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Research Article

Comparative Analysis of Selected Bio chemical Properties of Cordyla pinnata Fruit Dried Using a Solar Dryer and Open-Air Drying

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Abstract

This study aims to evaluate the influence of drying methods (open-air sun drying and solar dryer drying) on the biochemical composition of *Cordyla pinnata* fruit, which is used in phytotherapy and local diets in Senegal. The objective is to identify the most effective drying technique for preserving nutrients and nutritional properties while reducing post-harvest losses. To assess drying efficiency, two distinct techniques were compared: solar dryer drying and open-air drying. Dried fruit samples were analyzed to determine total ash content, proteins, sugars (total and reducing), and mineral composition. The results show that the solar dryer better preserves proteins (4.39 ± 0.69 g/100 g) and reducing sugars (3.53 g/100 g) compared to open-air drying (3.99 ± 0.41 g/100 g and 1.94 g/100 g, respectively). Total sugar contents were similar for both methods, whereas open-air drying retained higher levels of minerals, including macroelements and trace elements (63 ± 1 mg/100 g and 234 ± 1 mg/100 g). These findings indicate that solar drying is more effective in preserving primary metabolites, while open-air drying favors the conservation of certain minerals. Drying therefore represents a promising approach for valorizing local food products. Solar drying appears to be the most balanced method, combining accessibility, hygiene, performance, and nutrient preservation, making it a suitable technology for Africa with strong potential to enhance food security.

Keywords: *Cordyla pinnata*, drying methods, phytotherapy, food security

Introduction

The vastness and diversity of African flora, combined with ancestral knowledge of local populations and challenges related to drug dosage and bacterial chemoresistance, have increasingly directed research toward the scientific and controlled use of medicinal plants [1].

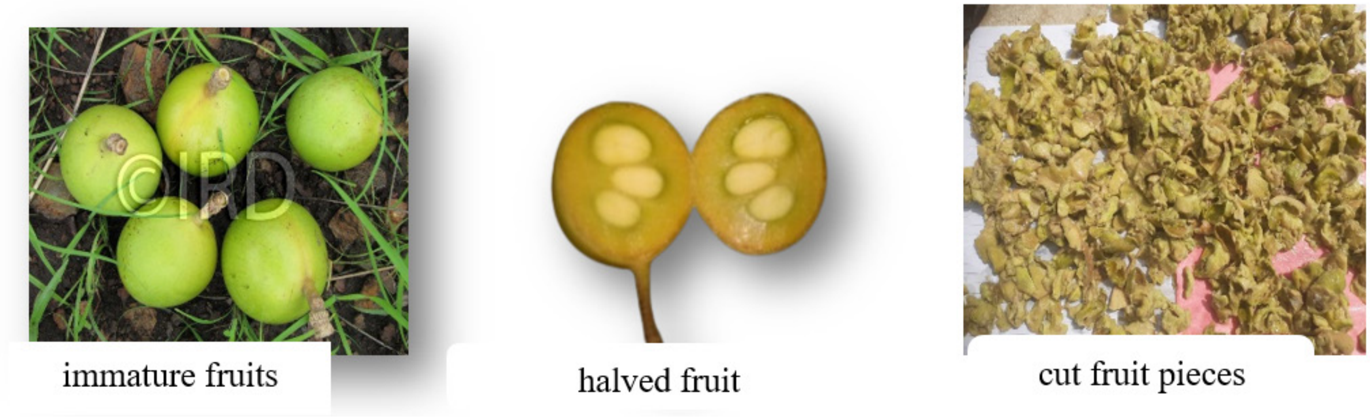
In Senegal, many plants are traditionally used in phytotherapy due to their remarkable biological activities. Among these plants is Cordyla pinnata, a dicotyledonous species belonging to the Fabaceae family, subfamily Faboideae. Native to tropical Africa, the genus comprises seven (7) recognized species [2]. African populations use C. pinnata to treat various ailments such as fever, headaches, and gastric pain. Leaves are used against appetite loss, colds, conjunctivitis, and ENT disorders, while bark is employed in the treatment of hepatic steatosis, liver cancer, accelerated aging, hypercholesterolemia, and diabetes. Roots are used to treat gastric ulcers and hemorrhoids [3].

The fruit of C. pinnata plays an important role in local diets. Ripe fruits yield a sweet yellowish juice, whereas immature fruits, after artisanal processing, accompany most cereal-based family meals [4]. However, C. pinnata fruits are highly perishable due to their high moisture content, resulting in significant losses during the rainy season. Improved valorization and integration into diets could help address nutritional and economic deficiencies. The limited development of drying techniques represents a major constraint in reducing these losses. In this context, the present study evaluates the influence of different drying methods on the biochemical composition of dried C. pinnata fruit.

MATERIALS AND METHODS

Plant Material

Mature fruits were harvested in July 2023 in the municipality of Diamal, located in the Birkelane Department, Kaffrine Region (14°07' N; 15°42' W), central Senegal. After harvesting, fruits were sorted and washed to remove impurities, then peeled, pitted, and the pulp cut into small pieces to accelerate drying.



immature fruits

halved fruit

cut fruit pieces

Figure 1: Preparation steps of immature fruits prior to drying.

METHODES

Drying Methods

Open-Air Sun Drying

Fruit slices were placed on trays covered with breathable mesh to promote air circulation. They were evenly spaced to ensure uniform sun exposure and homogeneous drying. Drying progress was monitored by hourly weighing using a precision balance (Sartorius, A200S, France).

Solar Dryer Drying

Fresh C. pinnata slices were prepared in precise quantities for each trial. Drying was carried out using a solar dryer oriented to maximize solar radiation exposure. Slices were spread uniformly without overlap on racks to ensure optimal air circulation. Drying kinetics were monitored by hourly weighing (±0.001 g) until mass stabilization was achieved. Drying was conducted between 10:00 a.m. and 6:00 p.m. over three consecutive days.

Moisture Content Determination

Moisture content was determined according to NF ISO 712 standard [5]. A 2 g sample was placed in a pre-cleaned, dried, and tared capsule, then dried in an oven at 130 °C for 90 minutes. After drying, the capsule was cooled in a desiccator and weighed. Moisture content (%) was calculated using the following relationship :

$$\% \, \text{Moisture} = \frac{m_1 - m_2}{m1 - m_0} x \, 100$$

m_0: mass of the empty capsule (g)
m_1: mass of capsule + sample before drying (g)
m_2: mass of capsule + sample after drying (g)

Protein Determination

Protein content was determined using the Kjeldahl method [6]. One gram of sample was mineralized in a digestion unit at 450 °C, followed by nitrogen distillation and titration with 0.1 N sulfuric acid. Protein content was calculated as:

$$\% \, Total \, Nitrogen = \frac{V1 \times N \times 14 \times 10 - 3 \times 100}{Pe}$$

Total protein (%) = Nitrogen (%) × 5.70

V1: equivalent volume of hydrochloric acid required for neutralization (mL)
N: normality of hydrochloric acid
Pe: mass of the test portion (g)
5.70: conversion factor

Sugar Analysis

Reducing and total sugars were determined using the Luff–Schoorl method [7] after acid hydrolysis with HCl for 3 minutes under boiling conditions. Sugars were oxidized by a hot alkaline copper solution, and excess copper was titrated iodometrically. Total sugar content (mg/100 g) was calculated based on standard correspondence tables.

$$\% \, Reducing \, sugars = m \times \frac{100}{25} \times d \times \frac{100}{E}$$

m: mass of sugar, expressed in mg, corresponding to the difference in volume between the blank and the sample (V0 − V1) according to the reference table
d: dilution factor
E: mass of the test portion (g)

Ash Content Determination

Total ash content was determined according to AOAC methods [8]. Samples (2 g) were incinerated at 550 °C for 4 hours in a muffle furnace, following gradual temperature increases. Ash content was expressed as a percentage of dry matter.

$$\% Ash \, content = \frac{M_2 - M_0}{M_1} \times 100$$

M0: mass of the empty capsule (g)
M1: mass of the capsule plus sample before drying (g)
M2: mass of the capsule plus sample after drying (g)

Mineral Analysis

Mineral composition was determined using a Niton XLT900s spectrometer equipped with a silver anode excitation source and a multi-filter detector [9].

Statistical Analysis

Data were analyzed using one-way ANOVA. Mean comparisons were performed using the LSD test at a significance level of 5% ($p < 0.05$) using Statistica software version 7.1.

RESULTS AND DISCUSSION

Determination of the moisture content of *Cordyla pinnata* fruits by gravimetry

Gravimetric analysis revealed a progressive decrease in sample mass during drying. Solar drying resulted in faster moisture loss compared to open-air drying, with an average difference of approximately 9.6%. Final moisture stabilization occurred after 32 hours for solar drying and 35 hours for open-air drying.

The initial moisture content of fresh *C. pinnata* fruit was 74.38%, confirming its high perishability. Final moisture contents were 13.54% for solar-dried samples and 15.71% for open-air dried samples, values comparable to those reported for dried tomatoes and mangoes [10–11]. Reduced moisture content limits microbial growth and enhances shelf life.

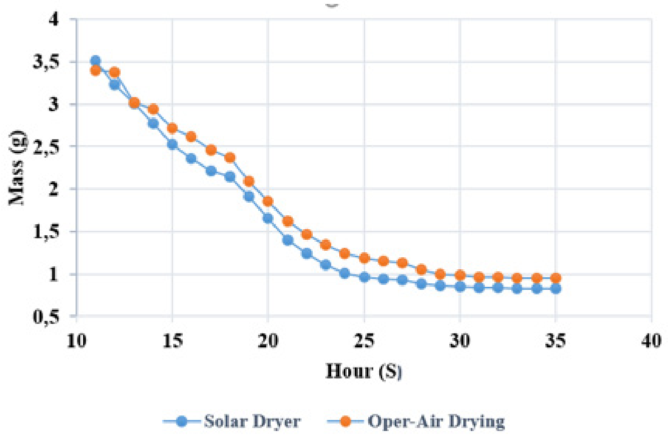


Figure 3: Evolution of water mass loss during fruit drying

This high water activity limits the storage duration of the fruits, making them highly perishable. The average minimum drying time was estimated at 33 hours, resulting in a final moisture content of 13.54% for samples dried using an indirect solar dryer and 15.71% for those dried under open-air conditions (Figure 3). These results are very close to those obtained for tomatoes subjected to the same drying process, for which the final moisture content is approximately 13%, corresponding to equilibrium moisture [10]. Similar observations have also been reported for dried mangoes [11]. The low moisture content protects the fruit against microbial growth, thereby promoting long-term preservation. Moisture is a key determinant of fruit quality and shelf life. It should be noted that water content directly influences fruit texture and varies considerably among different varieties. Moreover, fruit moisture content is closely related to ambient humidity; therefore, these values may vary from one region to another [12]. Reducing moisture content through drying minimizes water activity, leading to the inhibition of microbial processes and stabilization of the product [13].

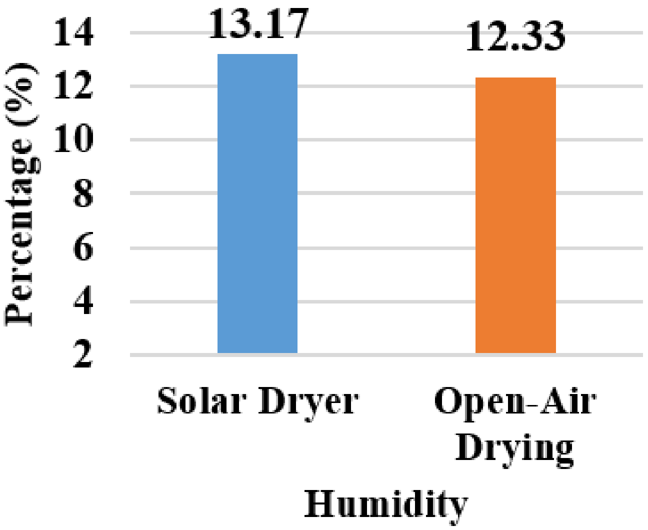


Figure 4 : Effect of drying technique on moisture content

Biochemical Composition

Proteins and Sugars composition

Solar-dried samples exhibited higher protein content (4.39 g/100 g) than open-air dried samples (3.99 g/100 g). Total sugar contents were similar, while reducing sugars were significantly higher in solar-dried samples (3.53 g/100 g) compared to open-air drying (1.94 g/100 g). Prolonged exposure to sunlight during open-air drying likely promotes non-enzymatic browning reactions, including Maillard reactions, reducing sugar content.

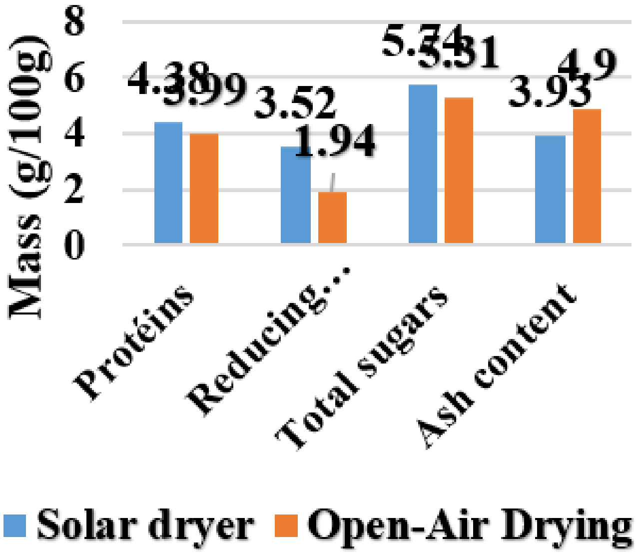


Figure 4 : Effect of drying methods on the ash, protein, and sugar contents of Drying methods differed significantly ($p < 0.05$) in terms of ash content. This figure presents the analytical results obtained for fruit sam-

ples using the two drying methods. The sample dried in the solar dryer exhibited a relatively lower ash content (3.93 ± g/100 g) compared to that dried under open-air conditions (4.9 ± g/100 g). These values are higher than those reported by Damien et al. [14]. Determination of ash content is essential in nutritional evaluation, as it reflects the mineral content of the samples. Based on the total ash content results, C. pinnata fruit can be considered a food of high nutritional value for consumers.

With regard to proteins, the sample dried in the solar dryer showed a higher content than that dried under open-air conditions, with values of 4.39 g/100 g and 3.99 g/100 g, respectively. The drying treatments had a beneficial effect on the nutritional value of proteins by improving their accessibility to digestive enzymes through the inactivation of protease inhibitors. Proteins play a crucial role in the daily renewal of skin, nails, hair, and muscle tissues [15]. They are also involved in the proper functioning of the body, particularly in immune defense mechanisms, and act as enzymes in numerous biological processes [16]. However, protein degradation may occur due to drying temperature and prolonged exposure to open-air conditions, which can disrupt hydrogen bonds that are relatively weak, rendering proteins more vulnerable [17].

Total sugar contents of fruit samples dried using the solar dryer and open-air drying were nearly similar, at 5.75 g/100 g and 5.31 g/100 g, respectively. A substantial amount of sugar was retained and concentrated in all dried samples, with only minor differences between the two methods. Therefore, it can be reasonably concluded that drying methods have little or no influence on total sugar content. In contrast, reducing sugar content was significantly higher in samples dried in the solar dryer (3.53 g/100 g) compared to those dried under open-air conditions (1.94 g/100 g). These values are markedly higher than those reported by Dadda et al. [18], who also demonstrated that reducing sugar content (glucose and fructose) is affected by the drying process. The observed difference may be explained by prolonged exposure to solar radiation during open-air drying, which promotes non-enzymatic browning reactions, particularly the Maillard reaction. Indeed, extended heat exposure during open-air drying can trigger both caramelization and Maillard reactions involving naturally occurring reducing sugars in fruits [19]. The Maillard reaction is a non-enzymatic chemical reaction between the carbonyl groups of reducing sugars and free amino groups of amino acids or proteins. These findings indicate that solar drying provides better process control by limiting direct ultraviolet (UV) exposure and maintaining a more stable temperature throughout drying. This reduces the degradation of reducing sugars and preserves higher sugar levels compared to open-air drying. Nevertheless, all dried samples remain an important source of carbohydrates, whose primary role in the body is to provide energy [20].

Mineral Content

The results presented in Table 1 show significant variations in the mineral content of Cordyla pinnata fruit depending on the drying method used (Table 1).

Table 1 : Mineral content (mg/100 g) of the samples according to the drying method.

Les Eléments Minéraux									
Macronutrients							Trace elements		
Drying methods	Ca	K	Mg	Cl	P	Fe	Zn	Mn	Cu
Solar Dryer	668 ± 1	109.38 ± 0.01	479.5 ± 0.1	69 ± 1	803 ± 1	63 ± 1	6.99 ± 0.1	41 ± 1	7.99 ± 0.01
Sun Drying	742 ± 1	123.62 ± 0.01	583.5 ± 0.1	88 ± 1	924 ± 1	234 ± 1	15 ± 1	62 ± 1	5.99 0.01

Macronutrient mineral content

The measured macroelements, namely calcium (Ca), potassium (K), magnesium (Mg), phosphorus (P), and chlorides (Cl), exhibited significantly higher levels in samples dried under open-air conditions (OAD). Specifically, calcium content increased from 668 mg/g in samples dried using a solar dryer to 742 mg/g in those dried under open-air conditions, while magnesium content increased from 479.5 to 583.5 mg/g. These results are consistent with the findings reported by Slavin and Vernaza [18,19], who indicated that the higher temperatures typically reached in solar dryers promote the degradation of compounds sensitive to heat and light, including certain minerals.

In fruits with high moisture content, such as , heat exposure may enhance the migration of minerals toward the surface, thereby facilitating their oxidation or loss through volatilization, particularly in environments with high air circulation. Previous studies have shown that mineral salts in tropical fruits such as mango and papaya exhibit greater stability when dried under open-air conditions compared to solar dryer or oven drying [20]. Solar dryers (SD) can generate temperatures ranging between 50 and 70 °C, depending on solar radiation intensity and the type of device used. These thermal conditions may lead to the alteration of certain thermosensitive compounds or promote their leaching as a result of condensation or intracellular sweating phenomena occurring during the drying process [21,22].

Trace mineral content

The results also indicate a significant increase in iron (Fe), zinc (Zn), and manganese (Mn) contents in samples dried under open-air conditions compared to those processed using a solar dryer. In particular, iron concentration increased from 63 mg/g in solar-dried samples to 234 mg/g after open-air drying, representing an increase of more than 270%. This observed difference may be explained by the thermal sensitivity of certain organo-mineral complexes, such as phytates or iron-bound organic acids. Under high-temperature conditions, these compounds may undergo accelerated degradation, leading to a reduction in their concentration or bioavailability in the final product [24]. Zinc, on the other hand, exhibited an increase of more than 100%, which may be attributed to the greater stability of its organic forms in the absence of intense heat.

In contrast, copper (Cu) content was slightly higher in samples dried using the solar dryer. This observation may be explained by the catalytic role of copper in oxidation reactions, which are favored at elevated temperatures and may result in the release of previously bound forms [25]. Mineral elements play a wide range of physiological roles in the human body, including mineralization processes, regulation of water balance, enzymatic and hormonal systems, as well as muscular, nervous, and immune functions [26]. However, open-air drying presents certain sanitary limitations, such as an increased risk of microbial contamination, insect infestation, and prolonged drying times that may promote fermentation [27]. Although required in small quantities, minerals are essential components of a balanced diet due to their fundamental role in the proper functioning of the brain, bones, and the body as a whole [28].

CONCLUSION

This comparative study demonstrates that drying methods significantly affect the biochemical properties of fruits. Solar drying ensures better preservation of primary metabolites such as carbohydrates and proteins due to improved control of drying conditions, whereas open-air drying favors mineral retention. Selecting an appropriate drying technique should therefore depend on the target nutritional components. Optimizing post-harvest processing methods could enhance the nutritional and functional value of C. pinnata fruits and contribute to food security and public health improvement.

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