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Evaluation of the Drying Quality of Two Types of Edible Mushrooms (*Termitomyces* sp. and *Pleurotus* sp.) and Their Impact on the Antioxidant Content

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Abstract

The objective of this work is to dry the mushrooms to evaluate the impact of drying on them. The drying of mushrooms in the oven, in the solar dryer and in the microwave indicated that for *Termitomyces* sp. the total polyphenol contents were 15.20 mgEAG/gMs for the microwave drying (280 W), 13.61 mgEAG/gMs for the oven drying (60˚C), and 9.81 mgEAG/gMs for the solar dryer drying (40˚C). For *Pleurotus* sp., the contents obtained were 13.79 mgEAG/gMs for microwave drying (280 W), 8.36 mgEAG/gMs for oven drying (60˚C) and 8.98 mgEAG/gMs for solar drying (40˚C). Regarding flavonoids, for *Termitomyces* sp., this revealed 0.5797 mgECa/gMs for microwave drying (280 W), 0.729 mgECa/gMs for oven drying (60˚C) and 0.5671 mgECa/gMs for solar drying (40˚C). The flavonoid contents for *Pleurotus* sp. gave 0.842 mgECa/gMs for microwave drying (280 W), 1.06 mgECa/gMs for oven drying (60˚C) and, 0.425 mgECa/gMs for solar drying (40˚C). For *Termitomyces* sp., the levels of free radical scavenging activity varied from 13.02 mg/mL for microwave drying, 25.08 mg/mL for oven drying, and 22.25 mg/mL for solar drying; while for *Pleurotus* sp., 15.96 mg/mL for microwave drying, 39.90 mg/mL for oven drying, and 31.60 mg/mL for solar drying.

Keywords

Evaluation, Quality, Drying, Fungi, Impact, Antioxidant

1. Introduction

In Africa, wild edible mushrooms are an important food source [1]. They provide a supplement to the daily diet that is particularly rich in trace elements, vitamins and proteins [2]. They are incredibly healthy foods, loaded with nutritious yet low-calorie food components [3] [4] [5]. They are rich in amino acids and vitamins, as well as protein and fiber [6]. Edible mushrooms contain fats, which are mainly composed of unsaturated fatty acids [7] [8]. Many of the mushrooms have medicinal properties [9] [10]. Mushrooms are consumed all over the world, and Zambia is no exception [11].

In poor and rural areas, this contribution is very important, especially when reserves are exhausted or when crops are not yet mature [1].

In Congo, edible mushrooms are harvested in all agro-ecological zones with a high proportion in the forests and savannah. During the flowering period, mushrooms are widely consumed. As such, they are considered strategic foods in the fight against the problems of nutrition and food insecurity that plague tropical African countries. Some African authors believe that mushrooms are a very good source of minerals [12] and a real source of protein [2]. Others in India, present mushrooms as a source of carotene, polyphenols and Lycopene [13].

However, the cultivation of mushrooms is not yet well developed and a shortage is observed in rural areas but also in large cities. Known as one of the oldest operations of food preservation, drying reduces the activity of water. It is therefore an operation of thermal separation that consists in eliminating by partial or total evaporation of water contained in food [14] [15]. It is a question of simultaneous transfers of heat and mass between the product to be dried and the surrounding air. Sun drying is commonly used in Africa but its impact on the finished product can be unpleasant [16]. Therefore, the use of controlled atmosphere devices can be an alternative for the preservation of the quality of dried products. The drying process follows an evolution that is a function of time and speed.

This phenomenon allows us to evaluate the drying behavior of a product by determining the relationship between the speed of the drying air, temperature, humidity and relative mass as a function of time [17]. But for this study, the purpose is not to evaluate the kinetics of drying but, on the other hand, to evaluate the quality of the product, especially the antioxidants, using different drying methods.

Antioxidants appear today as the keys to longevity and our allies in the fight against modern diseases. They are protective elements that have an extreme variety of structures and biological activities and act as free radical scavengers. For

this reason, an antioxidant is defined as a substance capable of preventing or slowing down the oxidation of other molecules [18].

Free radicals are produced daily in large quantities by the organism via the oxygen that is essential to our life, and are very reactive compounds with a single electron and necessary for vital mechanisms [19]. However, they become harmful when they are in excess and induce certain damage to the structure of proteins, lipids [20], nucleic acids [21] by causing oxidative stress that contributes to the processes of accelerated cellular aging and the development of many human pathologies such as cardiovascular diseases, cancers, arteriosclerosis [21], diabetes, Alzheimer's disease, rheumatism [22].

The aim of the present work is to evaluate the drying quality of mushrooms (*Termitomyces* sp. and *Pleurotus* sp.).

2. Material and Methods

This study was conducted in two research laboratories, the National Institute of Research in Engineering Sciences, Innovation and Technology (INRSIIT) and the National Institute of Agronomic Research (IRA).

2.1. Plant Material

The plant raw materials that were the subject of this study are:

- Mushrooms of the genus *Termitomycse* sp. (**Figure 1(a)**) from the locality of Brazzaville in southwestern Congo;
- Mushrooms of the genus *Pleurotus* sp. (**Figure 1(b)**). These fungi were collected at the foot of trees in the southwest of Brazzaville Congo.

2.2. Drying Equipment

The drying equipment consisted essentially of solar dryer of boat type (**Figure 2(a)**) and the Memmrt brand oven (**Figure 2(b)**)

2.3. Methods

Determination of Total Polyphenols and Total Flavonoids

1) Preparation of extracts

(a) (b)

Figure 1. *Termitomycse* sp. (a); *Pleurotus* sp. (b).

(a) (b)

Figure 2. Boat type solar dryer (a); oven (b).

The different extracts made for the determination of total polyphenols and flavonoids were obtained by mixing 30 g of the plant material in 2 × 500 mL of a 50% hydroethanol solution in the same proportions 50% (v/v). The mixture was then macerated under stirring for 72 h and filtered with filter paper. The filtrate obtained was concentrated to dryness at 50˚C under reduced pressure using a rotary evaporator model N-1 (Eyela, Tokyo Rikakikal Co., Ltd., Japan) and stored in an oven at 25˚C and kept in a cool place (+4˚C) waiting for analysis (**Figure 2**).

2) Determination of total polyphenols

The determination of the concentration of total phenols in the different samples was performed by the Folin Ciocalteu technique described by [18]. The Folin Ciocalteu reagent is reduced by the phenyl-copper complex which gives a blue coloration with maximum absorbance at 760 nm.

0.1 mL of the hydroethanol extract of mushrooms of concentration 2 mg/mL is introduced into a 2 mL Eppendorff tube. Subsequently 0.9 mL of distilled water and 0.9 mL of Folin-Ciocalteu reagent (1 N) are added and immediately afterwards 0.2 mL of Na_2CO_3 solution (20%) is added. The resulting mixture is incubated at room temperature for about 40 minutes in the dark. The absorbance is then measured with a spectrophotometer at 725 nm against a methanol solution used as blank. Note that a calibration line is previously performed before the analysis with gallic acid under the same conditions as the samples to be analyzed. The results obtained are expressed in mg gallic acid equivalent per gram of dry matter (EAG/gMs).

3) Determination of total flavonoids

The total flavonoid content of the extract of mushroom types was obtained by using aluminum trichloride ($AlCl_3$) [23]. In a 100 mL flask, 250 µL of the hydroethanol extract was successively introduced.

1 mL of distilled water, 7.5 µL of $NaNO_2$ (5%). The mixture was allowed to stand for 5 minutes. Then 75 µL of $AlCl_3$ (10%), was added before letting it stand again for 6 min. Then 500 µL of NaOH (1 N) and 2.5 mL of distilled water were added successively to the mixture. The analyses were performed at 25˚C.

The following reagents: NaOH, $NaNO_2$, Na_2CO_3, ethyl acetate, and formic acid were all from Merck.

Absorbance was measured by UV-Visible spectrophotometer, model Gd-752n at 510 nm and results were expressed as mg catechin equivalent per gram of dry matter (mgECa/gMs).

2.4. Determination of the Anti-Radical Activity of the Hydro-Ethanolic Extract

Determination of the Anti-Radical Activity of the Hydro-Ethanolic Extract

The antioxidant activity of the extract was measured using DPPH radical.

The evaluation of free radical activity was performed using 5 mL of 1.1-diphenyl-2-picrylhydrazyl (DPPH at 10 mg in 250 mL ethanol) solution and 100 µL of each extract diluted to concentrations ranging from 10 to 0.312 mg/mL, mixed in EDTA glass tubes. The DPPH radical is dissolved in 0.004% methanol solution stored at room temperature protected from light before use.

After 30 minutes of incubation in the dark, the free radical scavenging activity was measured by spectrophotometer at 517 nm in the dark [24]. The percentage of inhibition was calculated by the following relationship:

$$I\% = \frac{(\text{A517 of the white} - \text{A517 of the sample})}{\text{A517 of the white}} \times 100$$

With A517: Absorbance at 517 nm.

The reaction of the reduction of DPPH with phenolic compounds is shown in Figure 3 below.

3. Results and Discussion

3.1. Polyphenol and Flavonoid Content

Figure 4 shows the results of polyphenols and flavonoids of the studied mushrooms.

This figure reveals the interesting contents of total polyphenols and flavonoids of the studied samples. The results revealed that the samples studied are mainly composed of total polyphenols. The concentrations of polyphenols, for *Termitomyces* sp. vary from 11.18 mgEAG/gMs (fresh), from 15.20 mgEAG/gMs (microwave drying at 280 W), from 13.61 mgEAG/gMs (oven drying at 60˚C), and from 9.81 mgEAG/gMs (solar dryer at 40˚C); while for *Pleurotus* sp., the

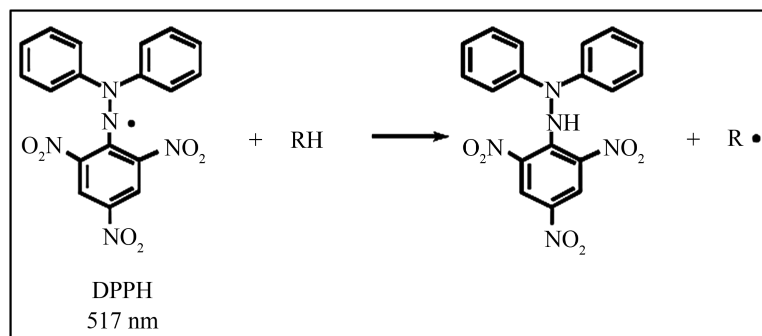

Figure 3. DPPH reduction reaction. Source: [24].

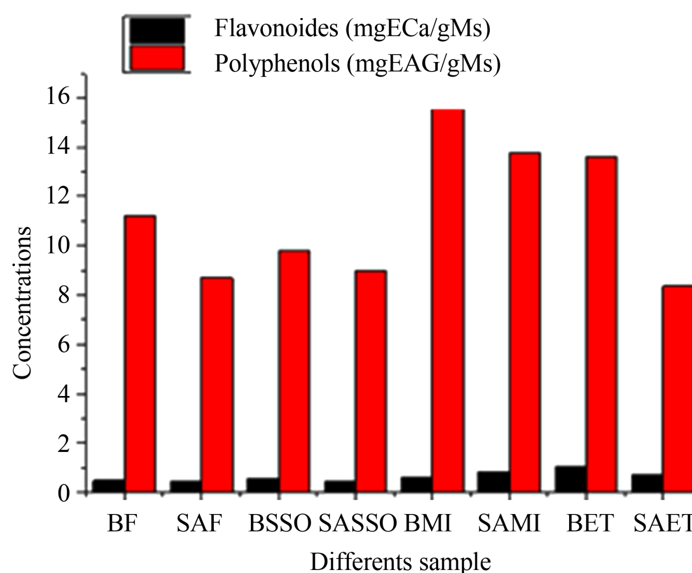

Figure 4. Quantitative composition of flavonoids and total polyphenols.

concentrations varied from 8.7 mgEAG/gMs (fresh), 13.79 mgEAG/gMs (microwave drying at 280 W), 8.36 mgEAG/gMs (oven drying at 60˚C), and 8.98 mgEAG/gMs (solar dryer at 40˚C).

Flavonoid contents for *Termitomyces* sp. ranged from 0.4964 mgECa/gMs (fresh), 0.5797 mgECa/gMs (microwave drying at 280 W), 0.729 mgECa/gMs (oven drying at 60˚C) and 0.5671 mgECa/gMs (solar dryer at 40˚C); while for *Pleurotus* sp., the concentrations vary from 0.4114 mgECa/gMs (fresh), 0.842 mgECa/gMs (microwave oven at drying at 280 W), 1.06 mgECa/gMs (oven drying at 60˚C), 0.425 mgECa/gMs (solar dryer at 40˚C).

The studied mushrooms are a good source of flavonoids.

Similar results were found by Muanda, N. F. [23] on several plants and showed that the extracts of *D. Oliveri* are quantitatively richer in phenolic compounds (polyphenols, flavonoids) with contents of 22 to 70 mgEAG/gMs of PPT and 96.73 to 120.8 mgECa/gMs of FVT.

The results on the extracts of *D. Adscendens* leaves gave 11.15 mgEAG/gMs of PPT and 12.94 mgEAG/gMs of FVT.

The results on the extracts of *F. capensis* gave 21.33 mgEAG/gMs of PPT and 115.2 mgEAG/gMs of FVT.

The results from the root barks of *S. Longependuculata* are richer in polyphonic compounds with values of 9.86 mg EGa/gMs of PPT and 5.85 mgECa/gMs of FVT. The work reported by Sompila, A. W. G. T., *et al.*, [25] revealed that the fronds of *P. aquilinum* are rich in polyphenols and flavonoids; similarly, the work of Nguie, R., *et al.* [26] revealed that the aquatic plant *L. schlechteri* was also rich in hydro-ethanol extracts.

3.2. Anti-Radical Activity Content (Anti-Oxidant)

Figure 5 presents the results of the anti-free radical activity of the studied fungi.

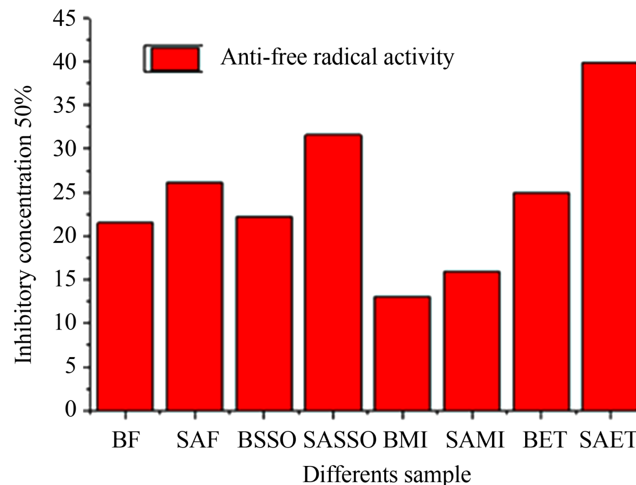

Figure 5. Quantitative composition of the anti-free radical activity of the studied fungi.

Figure 5 reveals interesting antioxidant properties of the studied samples. For *Termitomyces* sp., the concentrations vary from 21.25 mg/mL (fresh), 13.02 mg/mL (microwave drying), 25.08 mg/mL (oven drying), and 22.25 mg/mL (solar dryer); while for *Pleurotus* sp., they vary from 26.11 mg/mL (fresh), 15.96 mg/mL (microwave oven drying), 39.90 mg/mL (oven drying), 31.60 mg/mL (solar dryer). The studied mushrooms have interesting antioxidant properties. These results corroborate with those found by [19] on the same plants which show that the antioxidant capacity of the extracts analyzed is relatively important. This is the case for the extracts of *D. oliveri* "Et (2.9 µg/mL), Er (2.8 µg/mL), F (2.7 µg/mL)"; *V. doniana* "Et (2.9 µg/mL), Er (2.9 µg/mL), F (2.9 µg/mL)"; *D. adscendens* "F (4 µg/mL)"; *F. capensis* "Et (2.9 µg/mL)" and *S. rebaudiana* "Er (2.9 µg/mL)".

Barks of the roots of *S. longependuculata* "Er (5.5 µg/mL)" and extracts of *F. capensis* "Er (8.8 µg/mL)". Extracts of leaves of *F. capensis* (10.2 µg/mL), essential oils *S. rebaudiana* IC (23.3 µg/mL) and *F. capensis* (19.3 µg/mL).

4. Conclusion

This study aims to contribute to the valorization of two species of edible mushrooms from Congo, *Termitomyces* sp. and *Pleurotus* sp., which play an important role in the food and nutritional security of the populations of Congo. The drying of these products preserved the total polyphenols and flavonoids and the anti-root activity at satisfactory levels.

The evaluation of the anti-oxidant properties reveals that all these samples show an important anti-oxidant activity, with high activity for *Termitomyces* sp. of 25.08 mg/mL (oven drying), and 22.25 mg/mL (solar drying); while for *Pleurotus* sp. of 39.90 mg/mL (oven drying) and 31.60 mg/mL.

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Conflicts of Interest

No conflict on this article.

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Nomenclature

EGA: Gallic Acid Equivalent
ECa: Catechin Equivalent
Ms: Dry Matter
mg: Milligramme
mL: Milliliter
IC50: 50% Inhibitory Concentration
DPPH: 1.1-Diphenyl-2-Picrylhydrazyl
FVT: Total Flavonoid Content
PPT: Total Polyphenol Content
SAF: Salanga Molele fresh (*Pleurotus* sp.)
SASSO: Salanga Molele dried in a solar dryer (*Pleurotus* sp.)
SA-ET: Salanga Molele oven-dried (*Pleurotus* sp.)
SA-MI: Salanga Molele microwave dried (*Pleurotus* sp.)
BF: Bouloundi fresh (*Termitomyces* sp.)
B-SSO: Bouloundi dried in a solar dryer (*Termitomyces* sp.)
B-ET: Bouloundi oven-dried (*Termitomyces* sp.)
B-MI: Bouloundi microwave dried (*Termitomyces* sp.)