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Impact of Air- and Freeze-Drying Methods on Total Phenolic Content and Antioxidant Activity of *Fistulina antarctica* and *Ramaria patagonica* Fructification

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Abstract: *Fistulina antarctica* and *Ramaria patagonica* are wild edible fungi from Patagonia, which produce mushrooms that have been consumed since ancient times by those in local communities. Both species possess high protein and low fat contents and other bioactive compounds with remarkable antioxidant activity. Drying is a widely and commonly practiced preservation technique that is cost-effective. However, the process of drying can have an impact on the levels of bioactive compounds. In this study, the effects of drying methods on the total phenolic content (TPC) and antioxidant activity in the fructification of *F. antarctica* and *R. patagonica* were estimated. The analysis was conducted using fructifications that were fresh-frozen, dried at 50, 60, and 70 °C, and freeze-dried. The TPC was significantly higher for the fructifications that were fresh-frozen and dried at 60 °C in *R. patagonica* (with values of 14.78 and 13.67 mg GAE/mg of extract, respectively). Also, the fresh-freezing, freeze-drying. and 60 °C methods exhibited the highest inhibition of free radicals. In addition, *R. patagonica* had a notably higher concentration of phenols and showed higher antioxidant capacity than *F. antarctica*. The greatest losses concerning phenols occur in *F. antarctica* in the three evaluated air-drying temperatures (36.57, 29.76, 39.47% in 50, 60 and 70 °C respectively, compared with fresh-frozen). TPC and antioxidant activity were higher in fresh-frozen and freeze-dried samples. A drying temperature of 60 °C is advisable for both species, considering drying time and bioactivity. Overall, the fructifications from different processing methods exhibited unique functional properties. This information can be utilized to optimize the postharvest preservation and maximize the potential applications of these mushrooms.

Keywords: antioxidant activity; DPPH; edible mushrooms; Patagonia; postharvest preservation

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1. Introduction

The Patagonian Andean forests are home to a wide variety of wild fungi species that hold great potential as edible food, offering both high nutritional value and medicinal properties [1]. Certain species within these forests have been identified by Mapuche communities as having a long history of traditional use, remarkable sensory qualities, and promising economic viability [2]. In particular, the ancestral consumption records of the species *Fistulina antarctica* (n.v. lengua de vaca) and *Ramaria patagonica* (n.v. changle) are

widespread. Recently, the nutritional composition of these and other wild edible mushrooms (WEM) from Argentina and Chile has been investigated, with a particular focus on their fatty and organic acids, soluble sugars, phenolic compounds, and ergosterol contents, in addition to antioxidant and antimicrobial potential [3–5]. *Fistulina antarctica* showed low amounts of fat (0.83 ± 0.01 g/100 g dw), sugars (28.68 ± 0.58 g/100 g dw), proteins (3.71 ± 0.07 g/100 g dw), and phenolic compounds (9.85 ± 0.09 µg/100 g dw), compared with *R. patagonica*, which showed low amounts of fat (2.51 ± 0.10 g/100 g dw) and sugars (9.41 ± 0.35 g/100 g dw) and high amounts of proteins (19.68 ± 0.64 g/100 g dw) and phenolic compounds (134.39 ± 2.10 µg/100 g dw) [3,5].

Phenolic compounds are a significant category of bioactive substances that possess antioxidant, antibacterial, and anti-inflammatory properties. These compounds have the potential to enhance natural defense mechanisms in humans [6,7]. The antioxidant properties of these bioactive molecules are crucial in preventing the damage caused by free radicals; numerous studies have reported that this activity is related to their phenolic content [8,9]. Between the Patagonian species, *R. patagonica* presented the highest content of phenolic compounds of 50.82 mg GAE/g extract [3], with relatively high amounts of protocatechuic acid [5] and the most effective results in all antioxidant activity assays in comparison with other WEMs [3,5]. Instead, *Fistulina antarctica* showed the lowest antioxidant activity in terms of 2,2-diphenyl-1-picrylhydrazyl (DPPH) scavenging activity, thiobarbituric acid reactive substances' (TBARSs') inhibition, β-carotene bleaching inhibition assay [3], oxidative hemolysis inhibition (OxHLIA), and TBARS inhibition assay [5]; *Fistulina antarctica* also had a low phenols contents of 7.82 mg GAE/g [3] and 1.30 mg GAE/g extract [5].

Mushrooms are known for their perishability and relatively short shelf-life because they lack a protective cuticle, have a high respiratory rate, and contain a significant amount of water [10,11]. These factors make them susceptible to various deteriorative processes, including mechanical damage, microbial contamination, weight loss, and enzymatic browning [10]. Consequently, mushrooms suffer a rapid decline in quality shortly after harvest, so postharvest conditions as well as culinary treatments significantly affect their quality [12–14]. *Agaricus bisporus* and *Pleurotus ostreatus* are mushrooms that typically last for one to three days at room temperature and five to seven days when refrigerated [10]. The maximum shelf-life in conventional refrigerator conditions (at 4 °C) was in 4 days for *F. antarctica* and 8 days for *R. patagonica* [15]. This creates a problem for the distribution and marketing of fresh mushrooms. In addition, as edible wild mushrooms from Patagonia have strict fruiting seasonality (April and May for these species), to enable their consumption during the rest of the year, they must be preserved through drying.

Dehydration has become an efficient, widely used mushroom preservation process to extend their shelf life [16–18], as reducing the water content minimizes microbial spoilage and deterioration while preserving texture and flavor [15,19,20]. Dehydration constitutes the postharvest method commonly used for extending the shelf life of WEMs in Patagonia [2]. However, the changes that foods can undergo with this method make it necessary to search for other preservation techniques that maintain the quality and bioactive compounds and extend the shelf life of fresh mushrooms [15,16].

Hot-air drying (HD) and freeze drying (FD) are two of the most used methods for drying mushrooms [21–23]. HD involves exposing the mushrooms to circulating hot air, which causes moisture evaporation and subsequent drying. This method is relatively simple and cost-effective; nevertheless, HD can lead to losses in bioactivity and potentially affects the texture and color of mushrooms [7,13,14,20,23]. On the other hand, FD is a more advanced and specialized method. It involves freezing the mushrooms and then subjecting them to a vacuum environment, where the frozen water undergoes sublimation (directly changing from solid to a gas). FD is known for its ability to retain the original color, texture, and nutritional properties of mushrooms. FD is suitable for heat-sensitive compounds (such as phenols, tocopherols, carotenoids, and ascorbic acid, which have antioxidant properties) and results in high-quality dried mushrooms; however, the FD

is a more expensive and time-consuming process, requiring specialized equipment and expertise [22,24,25].

The selection of an ideal drying method for mushrooms is driven by the objectives of minimizing drying time and energy consumption, thereby reducing the cost, while ensuring the desired quality of the final product [17]. However, the choice between methods depends on various factors including available resources and cost considerations.

Thus, to select the most appropriate drying process and to analyze the cost/benefit relationship in the technological re-adaptation of traditional practices, it is necessary to analyze the bioactivity losses linked to dehydration methods and to different dehydration temperatures. By using suitable techniques, it is possible to maintain the integrity of these bioactive compounds and secondary metabolites, thereby increasing the shelf life of mushrooms [10].

Therefore, the aim of this study was to evaluate the impact of air-drying temperature and freeze drying on the total phenolic content (TPC) as well as antioxidant activity of *F. antarctica* and *R. patagonica*. Additionally, these research efforts are associated with initiatives to establish mycotourism and mycogastronomy as regional development alternatives. To achieve this, it is necessary to have solid information on different postharvest conservation techniques and storage methods that allow the sale of quality products with bioactive properties that are as similar as possible to those of fresh products.

2. Materials and Methods

2.1. Sample Collection and Processing

Wild *F. antarctica* and *R. patagonica* samples (Figure 1) were collected from Los Alerces National Park (LANP) in April–May 2023. The fresh fruiting bodies of both species were initially cleaned and sliced into small pieces (about 2–3 mm) on the day of harvesting to determine fresh moisture content, and the rest was divided into portions of 250 g for the air-drying treatments. Samples were immediately used fresh for air-drying temperature treatments and frozen at −80 °C until freeze-dried. Experiments were performed in the area of the Phytopathology and Applied Microbiology of Forest Research Center (CIEFAP).

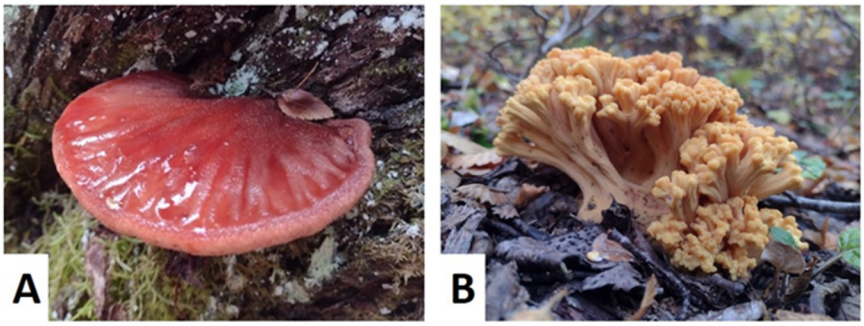

Figure 1. Samples of the wild edible mushrooms studied: (**A**) *Fistulina antarctica*; (**B**) *Ramaria patagonica*.

2.2. Moisture Content

Fresh initial moisture content was measured via the oven method [26]. In brief, a known amount of fresh sample was placed in Petri dishes in a drying oven (Dalvo instruments, Model UBF575, Santa Fe, Argentina) at 102 °C, dried to constant weight, taken out, cooled in a desiccator, and weighed using a precision balance (Explorer Ohaus, Parsippany, NJ, USA; 0.0001 g). Moisture content was established using the following formula:

$$X_{(db)} = \text{g } H_2O/\text{g DS}$$

where $X_{(db)}$ is the moisture content on a dry basis, and DS is dry solid. Three replicates were conducted for each treatment.

2.3. Drying Process

For the air-drying experiment, different drying temperatures (50 °C, 60 °C, or 70 °C) were applied using a commercial oven (Numak DHG-9203A), keeping the flush speed constant at 0.8 m/s and the relative air humidity at 7%). The weight losses of the partially dehydrated samples were obtained through discontinuous weighing using a digital analytical balance (Explorer Ohaus, USA; ±0.0001 g). Following Valiente et al. [26], samples were dried until equilibrium. The final dry weight was determined in a forced-air oven at 102 °C, until constant weight was reached, using the aforementioned balance. The relative moisture content was calculated as Xr (X/X0), where X is the moisture content at time t, and X0 is the initial moisture content, depending on the drying time (t).

For the freeze-drying experiment, fresh fructifications were packaged in plastic centrifuge tubes (50 mL), frozen at −80 ± 1 °C for 24 h, removed, and placed immediately in a freeze-dryer (BiOBASE, BK-FD10 Series) for 72 h. The temperature of the condenser was fixed at −64 °C, and the vacuum was kept at 20 Pa. Three replicates were conducted for each treatment.

2.4. Preparation of Extracts of Bioactive Compounds

The dry or freeze-dried samples (2 g equivalent to 20 g of fresh-frozen) were ground and extracted using 50 mL of a solution of ethanol/water (80:20 v/v) for 2 h at room temperature in a shaker (IKA-MAG, Type RCT, Staufen, Germany). The extracts were concentrated in a rotating evaporator, lyophilized, and stored before use. Then, samples were redissolved in methanol at a 5 mg/mL concentration for bioactive analysis. All analyses were carried out in triplicate.

2.5. Total Phenolic Content (TPC)

The concentration of TPC was determined using the Folin-Ciocalteu method [27]. Folin-Ciocalteau reagents (50 µL) were added to 500 µL of the extract and mixed. The protocol of Valiente et al. was followed [26]. Absorbance was measured at 765 nm using a Multiskan Sky High spectrophotometer (Thermo Scientific, Waltham, MA, USA). A standard of gallic acid (mg/L) was used. The results are expressed as milligrams of equivalent gallic acid per 100 grams of fresh or dried mushrooms on a dry weight basis (mg GAE/100 g).

2.6. Evaluation of Antioxidant Activity

2.6.1. ABTS Radical Scavenging Activity

The ABTS radical scavenging was determined using the method reported by Gąsecka et al. [28] with some changes. Briefly, 200 µL of ABTS-adjusted solution was added to 20 µL of each extract. The absorbance was measured at 734 nm after 10 min of incubation. Controls contained 50 µL of distilled water. The ABTS radical scavenging activity (RSA) was estimated using the formula:

$$\text{ABTS RSA (\%)} = [(A0 - A1)/A0] \times 100$$

where $A1$ is the absorbance value of samples; $A0$ is the absorbance value of the ABTS solution without samples.

2.6.2. 2,2-Diphenyl-1-Picrylhydrazyl (DPPH) Radical Scavenging Activity

The DPPH radical scavenging capacity was evaluated according to a modified version of the method reported by Blois [29]. Briefly, 270 µL of 0.06 mM methyl alcohol DPPH solution was added to 30 µL of ethanolic extract mushroom species in a 96-well plate. The mixture was shaken vigorously and allowed to stand at room temperature for 60 min. The absorbance was measured at 515 nm after 60 min of incubation at room temperature.

The DPPH radical scavenging effect was calculated as follows:

$$\text{DPPH RSA (\%)} = (A0 - A1)/A0 \times 100\%,$$

where $A1$ is the absorbance value of the solution samples, and $A0$ is the absorbance value of the DPPH solution without samples.

2.6.3. Ferric-Reducing Antioxidant Power Assay (FRAP)

Reducing power was determined according to Kozaski et al. [30]. The absorbance of 200 µL of the mix solution was measured at 700 nm. The blank was the solution with all reagents without mushroom extract. A higher absorbance indicates a greater reducing power. A calibration curve between 0 and 30 mg/mL of ascorbic acid (AA) was used to express the results as AA equivalents in 100 mL.

2.6.4. Inhibition of Lipid Peroxidation (LIP)

The conjugated diene method, with some modifications, was used for antioxidant activity determination [31]. The absorbance was recorded at 234 nm at 0, 24, and 48 h of incubation time. The samples were incubated at 37 °C and 150 rpm, without light. A blank without-mushroom extract was used. The proportional antioxidant activity was calculated as follows:

$$[(\Delta A0 - \Delta A1)/\Delta A0] \times 100$$

where ΔA0 is the difference in the absorbance between 0 and 24 h of incubation of the control reaction, and ΔA1 is the difference in the absorbance in the presence of the sample. Ascorbic acid was used as a positive control. A value of 100% indicated a stronger inhibitory ability.

2.7. Statistical Analysis

Three different samples of each of the two mushrooms were tested. Measurements were conducted in triplicate, and the resulting data from the experiments were collected and analyzed using the Statistical Package RStudio (version 1.1.485—© 2009–2022 RStudio, Inc., Boston, MA, USA). The results presented in tables and figures are shown as the mean value of three replicates and its corresponding standard deviation. Differences between mean values were evaluated using one-way analysis of variance (ANOVA) followed by post hoc Tukey's test with a significance level of 0.05 and a confidence interval of 95% ($p < 0.05$).

3. Results and Discussion

3.1. Moisture Contents and Air-Drying Behavior

The fresh moisture contents of *F. antarctica* and *R. patagonica* were 90.65 ± 3.7% and 91.5 ± 1%, respectively. The moisture content of the tested species as a function of drying time (Xr = X/X0, fixing a relative moisture of Xr = 0.01) for different temperatures is presented in Figure 2. Significantly less dehydration time was required at 70 °C for both species (Table 1). Between mushrooms, a remarkable difference in drying time was detected, as *Fistulina antarctica* required almost twice the drying time compared with *R. patagonica* (Table 1). The coralloid shape of *R. patagonica*, with a cylindrical axis of 0.5 cm diameter, on average, can explain the difference found with *F. antarctica*.

Table 1. Drying times at different air-drying temperatures. Different letters indicate significant differences between temperatures for each species ($p < 0.05$).

	50 °C	**60 °C**	**70 °C**
F. antarctica	9.75 ± 1.06 ^{b}	7.37 ± 0.53 ^{b}	3.62 ± 0.17 ^{a}
R. patagonica	3.87 ± 0.18 ^{b}	2.37 ± 0.70 ^{b}	1.62 ± 0.77 ^{a}

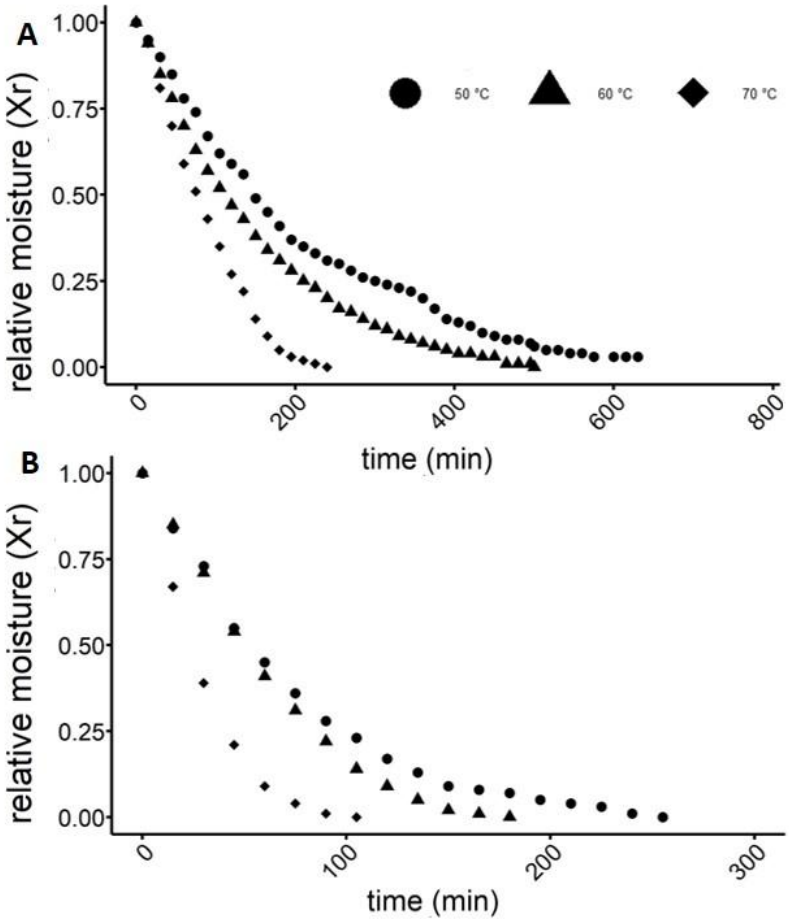

Figure 2. Drying curves at the tested temperatures for *Fistulina antarctica* (**A**) and *Ramaria patagonica* (**B**).

The moisture of the fresh fructifications was similar to those reported for other edible mushrooms, for example, a moisture content for *Fistulina hepatica* of 87.51% [32], for *Flammulina velutipes* of 90.7% [33], for *Lactarius deliciosus of* 90.0% [12], for *Lentinula edodes* of 88.4% [34], for *Lepista nuda* of 93.8% [35], for *Pleurotus ostreatus* of 91.5% [36], for *Ramaria aurea* of 88.5% [33], and for *R. botrytis* of 89.8% [35]. Beyond the morphology of the fruitings, the water contents of the edible mushrooms were very similar.

The shorter drying time (3.62 h and 1.62 h at 70 °C for *F. antarctica* and *R. patagonica*, respectively) is an advantage in comparison with other edible mushrooms that are used for global consumption and production. Since there are no previous reports of drying of species of the genus *Fistulina* and *Ramaria*, our results are compared to those for other edible mushrooms. In the case of *Hericium erinaceus*, the drying times at 40 °C and 70 °C were 12 and 7 h, respectively [7]. In the case of *Agaricus bisporus*, the drying times were 8.6 and 2.6 h at 50 °C and 75 °C, respectively [37]; for *Lentinula edodes*, this time was 7.5 h at 60 °C [22] and drying time was 8, 7, and 6 h at 50 °C, 60 °C, and 70 °C, respectively, for *Pleurotus ostreatus* [38].

3.2. Effect on Total Phenolic Content

The TPCs were higher in the *R. patagonica* than in the *F. antarctica* samples and varied significantly between the mushrooms in the fresh-frozen, freeze-dried, and dehydrated treatments, although with different patterns. Fresh freeing and a 60 °C dehydration temperature produced significantly higher TPC values for *R. patagonica* (14.78 ± 0.09 and 13.67 ± 0.43 mg GAE/mg extract, respectively), followed by the other treatments, although with no significant differences between them. Instead, for *F. antarctica*, freeze-dried samples presented the significantly highest value (8.66 ± 0.16 mg GAE/mg extract) followed by

fresh-frozen samples (7.93 mg GAE/mg extract) and then by the samples in the three different dehydration temperature treatments (Table 2).

Table 2. Antioxidant activity in fresh frozen, dried, and freeze-dried simples. Different letters indicate significant differences ($p < 0.05$). nd = not detected.

	TPC (mg GAE/mg Extract)	ABTS (% of Inhibition)	DPPH RSA (%)	FRAP (mg AAE/100 mL)	ILP (%)	
					t 24	t 48
F. antarctica						
Fresh-frozen	7.93 ± 0.64 ^{c}	79.75 ± 0.58 ^{bc}	68.94 ± 1.99 ^{c}	43.01 ± 0.21 ^{ab}	39.02 ± 1.30 ^{a}	27.71 ± 0.80 ^{a}
50 °C	5.03 ± 0.20 ^{a}	63.00 ± 3.77 ^{a}	47.21 ± 4.75 ^{b}	24.77 ± 6.28 ^{ab}	nd	nd
60 °C	5.57 ± 0.10 ^{b}	70.73 ± 7.90 ^{ab}	48.39 ± 0.44 ^{b}	32.86 ± 2.50 ^{ab}	nd	nd
70° C	4.80 ± 0.11 ^{a}	57.05 ± 1.74 ^{a}	24.31 ± 0.55 ^{a}	24.58 ± 1.99 ^{a}	nd	nd
Freeze-dried	8.66 ± 0.16 ^{d}	82.35 ± 0.11 ^{c}	43.41 ± 7.64 ^{b}	38.88 ± 1.20 ^{a}	37.36 ± 0.90 ^{a}	22.62 ± 0.58 ^{c}
R. patagonica						
Fresh-frozen	14.78 ± 0.09 ^{b}	99.03 ± 0.87 ^{b}	99.31 ± 4.23 ^{b}	98.08 ± 0.70 ^{d}	97.72 ± 0.90 ^{c}	99.03 ± 0.87 ^{b}
50 °C	9.54 ± 0.43 ^{a}	90.77 ± 1.06 ^{a}	81.25 ± 1.66 ^{a}	72.90 ± 6.64 ^{a}	86.57 ± 0.80 ^{cd}	81.82 ± 0.20 ^{b}
60 °C	13.67 ± 0.43 ^{b}	91.59 ± 1.83 ^{a}	82.58 ± 0.66 ^{a}	97.60 ± 2.28 ^{b}	93.09 ± 1.30 ^{bc}	85.52 ± 1.20 ^{a}
70 °C	11.11 ± 0.34 ^{a}	92.83 ± 0.29 ^{a}	81.57 ± 0.55 ^{a}	89.02 ± 8.90 ^{ab}	82.79 ± 0.90 ^{a}	83.51 ± 2.10 ^{a}
Freeze-dried	10.52 ± 0.53 ^{a}	90.01 ± 1.16 ^{a}	82.43 ± 0.44 ^{a}	96.54 ± 2.06 ^{b}	92.51 ± 0.80 ^{b}	99.55 ± 1.20 ^{c}

High amounts of TPC have been previously reported for *R. patagonica* [3,5] and other *Ramaria* species such as *R. flava*, *R. subaurantiaca* [4], and *R. botrytis* [5]. The major phenolic compounds in *F. antarctica* were gallic acid (3.14 ± 0.05 µg/100 g dw) and p-hydroxybenzoic acid (6.71 ± 0.25 µg/100 g dw); for *R. patagonica*, they were gallic acid (4.56 ± 0.06 µg/100 g dw), p-hydroxybenzoic acid (126.42 ± 2.16 µg/100 g dw), and p-coumaric acid (3.41 ± 0.01 µg/100 g dw) [3,5]. The greatest losses concerning phenols occurred in *F. antarctica* for the three evaluated air-drying temperatures (Table 3), with the highest loss occurring at 70 °C (39.47% loss with respect fresh-frozen TPC values); in *R. patagonica*, the highest lost occurred at 50 °C with respect to the values of the fresh-frozen samples (lower by 35.45%).

Table 3. Percentage of loss of TPC and antioxidant activity for the different drying methods. nd = not detected. nrd = not reduction detected.

Mushroom	Drying Methods	Reduction in TPC (%) (Compared to Fresh Frozen)	Reduction in Antioxidant Activity (%) (Compared to Fresh Frozen)				
			ABTS	DPPH	FRAP	ILP	
						t 24	t48
F. antarctica	50 °C	36.57	21.00	31.52	43.33	nd	nd
	60 °C	29.76	11.31	29.80	23.59	nd	nd
	70 °C	39.47	28.46	64.73	42.85	nd	nd
	Freeze-dried	nrd	nrd	37.03	9.60	4.25	19.34
R. patagonica	50 °C	35.45	8.34	18.18	25.67	11.41	17.38
	60 °C	7.51	7.51	16.84	0.49	4.73	13.64
	70 °C	24.83	6.26	17.86	9.23	15.28	15.67
	Freeze-dried	28.82	9.11	16.99	1.57	5.33	nrd

3.3. Antioxidant Activity

The inhibition of free radicals by *F. antarctica* extracts showed a decreasing trend in the following order: freeze-dried samples (with the best percent inhibition activity in the

ABTS and ILP assays, at 82.35 ± 0.11% and 82.35 ± 0.11% at 48 h, respectively), fresh-frozen samples (with the best percent inhibition activity in DPPH and FRAP assays, at 68.94 ± 1.99% and 43.01 ± 0.21%, respectively), and samples that were heat-dried. In the ILP assay, no activity was detected for any of the dried *F. antarctica* samples. In *R. patagonica*, the samples produced by the fresh-freezing, freeze-drying, and 60 °C methods showed the best inhibition of free radicals (in all assays: 99.03 ± 0.87% for ABTS, 99.31 ± 4.23% for DPPH RSA, 98.08 ± 0.70% for FRAP, and 99.03 ± 0.87% for ILP for fresh-frozen samples; 90.01 ± 1.16% for ABTS, 82.43 ± 0.44% for DPPH RSA, 96.54 ± 2.06% for FRAP, and 99.55 ± 1.20% for ILP for freeze-dried samples; and 91.59 ± 1.83% for ABTS, 82.58 ± 0.66% for DPPH RSA, 97.60 ± 2.28% for FRAP, and 85.52 ± 1.20% for ILP for the 60 °C air-dried samples) in comparison with the other hot-air-dry methods (Table 2).

The antioxidant activity of the methanolic extract of the two analyzed mushroom species were evaluated using different antioxidant activity assays because no single method can provide a complete overall evaluation [39]. Higher levels of phenolic compounds in mushrooms tend to be correlated with stronger antioxidant activity (Table 2), as reported in a previous study [12]. This relationship suggests that the phenolic compounds present in mushrooms contribute significantly to their antioxidant properties. In general, the fresh-frozen and freeze-dried mushrooms had the highest phenol contents and best antioxidant properties; in some cases, the mushrooms air-dried at 60 °C showed no significant differences from these. In agreement with a previous report [7], drying typically results in a decrease in total phenol content and antioxidant activity in extracts from *F. antarctica* fruiting bodies, with the highest level of reduction for compounds generally observed at 70 °C. Natural antioxidants, such as phenolic compounds, are highly susceptible to degradation when exposed to elevated temperatures. When p-hydroxybenzoic acid, the main compound in *F. antarctica* and *R. patagonica*, undergoes decarboxylation, it loses its bioactive properties such as its antioxidant activity. Thus, the decarboxylation of p-hydroxybenzoic acid can have a direct effect on its antioxidant properties [40]. In concordance with Radzki et al. [41], who studied wild edible mushrooms from Poland, our assays showed that hot-air drying can have either a positive or a negative impact on phenolic content and antioxidant activity, depending on the antioxidant assay used or the mushroom species. But, it is noted that the occurrence of negative effects is more common with hot-air drying than with the FD method. In the latter, drying is performed at low temperatures, minimizing thermal damage to heat-sensitive nutrients, therefore making it more effective in maintaining bioactive/antioxidant activities [42].

Among the temperatures used for dehydration, we found that, for *P. ostreatus*, 60 °C was the best temperature to preserve the contents of phenols and antioxidants as well as color of the samples, while a temperature of 70 °C negatively affected the TPC [26]. Additionally, an increase in antioxidant activity with drying at 60 °C was observed for *B. edulis* [43]. In other organoleptic evaluation studies, a hot-air-drying temperature of 65 °C was found to produce a mushroom soup and rehydrated slices of desirable quality that were also acceptable to consumers [44]. Others demonstrated that the total free amino acid content in samples treated with hot-air drying at 60 °C was the highest compared with that of the other dried and freeze-dried samples [23]. The inhibition of DPPH radicals decreased from 69 to 24% for *F. antarctica* and from 99 to 81% for *R. patagonica* after drying (70 °C in comparison with fresh-frozen samples). Regarding the scavenging effects, our results agree with those for *H. erinaceus*, *L. scabrum* [7], *P. colossus* [45], *G. frondosa* [46], *P. ostreatus*, and *A. bisporus* [47], which demonstrated a severe decrease in the ability to scavenge DPPH radicals after drying in comparison with fresh mushrooms.

Ramaria patagonica extracts (concentration 5 mg/mL) displayed remarkable scavenging effects on ABTS and DPPH radicals and FRAP and ILP in the range of 81.25–99.31%. The high antioxidant activity of *Ramaria patagonica* agrees with the findings of previous research [3,5], which showed that this edible mushroom is one of the best among more than twenty edible Patagonian species according to the results of DPPH scavenging assay, β-carotene bleaching inhibition, inhibition of lipid peroxidation (TBARS), and oxidative

hemolysis inhibition assay (OxHLIA). Other *Ramaria* species, such as *R. aurea* and *R. botrytis*, proved to have high antioxidant activity [33,35]. On the other hand, *F. antarctica* presented comparatively lower antioxidant activity, in agreement with other findings [3,5], probably due to the low content of total phenolics in the fruiting bodies extracts. Another study [48] reports that *Fistulina hepatica* (beefsteak fungus) extracts exhibited high pro-oxidant activity due to the amounts of ascorbic acids, despite the good capacity to act as a scavenger of DPPH radicals.

4. Conclusions

This study emphasizes the value of postharvest methods regarding their effectiveness in preserving food, TPC, and antioxidant qualities, enabling the choice of the most suitable technology to enable the conservation and use of wild native Patagonian mushrooms out of season. *Ramaria patagonica* showed high antioxidant activity. The contents of total phenols and bioactivity were much better when preserved via fresh-freezing or freeze-drying methods in comparison with drying methods for both species. In this sense, the air-drying temperature did not affect the tested parameters, so other factors such as energy consumption can be taken into account when choosing the drying time. For this reason, the best option for these mushrooms would be drying at 60 °C. This study emphasizes the advantage of using familiar technology, with low-cost dehydration ovens, which are adaptable to rural areas for family or community use.

Mushroom consumers and traders attach a great deal of importance to bioactive compound contents; knowledge about correct postharvest processing will be the first step in making food protocols to help inform future public-health decisions. In this sense, if the decision is to increase the bioactive/antioxidant activities of functional foods, higher investment will be needed in increasing lyophilization capability, which maintains antioxidant values and phenolic concentrations in food like fresh *F. antarctica* and *R. patagonica*. The quick freeze-drying process that almost fully preserves the phenol and antioxidant contents, along with texture (compared with −20 °C freezers that completely alter mushroom texture) also requires special equipment (blast chillers and individual quick-freezing (IQF) equipment) and a suitable, reliable, and more expensive logistics for distribution.

The information generated in this study on the postharvest practices of edible wild mushrooms, through the application of different treatments aimed at extending their shelf life, significantly contributes to their commercialization. Using a suitable method facilitates and extends distribution timelines and enhances mushroom shelf life at sales locations. This study specifically addressed drying methods that are suitable for implementation in environments with limited resources and provides useful guidance to preserve these nontimber forest products after harvest and to enhance local products or family businesses in Patagonia, promoting multiple and sustainable applications of native forests.

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