare ground, is still widely practiced because it is simple and cost-free. However, this method exposes vegetables to dust, insects, contamination, and unpredictable weather conditions, often resulting in products of poor hygienic and nutritional quality. Studies have shown that open sun drying causes significant losses of light- and heat-sensitive nutrients such as vitamin C and β-carotene

(Ade *et al.*, 2018). In contrast, improved technologies such as parabolic solar dryers provide a more controlled environment by concentrating solar energy within an enclosed structure, leading to faster moisture removal and reduced microbial contamination. Research has demonstrated that parabolic solar dryers achieve higher drying rates and better quality retention than open sun drying, including brighter colour, reduced drying time, and higher nutrient preservation (Salaudeen and Okedokun, 2022). The growing adoption of solar drying technologies in Nigeria offers a sustainable pathway to reducing postharvest losses, improving food safety, and increasing the availability of nutrient-rich vegetables like fluted pumpkin throughout the year.

1.1 Justification of the Study

The preservation of perishable leafy vegetables such as fluted pumpkin (*Telfairia occidentalis*) is critical to improving food security, reducing postharvest losses, and maintaining year-round availability in Nigeria. Despite their high nutritional and economic value, these vegetables deteriorate rapidly after harvest due to their high moisture content and the absence of efficient preservation methods. The traditional open sun drying technique, though widely practiced, exposes vegetables to contamination, uneven drying, and quality degradation, thereby affecting their market acceptability and safety.

Introducing and optimizing improved technologies such as the parabolic shaped solar dryer presents a sustainable and energy-efficient alternative capable of overcoming these limitations. By providing a controlled drying environment, this technology can minimize contamination, shorten drying time, and improve overall product quality. However, empirical data comparing the performance and effectiveness of parabolic shaped solar drying and open sun drying for these two widely consumed vegetables remain limited in the Nigerian context.

Therefore, this study is justified as it seeks to generate scientific evidence on the comparative efficiency and product quality resulting from the two drying methods. The findings will inform farmers, processors, and policymakers on appropriate postharvest technologies to adopt for leafy vegetables, thereby promoting value addition, reducing wastage, and improving income opportunities. Ultimately, the study contributes to sustainable food preservation strategies that align with Nigeria's goals for food and nutrition security.

1.2 Objectives of the study

The main objective of this study is to conduct a comparative analysis of the characteristics of fluted pumpkin dried under open sun and parabolic shaped solar drier.

1.3 Specific Objectives

The specific objectives are to:

i. Compare drying performance by measuring drying rates, time required to reach safe moisture content, and overall efficiency of open sun drying versus parabolic shaped solar drying.

ii. Evaluate the sensory and hygienic quality of dried fluted pumpkin including appearance, colour, odour, and possible microbial contamination.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Introduction to Solar Drying Technologies

Solar drying is one of the oldest and most sustainable methods of food preservation, commonly used in tropical and subtropical regions to reduce post-harvest losses of perishable crops such as fruits and leafy vegetables (Kumar *et al*., 2017; Bennamoun, 2011). It works by removing moisture from agricultural products, thereby inhibiting microbial activity and enzymatic reactions that cause spoilage (Pirasteh *et al*., 2014). In developing countries like Nigeria, where electricity and fuel costs can be high, solar drying provides a low-cost, eco-friendly, and renewable method of food preservation (Ndukwu *et al*., 2020).

The basic principle of drying involves applying heat to evaporate water while ensuring airflow to remove the vaporized moisture. For effective drying, parameters such as temperature, air velocity, and relative humidity must be carefully balanced to avoid quality degradation (Bennamoun, 2011). In recent years, solar drying technology has evolved from traditional open-air drying to improved, controlled systems such as parabolic, cabinet, and tunnel dryers that enhance efficiency and product quality (Sathishkumar, 2025).

2.1.1 Classification of Solar Drying Systems

Solar dryers are broadly classified into two categories: direct solar dryers and indirect (or hybrid) solar dryers.

In direct dryers, products are exposed to sunlight directly under transparent covers that trap heat, while in indirect systems, air is heated in a solar collector before being circulated through the drying chamber (Belessiotis and Delyannis, 2011). Among the various designs, the parabolic-shaped solar dryer has received considerable attention for its improved drying rate, higher achievable temperatures, and protection from contamination (Ndukwu *et al*., 2020).

2.2 Open Sun Drying: Principles, Applications, and Limitations

Open sun drying (OSD) is the most traditional and widely practiced drying technique, especially in rural communities. In this method, harvested crops are spread on mats, concrete floors, or trays and exposed directly to the sun's radiation (Oboh, 2005). The process is inexpensive and simple but has several limitations. It depends heavily on weather conditions, often requires several days to complete, and leaves the product susceptible to contamination by dust, insects, and microorganisms (Adebayo, 2025; Ojo and Adejumo, 2020).

For fluted pumpkin leaves, open sun drying typically results in significant moisture reduction but at the expense of some nutrients such as vitamins and proteins, which are sensitive to prolonged exposure to sunlight and high temperatures (Obembe *et al*., 2020). Additionally, uneven drying and colour deterioration are common challenges. Despite these drawbacks, open sun drying remains the most accessible preservation technique in smallholder farming systems where access to electricity or mechanical dryers is limited (Adeleye, 2018).

2.3 Parabolic Solar Drying: Design and Technological Advantages

The parabolic-shaped solar dryer (PSSD) is an advanced form of solar drying technology designed to optimize the capture and concentration of solar radiation (Hempattarasuwan *et al.*, 2020). Its curved reflector concentrates sunlight into a focal area where the drying chamber is located, generating higher and more uniform temperatures. The system's transparent cover allows solar radiation in while trapping heat, creating a greenhouse effect that raises internal temperatures up to 68 °C—significantly higher than the 47 °C typically achieved in open sun drying (Sathishkumar, 2025).

Air vents and sometimes solar-powered fans help circulate hot air and remove moist air, reducing drying time and preventing microbial growth (Ndukwu *et al.*, 2020). Compared to open sun drying, parabolic solar dryers offer several advantages: shorter drying duration, improv-ed nutrient retention, reduced contamination, and higher product quality (Hempattarasuwan *et al.*, 2020).

For perishable vegetables like fluted pumpkin, which are rich in protein and vitamins, this controlled environment is particularly beneficial because it minimizes nutrient loss and maintains colour and flavour integrity (Obembe *et al.*, 2020).

2.4 Comparative Analysis of Drying Methods

Studies comparing traditional and improved drying methods have shown consistent differences in product quality and drying efficiency. For instance, Adebayo (2025) reported that parabolic solar dryers achieved a drying rate of 5.2 kg/day compared to 1.3 kg/day in open sun drying. The final moisture content of parabolic-dried samples was also lower (14.5%) than those dried under open sunlight (17.8%), indicating better dehydration and longer shelf life.

In leafy vegetables such as *Telfairia occidentalis*, the benefits of parabolic drying include greater retention of chlorophyll, carotenoids, and vitamin C, alongside better colour and texture (Sathishkumar, 2025). Open sun drying, on the other hand, often results in oxidation of pigments and degradation of sensitive nutrients (Adeleye, 2018). Furthermore, parabolic solar drying provides superior hygienic conditions because products are enclosed and shielded from environmental contaminants.

Overall, the controlled temperature and airflow of parabolic dryers enhance the physical, nutritional, and microbiological quality of dried fluted pumpkin compared to the traditional open sun method.

2.5 Drying Kinetics and Mathematical Modelling

Drying kinetics describes how moisture is removed from a product over time. The rate of drying depends on variables such as temperature, humidity, and air velocity (Ndukwu *et al*., 2020). Mathematical models like the Page, Newton, and Midilli models are often used to predict drying behaviour and optimize dryer performance.

For fluted pumpkin, moisture content typically decreases exponentially with time, and higher drying temperatures lead to faster moisture removal (Obembe *et al*., 2020). Effective moisture diffusivity (the rate at which moisture migrates within the leaf tissue) also increases with temperature. Parabolic dryers, with their stable and elevated heat levels, achieve higher diffusivity values, meaning faster and more uniform drying. These kinetic insights are essential for designing energy-efficient dryers and determining optimal drying durations that preserve nutrients while achieving sufficient dehydration for safe storage.

2.6 Overview of Fluted Pumpkin (*Telfairia occidentalis*)

2.6.1 Botanical Description and Distribution

Fluted pumpkin (*Telfairia occidentalis*) is characterized by its long, creeping stems that can reach up to 10 meters, climbing with coiling tendrils. The leaves are large, palmate, and deeply lobed with a glossy surface and prominent venation (Imosemi, 2018). The plant produces separate male and female flowers, with the female flowers developing into large, ribbed, pumpkin-like fruits containing flat, oil-rich seeds (Badifu and Ogunsua, 1991). It thrives in the humid, tropical climates of West Africa, preferring well-drained, fertile soils. Traditionally harvested from the wild, it is now widely cultivated across Nigeria and neighboring countries, forming an essential part of the local agriculture and diet (Ndubueze-Ogaraku, 2017).

2.6.2 Nutritional and Phytochemical Composition of Fluted Pumpkin

Fluted pumpkin is nutritionally rich, containing 19–29% protein, 15–18% fat, and 12–17% fibre on a dry weight basis (Ajala *et al.*, 2021). It is also a good source of minerals such as calcium, iron, potassium, and zinc, and vitamins A, C, E, and B-complex (Imosemi, 2018). The seeds are especially high in oil (about 32%) and protein (up to

34%), which makes them valuable in addressing malnutrition and micronutrient deficiencies (Iweala and Obidoa, 2009; Chuku and Chinaka, 2021).

Beyond basic nutrition, the leaves contain a plethora of bioactive compounds. Phytochemical analyses have confirmed the presence of alkaloids, flavonoids, tannins, saponins, and phenolic compounds, which contribute to its documented antioxidant, anti-inflammatory, and antimicrobial properties (Eseyin *et al.*, 2014; Oboh *et al.*, 2011). However, the leaves also contain anti-nutritional factors like oxalates and phytates, which can be significantly reduced through appropriate processing methods such as blanching and boiling (Adefegha and Oboh, 2011)

However, because the leaves have a high moisture content (up to 85%), they deteriorate rapidly after harvest. Hence, drying is crucial to reduce microbial spoilage and retain nutrients for longer storage (Adeleye, 2018).

2.6.3 Culinary and Medicinal Uses

Fluted pumpkin (*Telfairia occidentalis*) is primarily valued for its tender, edible leaves, which are a staple vegetable in many West African cuisines (Dimejesi, 2020). The leaves are usually chopped and added to soups and stews such as ogbono soup and vegetable soup to impart flavour and nutrition. The tender leaves (and even immature seeds) may be cooked alone or combined with other ingredients. For example, they are often cooked with okra, *Irvingia* (dika nut), or melon (*egusi*) seeds, and sometimes mixed with **ẹ̀wẹ̀** (Gnetum *africanum*) or the leaves of *Pterocarpus soyauxii*. Common dishes include cooking the leaves with fish, meat, and tapioca (fermented cassava), and then eating the vegetable with starchy fufu bases such as pounded yam, *eba*, *apu* (cassava dough), or *amala* (yam flour dough) (Grubben *and* Denton, 2004; Schippers, 2002). When the leaves become coarse, they are often mixed with softer greens like waterleaf (*Talinum fruticosum*) to improve texture.

Table 1: Proximate Composition of Fluted pumpkin leaves (per 100 g dry matter)

Nutrient	Leaves (%)	Source
Protein	19–29	Chuku and Chinaka, 2021
Fat	15–18	Ajala *et al*., 2021
Fiber	1–2	Oboh, 2005
Carbohydrates	2–4	Giami, 2000
Ash	1–2	Lawal *et al*., 2021

Source: (Ajala *et al.,* 2021; Chuku and Chinaka 2021)

Traditionally, *Telfairia occidentalis* is prized for its health benefits, especially its ability to treat anemia and other blood disorders due to its high iron and folate content (Gbile, 1986, Alada, 2010). The plant is commonly used in folk remedies for diabetes, hypertension (high blood pressure), and as a general “blood purifier.” Scientific studies support some of these uses: leaf extracts of fluted pumpkin exhibit antioxidant and anti-inflammatory activities, which may underlie its health effects. In animal studies, fluted pumpkin extracts have been shown to ameliorate chemically-induced anemia and protect against oxidative damage in organs (Eseyin *et al.*, 2005; Adaramoye, 2007). In combination with other herbs, *Telfairia* can have synergistic effects. For instance, giving fluted pumpkin leaves together with bitter leaf (*Vernonia amygdalina*) helped reduce garlic-induced liver toxicity in rats, suggesting enhanced liver-protective benefits (Sabiu *et al.*, 2014).

2.7 Effects of Drying Methods on Fluted Pumpkin

Several studies have investigated how drying methods affect the quality of fluted pumpkin. Obembe *et al*. (2020) found that oven-dried samples had the highest protein and ash content, followed by air-dried and sun-dried samples. Sun-dried leaves, though effective at moisture removal, exhibited higher losses of vitamin C and protein due to long exposure to direct sunlight.

Adeleye (2018) observed that after five hours of drying at 60 °C, fluted pumpkin leaves reached about 4% final moisture content, but the samples had higher bacterial and fungal counts than other vegetables like lettuce and spinach. This suggests that while heat aids in drying, uncontrolled exposure (as in open sun drying) can promote contamination.

Comparatively, the parabolic solar dryer ensures shorter drying times and reduces microbial load by maintaining steady heat and air circulation (Hempattarasuwan *et al*., 2020). The resulting products retain more natural colour and nutritional compounds, demonstrating that improved solar drying technologies significantly enhance the quality of dried *T. occidentalis* leaves.

2.8 Conclusion

Solar drying remains a crucial method for preserving leafy vegetables like fluted pumpkin. Although open sun drying is widely used due to its simplicity and low cost, it poses major drawbacks, including contamination risk, nutrient loss, and weather dependence. Parabolic solar drying, on the other hand, provides a controlled environment that enhances drying efficiency, nutrient retention, and product hygiene.

For *Telfairia occidentalis*, the adoption of parabolic solar dryers could significantly reduce post-harvest losses and improve product quality, ensuring year-round availability of this important vegetable. Strengthening research and practical implementation of such technologies will contribute to food security, nutrition enhancement, and sustainable agricultural development in Nigeria and other tropical regions.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Research Design and Experimental Setup

This study employed an experimental research design to compare the drying performance of traditional open sun drying against a parabolic solar drying system for fluted pumpkin leaves. The experiment was conducted over several days, with triplicate samples for each drying method to ensure reliability and account for variability.

3.2 Study Area

The experimental and laboratory analyses were carried out at the Department of Food Science and Nutrition, Faculty of Agriculture in Ugbowo Campus, University of Benin (UNIBEN), Edo State, Nigeria. The campus is located between latitude 6°30' N of the equator and longitude 5°40'–6° E of the Greenwich Meridian in the forest zone with an average temperature of 27.6°C (NAA, 2014; Google Earth, 2021). Drying trials were performed in an open area within the Department of Food Science and Technology premises for open-sun drying and, in the department’s NSPRI-type parabolic-shaped solar dryer.

3.3 Sample Collection and Preparation

Fresh fluted pumpkin leaves were procured from Uselu market in Benin Metropolis, Ovia North Local Government Area, Edo State, Nigeria. The leaves were sorted to remove damaged, diseased, and decayed parts, foreign matter, and stems larger than 3–5 mm. The petioles (stalks) were trimmed to ensure uniformity. The leaves were thoroughly washed in potable water (2–3 changes) to remove soil and debris, drained for 10 minutes on a stainless-steel draining rack to remove surface moisture.

Collected leaves were transported to the laboratory in ventilated crates within 2 hours of harvest/purchase. The initial fresh weight of each sample (120 g) and initial moisture content (determined on a subsample using the oven-drying method) were recorded. The cleaned leaves were divided into two lots: one dried inside the parabolic-shaped solar dryer (PSSD) and the other using open sun drying (OSD).

3.4 Drying Procedures

3.4.1 Drying Endpoint and Monitoring

Mass Monitoring: The mass of each sample was recorded at regular intervals until the drying endpoint was reached. The time for each measurement was also recorded.

Endpoint Determination: The drying endpoint was defined as the point where the leaves reached a safe moisture content of 10% (wet basis), as established in post-harvest literature for similar leafy vegetables (source).

Based on the initial moisture content of fresh fluted pumpkin leaves (83.3%), the target final mass was calculated as follows:

Bone Dry Mass (Solids) = Initial Mass - Initial Water Mass

$$= 120\ \text{g} - (120\ \text{g} \times 0.833) = 20.04\ \text{g}$$

At 10% moisture content, the dry solids constitute 90% of the final mass:

Final Mass = Dry Solids Mass / 0.90

$$= 20.04\ \text{g} / 0.90 = 22.27\ \text{g}$$

Therefore, the drying process was considered complete when a sample's mass stabilized at approximately 22.3 g.

3.4.2 Open Sun Drying

For each open-sun replicate, 120 g of drained leaves was spread in a single layer on clean, elevated drying racks covered with food-grade foil paper to allow airflow. The leaves were spread evenly on a metallic tray lined with foil paper and dried under direct sunlight for at least six hours per day for two days.

The leaves were turned manually every 2–3 hours to promote even drying and were weighed at one-hour intervals during daytime and at the start/end of each drying day until a constant weight was maintained at three consecutive readings (Awogbemi and Ogunleye, 2009).

Racks were placed in an unobstructed open area exposed to direct sunlight. Samples were protected from contamination as much as possible (using mesh covers overnight) but were exposed to ambient conditions as per traditional practice.

3.4.3 Parabolic Solar Drying

3.4.3.1 Description of the Parabolic-Shaped Solar Dryer (PSSD)

The structural dimensions of the Parabolic-Shaped Solar Dryer (PSSD) are 15 m x 9 m x 2.4 m. The dryer is constructed so that the longer side faces the east-west direction for maximum reception of solar radiation. It has a black tiled floor for heat retention and an underlying insulation that inhibits heat loss. The parabolic-shaped structure is 2.4 m high and is made with galvanized steel pipes. The PSSD is covered with a transparent acrylic material. The drying chamber has 2 tray racks with 2 layers each made of mild steel angle iron and 64 trays of 0.55 m x 0.55 m made of square pipe and wire mesh. It has an effective drying area of 40.8 m^2. There are two inlet vents on each side which allow natural flow of air into the drying chamber. Four pneumatic aspirators are fixed at the top; also, four solar-powered air extractors are fitted at the top front and back for extraction of moisture from the drying chamber. An access door is also provided at one end of the structure (Figure 2).

Plate 1: Fluted pumpkin leaves during drying in Open Sun

Plate 2: NSPRI Parabolic Shaped Solar Drier at the Department of Food Science and Nutrition, Faculty of Agriculture, University of Benin (UNIBEN).

3.4.3.2 Drying of Leaves

The drying was carried out using two drying systems, namely PSSD and OSD (control). A parabolic solar dryer was set up according to the department's available model (NSPRI-type). The dryer consists of a parabolic concentrator that reflects and concentrates sunlight into an insulated drying chamber with trays and an outlet for moisture-laden air.

For each replicate, 120 g of leaves was spread evenly in a single layer on drying trays inside the parabolic dryer. The dryer was oriented optimally to the solar angle; trays were turned every 2–3 hours to ensure uniform exposure. The leaves were dried for approximately 5 hours.

Temperature and relative humidity within the dryer were continuously recorded. Weighing intervals mirrored the open-sun protocol until constant weight was reached.

3.4.4 Safety and Operational Notes

Operators wore gloves and hairnets when handling samples. The parabolic dryer's hot surfaces were handled with heat-resistant gloves.

3.5 Sample Packaging and Storage

Immediately after drying to constant weight, dried samples were cooled for 30 minutes to room temperature, then subdivided into labelled sub-samples. Primary storage was in airtight black polyethylene bags, sealed and labelled with sample ID, date, and treatment. Bags were stored in a cool, dark cupboard in the laboratory at ambient room temperature (~25°C) and analyzed within seven days for the planned analyses.

Plate 3: Fluted pumpkin leaves during drying in PSSD

3.6 Physical and Laboratory Analyses

3.6.1 Physical Analyses

3.6.1.1 Moisture Content (Gravimetric Method)

Moisture content of the samples was determined gravimetrically using the oven-drying method. This parameter is essential to evaluate the degree of dehydration achieved by each drying method and its implication for microbial stability and shelf life. A representative subsample (2–5 g) was weighed into pre-dried crucibles and dried in a hot-air oven at 105 ± 1 °C until constant weight. The difference between initial and final weights was used to compute moisture content. Results were expressed on a dry basis (% db) to enable effective comparison between treatments.

Moisture content was calculated as follows:

$\%\ \text{Moisture Content} = [(W1 + W2) - W3] / W2 \times 100$

Where:

W1 = the weight of the empty crucible after cooling

W2 = weight of about 2 g well-mixed portion of the sample

W3 = weight of crucible plus sample after drying and cooling to room temperature

3.6.1.2 Weight Loss and Drying Rate Determination

Trays from each drying system were weighed daily to monitor the amount of moisture lost. The leaves were dried until the safe moisture content was attained. The drying rate was determined using Equation 1.

$$DR = (M_0 - M_e) / dt \quad (1)$$

Where:

M_0 = initial weight of sample (g)

M_e = weight of dried sample at time t (g)

dt = drying time (day)

Weight loss = $M_0 - M_e$ (2)

3.7 Sensory and Hygienic Quality Evaluation

3.7.1 Sensory Evaluation

A trained sensory panel utilized a 9-point Hedonic Scale to evaluate key physical attributes, including appearance, colour, odour, and overall acceptability. Additionally, a consumer perception survey employed scales (e.g., Just-About-Right, JAR) to assess the marketability of the product, focusing on colour vibrancy, appealing texture, and pleasant odour, thereby determining purchase intent (Addo-Preko *et al.*, 2023)

3.8 Data and Statistical Analysis

The collected data were used to calculate the following performance indicators:

1. Moisture Loss (g): Initial Mass - Final Mass

2. Total Drying Time (hr): Total duration from start until the mass reached ~22.3 g.

3. Average Drying Rate (g/hr): Total Moisture Loss (g) / Total Drying Time (hr)

4. Moisture Ratio (MR): To normalize the data for drying curves, the Moisture Ratio was calculated as:

$$MR = \frac{M_t - M_e}{M_0 - M_e}$$

Where:

- M_t = mass at time t (g)
- M_e = equilibrium mass (22.27g)
- M_0 = initial mass (120g)

The results for the two drying methods were compared using descriptive statistics. An independent samples t-test was conducted using SPSS (or other software) at a 5% significance level (α = 0.05) to determine if the difference in their average drying rates was statistically significant.

CHAPTER FOUR

4.0 RESULTS

4.1 Comparison of Drying Performance: Drying Rates and Time to Safe Moisture Content

4.1.1 Drying Performance Metrics

The drying performance of fluted pumpkin leaves was evaluated using open sun and parabolic solar drying methods. As summarized in Table 1, both methods successfully reduced the moisture content to the safe level of below 10% (wet basis). However, distinct differences in efficiency were observed. The parabolic solar dryer achieved a lower average final mass (21.0 g) compared to open sun drying (22.3 g), and did so in a significantly shorter average time (4.55 hours vs. 6.05 hours). Consequently, the parabolic solar dryer demonstrated a higher average drying rate (21.78 g/hr) than the open sun method (16.22 g/hr), indicating a more rapid removal of moisture.

4.1.2 Statistical Analysis of Drying Rates

A t-test was conducted to determine if the difference in average drying rates between the two methods was statistically significant. The results, presented in Table 2, show a p-value of 0.027. Since this p-value is less than the significance level ($\alpha=0.05$), it confirms that the parabolic solar dryer's higher drying rate is statistically significantly different from the open sun drying rate.

4.1.3 Moisture Ratio

The moisture ratio (MR) over time for both drying methods is shown in Table 3. The MR declined more rapidly for the parabolic solar dryer throughout the drying process. For instance, at the 3-hour mark, the average MR for the parabolic solar dryer was 0.083, compared to 0.181 for the open sun method. The parabolic solar samples also reached and slightly overshot the target equilibrium mass (indicated by a negative MR value) by 4.5 hours, while the open sun samples took 6 hours to approach zero MR.

Table 2: Comprehensive Drying Performance Analysis

Drying Method	Initial Mass (g)	Final Mass (g)	Final Moisture Content (%)	Reached Safe MC?	Total Drying Time (hr)	Moisture Loss (g)	Average Drying Rate (g/hr)
Open Sun							
1	120	22	**9.8**	**Yes**	6.00	98	16.33
2	120	23	**9.8**	**Yes**	6.58	97	14.74
3	120	22	**9.8**	**Yes**	5.57	98	17.59
Average	**120.0**	**22.3**	**9.8**	**Yes**	**6.05**	**97.7**	**16.22**
Parabolic Solar							
	120	21	**9.8**	**Yes**	4.32	99	22.92
	120	20	**10.0**	**Yes**	4.62	100	21.65
	120	22	**9.8**	**Yes**	4.72	98	20.76
Average	**120.0**	**21.0**	**9.9**	**Yes**	**4.55**	**99.0**	**21.78**

Note: Safe moisture content is 10% wet basis. Target dry mass = 22.27g

Table 3: T-test showing the difference between the average drying rates

t-statistics	Degrees of Freedom	p-value
3.42	4	0.027

Table 4: Average Moisture Loss vs. Time for each Drying Methods

Time (hr)	Average Open Sun MR	Average Parabolic Solar MR
0.00	1.000	1.000
1.00	0.494	0.454
1.50	0.437	0.284
2.50	0.300	0.168
3.00	0.181	0.083
4.00	0.116	0.017
4.50	-	-0.005
5.00	0.031	-
6.00	0.007	-

Note: A negative MR indicates the sample mass has fallen below the calculated target dry mass, meaning it is drier than the 10% moisture content target.

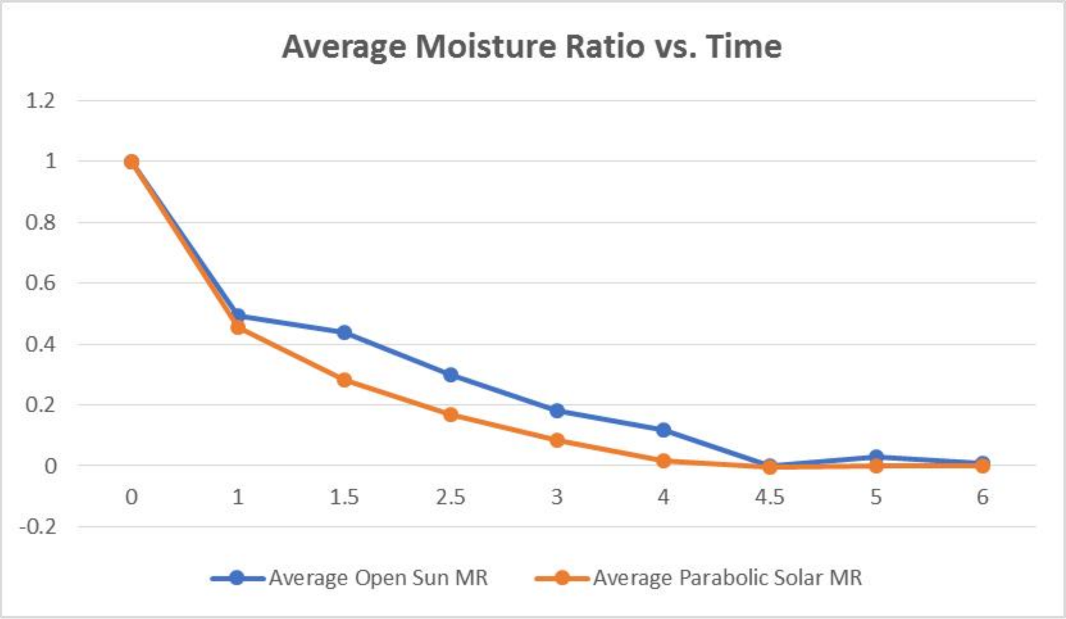

Fig 1: The average moisture loss per time for each method

4.1.4 Instantaneous Drying Rates

The analysis of instantaneous drying rates, detailed in Table 4, reveals the drying behavior at different stages. Both methods exhibited their highest rates in the initial (0-1 hour) period, with the parabolic dryer maintaining a consistently higher rate. The difference in drying rates between the two methods was most pronounced during the falling rate period (e.g., 28.75 g/hr vs. 11.00 g/hr at the 2.5-hour midpoint), indicating the parabolic solar dryer's superior efficiency in removing moisture when it was more tightly bound within the leaf material.

4.2 Evaluation of Physical and Sensory Quality of Dried Fluted Pumpkin Leaves

4.2.1 Sensory Evaluation Results

The sensory quality of the dried leaves was assessed using a 9-point hedonic scale, with results presented in Table 5. The leaves dried using the parabolic solar method received significantly higher mean scores across all attributes, including appearance/texture, colour, odour, overall acceptability, and purchase intent. The average overall acceptability for parabolic solar-dried leaves was 7.9 ("Like moderately" to "Like very much"), compared to 5.9 ("Like slightly") for open sun-dried leaves. This preference was reflected in the purchase intent (Table 6), where 80% of panellists were in the "Probably" or "Definitely Would Buy" categories for parabolic solar-dried leaves, compared to only 20% for open sun-dried leaves.

Table 5: Instantaneous Drying Rates (g/hr) for Different Time Intervals

Time Interval (hr)	Midpoint Time (hr)	Avg. Open Sun Rate (g/hr)	Avg. Parabolic Solar Rate (g/hr)
0 - 1	0.5	55.00	59.00
1 - 2	1.5	34.00	45.50
2 - 3	2.5	11.00	28.75
3 - 4	3.5	6.00	15.25
4 - 5	4.5	4.00	8.50
5 - 6	5.5	2.00	4.25

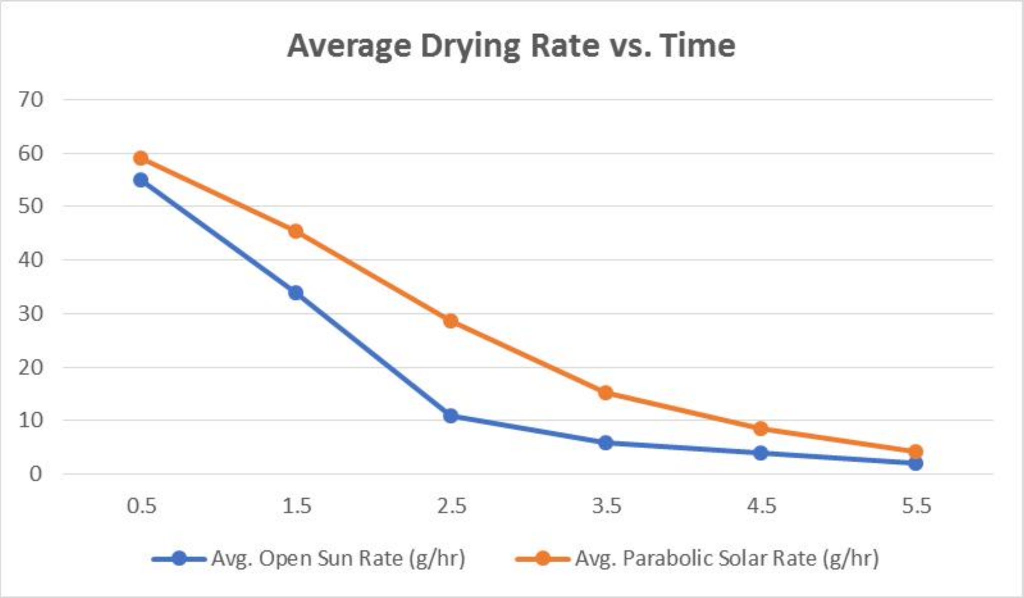

Fig 2: Average Drying rate per time for each drying method

Table 6: Mean Hedonic Scores of Dried Fluted Pumpkin Leaves

Drying Method	Sample Code	Appearance /Texture	Colour	Odour	Overall Acceptability	Purchase Intent
Parabolic Solar	PS1	7.9 ± 0.35	7.8 ± 0.42	8.3 ± 0.28	8.1 ± 0.31	4.2 ± 0.26
	PS2	7.7 ± 0.41	7.4 ± 0.38	8.0 ± 0.35	7.8 ± 0.29	4.0 ± 0.32
	PS3	7.8 ± 0.33	7.6 ± 0.45	8.2 ± 0.31	7.9 ± 0.36	4.1 ± 0.29
Average		**7.8 ± 0.12**	**7.6 ± 0.10**	**8.2 ± 0.09**	**7.9 ± 0.09**	**4.1 ± 0.06**
Open Sun	OS1	6.5 ± 0.52	6.2 ± 0.58	6.8 ± 0.47	6.5 ± 0.44	2.8 ± 0.38
	OS2	5.2 ± 0.63	4.8 ± 0.71	5.5 ± 0.59	5.1 ± 0.52	2.0 ± 0.45
	OS3	6.3 ± 0.48	5.9 ± 0.55	6.5 ± 0.51	6.2 ± 0.47	2.7 ± 0.41
Average		**6.0 ± 0.38**	**5.6 ± 0.41**	**6.3 ± 0.36**	**5.9 ± 0.42**	**2.5 ± 0.24**

Values represent mean ± standard deviation; Scale: 9-point hedonic scale

Table 7: Frequency Distribution of Purchase Intent Responses (%)

Drying Method	Definitely Would Buy	Probably Would Buy	Might/Might Not	Probably Would Not Buy	Definitely Would Not Buy
Parabolic Solar	33.3	46.7	13.3	6.7	0.0
Open Sun	6.7	13.3	26.7	33.3	20.0

4.2.2 Statistical Analysis of Sensory Attributes

An independent samples t-test was performed on the sensory scores, and the results are shown in Appendix B. The analysis revealed highly significant differences ($p < 0.001$) for all sensory attributes. The high t-values confirm that the parabolic solar-dried leaves were statistically and significantly preferred over the open sun-dried leaves in terms of appearance/texture, colour, odour, overall acceptability, and purchase intent.

CHAPTER FIVE

5.0 DISCUSSION

5.1 Drying Performance: Efficiency and Kinetics

The primary finding of this study is the superior performance of the parabolic solar dryer over traditional open sun drying. The significantly shorter drying time (4.55 vs. 6.05 hours) and higher drying rate (21.78 vs. 16.22 g/hr) achieved by the parabolic solar dryer can be attributed to its ability to achieve higher internal temperatures and reduce the relative humidity around the product, thereby enhancing the moisture removal driving force (Kareem *et al*., 2017). This finding aligns with previous research on solar drying of agricultural products, such as mint and tomatoes, where designed solar dryers consistently outperformed open sun drying by reducing drying time by 25-40% (El-Sebaii *and* Shalaby, 2012).

The moisture ratio and instantaneous drying rate data provide further insight into the drying kinetics. The steeper decline in MR for the parabolic solar dryer indicates a more efficient drying process throughout. The notably higher instantaneous drying rates during the mid-phase (e.g., at 2.5 hours) suggest that the parabolic dryer was more effective in overcoming the internal resistance to moisture movement during the critical falling rate period. This is a common advantage of active or semi-active dryers that maintain better control over the drying environment compared to the passive, fluctuating conditions of open sun drying (Diamante *and* Munro, 1993).

5.2 Product Quality and Consumer Acceptability

The highly significant differences in all sensory attributes underscore a critical advantage of the parabolic solar dryer: superior product quality. The open sun-dried leaves received lower scores, particularly for colour and odour, which is consistent with literature documenting the degradative effects of direct ultraviolet radiation, dust, insect contamination, and uncontrolled enzymatic reactions (Mwithiga *and* Olwal, 2005). The parabolic solar dryer, likely by shielding the product from direct exposure and allowing for a more controlled, faster drying process, better preserved the chlorophyll (green colour) and volatile compounds responsible for the fresh odour.

The dramatically higher purchase intent for parabolic solar-dried leaves (80% positive intent vs. 20% for open sun) translates the technical and sensory advantages into a clear commercial implication. This finding corroborates with studies on dried herbs and vegetables, where improved colour and aroma retention directly correlate with increased consumer willingness to purchase (Yemmireddy *et al.*, 2013). The poor sensory scores and high percentage of Would Not Buy responses for open sun-dried leaves highlight the market-limiting drawbacks of this traditional method.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion and Recommendations

In conclusion, this study establishes that the parabolic solar drying method is markedly superior to the traditional open sun technique for processing fluted pumpkin leaves. The primary conclusion is that the parabolic solar dryer offers a significant enhancement in both processing efficiency and final product quality. This is demonstrated by a reduction in drying time of approximately 25% and a statistically significant increase in the average drying rate, which directly translates to higher throughput and potential energy savings. Furthermore, the parabolic solar dryer proved to be instrumental in preserving the sensory attributes critical to consumer acceptance. The leaves dried using this method were statistically superior in colour, odour, texture, and overall acceptability, receiving hedonic scores that indicate a strong consumer preference. This enhanced quality directly correlates with a substantially higher purchase intent, making the parabolic solar-dried product significantly more viable in the market. Therefore, the adoption of parabolic solar drying technology presents a compelling solution for producing high-quality, market-ready dried fluted pumpkin leaves in a more efficient and controlled manner than open sun drying allows.

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APPENDIX

A. Sensory Evaluation of Dried Fluted Pumpkin Leaves

Instructions: Please evaluate the provided samples of dried fluted pumpkin leaves based on their appearance, colour, and odour, and indicate your overall acceptability. For each attribute, check the box that best describes your perception.

Thank you,

Victoria Gabriel (Miss)

Panellist ID: ___________ Sample Code: ___________ Date: ___________

Attribute	Description	Hedonic Scale (Please check one)
Appearance / Texture	Evaluate the physical state: shrunken, wrinkled, uniformity, presence of defects.	☐ Like Extremely ☐ Like Very Much ☐ Like Moderately ☐ Like Slightly ☐ Neither Like Nor Dislike ☐ Dislike Slightly ☐ Dislike Moderately ☐ Dislike Very Much ☐ Dislike Extremely
Colour	Evaluate the greenness and uniformity. A desirable dried leaf should retain a green colour, not be brown or blackened.	☐ Like Extremely ☐ Like Very Much ☐ Like Moderately ☐ Like Slightly ☐ Neither Like Nor Dislike ☐ Dislike Slightly ☐ Dislike Moderately ☐ Dislike Very Much ☐ Dislike Extremely
Odour	Smell the sample. Check for a pleasant, characteristic smell versus off-odours (musty, smoky, burnt).	☐ Like Extremely ☐ Like Very Much ☐ Like Moderately ☐ Like Slightly ☐ Neither Like Nor Dislike ☐ Dislike Slightly ☐ Dislike Moderately ☐ Dislike Very Much ☐ Dislike Extremely

Attribute	Description	Hedonic Scale (Please check one)
Overall Acceptability	Based on all the above attributes, what is your overall liking of the product?	☐ Like Extremely ☐ Like Very Much ☐ Like Moderately ☐ Like Slightly ☐ Neither Like Nor Dislike ☐ Dislike Slightly ☐ Dislike Moderately ☐ Dislike Very Much ☐ Dislike Extremely
Purchase intent	If you were shopping for dried leaves, how likely would you be to purchase this product?	☐ Like Extremely ☐ Definitely Would Buy ☐ Probably Would Buy ☐ Might or Might Not Buy ☐ Probably Would Not Buy ☐ Definitely Would Not Buy

B. Statistical Analysis of Sensory Evaluation Scores

Sensory Attribute	t-value	df	p-value	Significance
Appearance/Texture	4.82	28	< 0.001	**
Colour	5.91	28	< 0.001	**
Odour	6.45	28	< 0.001	**
Overall Acceptability	5.76	28	< 0.001	**
Purchase Intent	7.12	28	< 0.001	**

**p < 0.001 indicates highly significant difference