# Edible Mushroom, an Ecosystem Service of Pine Forests (*Pinus Radiata*): A Study of the Communities Cuyuni and Yuracmayo (Cusco, Peru)

Z.M. Díaz Córdova[1], L.A. Bravo-Toledo[2*], C.O. Tome-Ramos[3], J. Cáceres-Paredes[4], K. Vigo-Ingar[5], S. García-Flores[6], J. Valdivia-Zuta[7], N.E. Feijoo Pérez[8].

[1]*Universidad Nacional del Callao, Faculty of Environmental Engineering, Callao, Perú,*

[2,3]*Universidad Nacional de Callao, Faculty of Environmental Engineering and Natural Resources, Av. Juan Pablo II 306, Bellavista, Callao, Perú; E-mail: labravot@unac.edu.pe*

[4,5,6,7]*Universidad Nacional del Callao, Research Center Science and Technology of Bread-making for Healthy Food, Av. Juan Pablo II 306, Bellavista, Callao, Perú.*

[8]*Universidad Nacional del Callao, Unidad de Institutos de Investigación Especializados, Av. Juan Pablo II 306, Bellavista, Callao, Perú.*

**Abstracts:** The present study aims to identify and quantify the edible mushroom with high production value in *Pinus radiata* forests, and their natural production as an ecosystem service for the peasant communities of Cuyuni and Yuracmayo in the district of Ccatca (Cusco, Peru). Fifty fungal samples were collected according to cap diameter (10 cm, 15 cm and 20 cm), for counting and taxonomic identification. The samples were collected in 5 Pinus radiata forests with different growth ages (forest younger than 3 years, between 4 to 7 years and older than 7 years). The edible fungal species identified were *Laccaria laccata* and *Suillus luteus*, both in symbiotic growth with *Pinus radiata*, the latter being the most representative species due to its abundance and usefulness food, which gives it a high commercial value. The non-parametric Kruskal-Wallis test of SPSS software was used and determined that there is a statistical difference between different groups of the *Suillus luteus* and *Pinus radiata* forests with different growth ages. For example, it presents a higher average growth rate in *Pinus radiata* forests older than 7 years with an average production rate of 523.6 kg in fresh weight per harvesting season. However, there is also a homogeneity of the *Suillus luteus* species in all the *Pinus radiata* forests. Therefore, this type of fungus represents the most productive edible mushroom component for the Cuyuni and Yuracmayo communities.

**Keywords:** Suillus Luteus, Laccaria Laccata, Traditional Mycological, Mushroom Production, Cusco.

## 1. INTRODUCTION

Since ancient times, mushrooms have been known as a traditional source of nutrition among various communities in different regions of the world [1]. Their importance is related to the human diet for its incomparable taste, aroma, high content of proteins, vitamins, minerals and fatty acids [2]. In addition to a high content of anticancer, liver function stimulating, anti-cholesterol, immunomodulatory and antitumor biological actives [3].

In recent years, worldwide consumption of mushrooms has intensified in proportion to their collection and production [4], with a per capita consumption that increases annually in a sustained manner, reaching 2.5-3 kg per person in some countries [5], making it a sustainable productive activity.

The development of knowledge of mushroom gathering and production activities is mainly widespread among communities in various parts of the world [6]. Mushroom collection has increased considerably since the 1980s and is becoming a regionally and locally important activity [7]. In Peru, the collection and production of edible mushrooms began in 1960 with the cultivation of the mushroom *Agaricus bisporus* (Mushroom) reaching industrial levels in 1980. Then, mushrooms from the cultivation of Pleurotus ostreatus and for the first time the *Lentinula edodes* (shiitake) mushroom were used [8].

Knowledge about mushroom gathering and production activities is generally transmitted among family members and residents of the same community [9]. The development of these activities requires expertise on the ecosystem and the communities' capacity to develop in the forest. This expertise is based on collection during the rainy season, knowledge of their shape, color, consistency, place of growth and time of development. Villagers have learned to classify them because of the knowledge they have inherited from their ancestors [10], but also, these activities depend on the potential ecosystem service of the forest itself.

Forests simultaneously provide a dynamic and complex great diversity of ecosystem services such as wood, climate regulation, air quality, water, recreation [11], mycorrhizal use, medical uses, mycotourism [12], soil decontamination, energy products derived from wild plants, fungi, algae, bacteria, and wild animals [11].

Fungi are considered as an important resource generated by forests Thus, they constitute a cultural ecosystem service, producing that the collection and commercialization activities are subject to a market with an established cost [13]. Consequently, the proliferation of fungi related to pine forests plays an important role in the subsistence of the communities of Cuyuni and Yuracmayo in the Cusco region and is considered to be an important source of economic income.

Therefore, the objective is to identify and quantify the edible mushroom specie with high productive value in *Pinus radiata* forests, and its natural production as an ecosystem service for the peasant communities of Cuyuni and Yuracmayo, in the district of Ccatca (Cusco, Peru).

## 2. MATERIEL AND METHODS

### 2.1. Description of the Study Site

The research was carried out in the *Pinus radiata* forest plantations belonging to the rural communities of Cuyuni and Yuracmayo, in the district of Ccatca, 45 km east of the city of Cusco. They are located at an altitude of 3,750 meters above sea level, average monthly temperature of 8.01 °C, precipitation of 500 to 550 mm/year and relative humidity of 73% [14]. The characteristic vegetation of the area is high Andean grasslands with a predominance of grains and introduced vegetation with a predominance of *Pinus radiata.*

### 2.2. Sampling Area

To evaluate the number of mushrooms, the sampling unit was 100 $m^2$ with an average of 50 trees per *Pinus radiata* forest, representing an approximate density of 1000 individuals/ha. In the Cuyuni community, four (4) forests were sampled (Figure **1a**) with *Pinus radiata* trees at a distance of 1.5 to 2.0 m from each other. The area of forest 1 is about 2,870 $m^2$ with trees less than 3 years old, the area of forest 2 is 3,200 $m^2$ with trees between 3-7 years old, and the area of forest 3 is 1,200 $m^2$ with trees older than 7 years old, and finally the area of forest 4 is 1,200 $m^2$ with trees older than 7 years old. All forests belong to the Cuyuni community. In the community of Yuracmayo, one (1) forest was sampled (Figure **1b**), with an area of 3,450 $m^2$ with trees older than 7 years old.

### 2.3. Method Of Collection

In order to identify the species to which the mushrooms correspond, specimens were collected in the different forests, following the guidelines established by [15] for extraction, description of the macroscopic morphological characteristics, photographing, dehydration, microscopic examination and taxonomic identification.

During the sampling, mushrooms were counted and grouped into three groups of 10, 15 and 20 cm according to the diameter of the cap. This grouping was done because mushrooms with a larger cap diameter are not very suitable for drying and subsequent use in food, since they tend to decompose more easily.

### 2.4. Microscopic Anatomical Analysis

The petiole, stipe, pores, veil and ring of at least two mushrooms per forest with six replicates were examined microscopically. Briefly, the mushroom and its roots were thoroughly washed with water, and the soil material was cleaned prior to examination. Several pieces of longitudinal and transverse sections were prepared using a half portion of a double-edged razor blade under a dissecting microscope and mounted on a slide glass with a drop of lactic acid.

### 2.5. Determination Of Mushroom Production

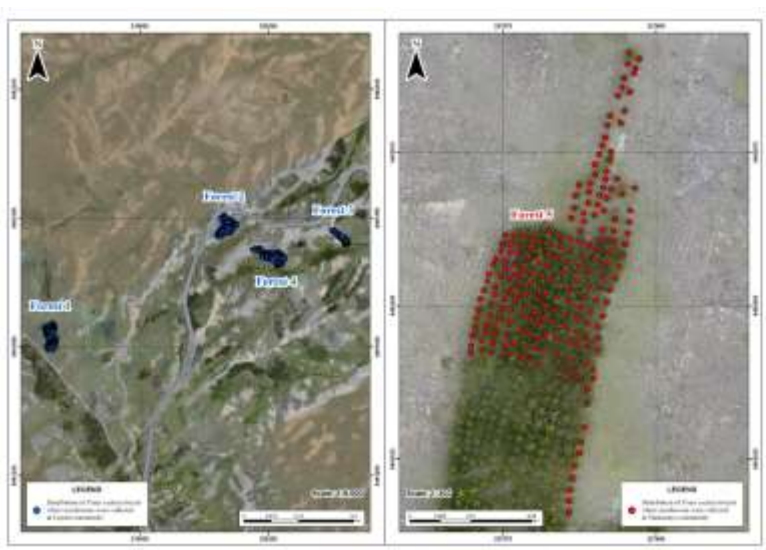
To project the productivity level of all *Pinus radiata* forests in the communities, the most frequent and abundant mushroom was analyzed. Then, calculations were made on the total sum of the evaluated areas and the weight of fresh mushroom.

### 2.6. Data Analysis

The data obtained were analyzed using descriptive analyses, compliance with the test for normality was determined using Kolmogorov-Smirnov and the statistical test used to compare variability was Krukall-Wallis, both using SPSS statistics software.

## 3. RESULTS AND DISCUSSIONS

### 3.1. Identification of Mycorrhizal Fungi



**(a)** **(b)**

**Figure 1**: Distribution of *Pinus radiata* forests where mushrooms were collected (a) Cuyuni community, (b) Yuracmayo community.

#### 3.1.1. Mushrooms Suillus Luteus

*Suillus luteus* is the most abundant fungus identified in *Pinus radiata* forests. They have a macroscopic form typical of agaricales (Figure **2a**), with a developed umbrella-shaped carpophore.

The petiole of the sampled mushrooms is convex in shape, with smooth, shiny and viscous cuticle due to its mucilaginous coating. This cuticle is of a yellowish meadow to reddish-brown color that is easily separable from the cap flesh, without zonation in the context with a diameter ranging between 4 - 12 cm (Figure **2b**). The same characteristics have been reported in different studies on *Suillus luteus* [16] [17] [18].

The tubes are adnate or slightly decurrent, quite long, pale yellow, darkening in the more mature or aged samples towards olivaceous tones, which is easily separated from the context. The pores are small and angular with a yellow border (Figure **2c**).

The stipe is cylindrical in shape and curved at the base. It is 3 to 10 cm long and 1 to 1.5 cm thick, white or pale yellow in color with granulations above the ring and reddish-brown on top.

Its ring or veil is white above and purplish below, which tends to disappear over time (Figure **2d**) [10].

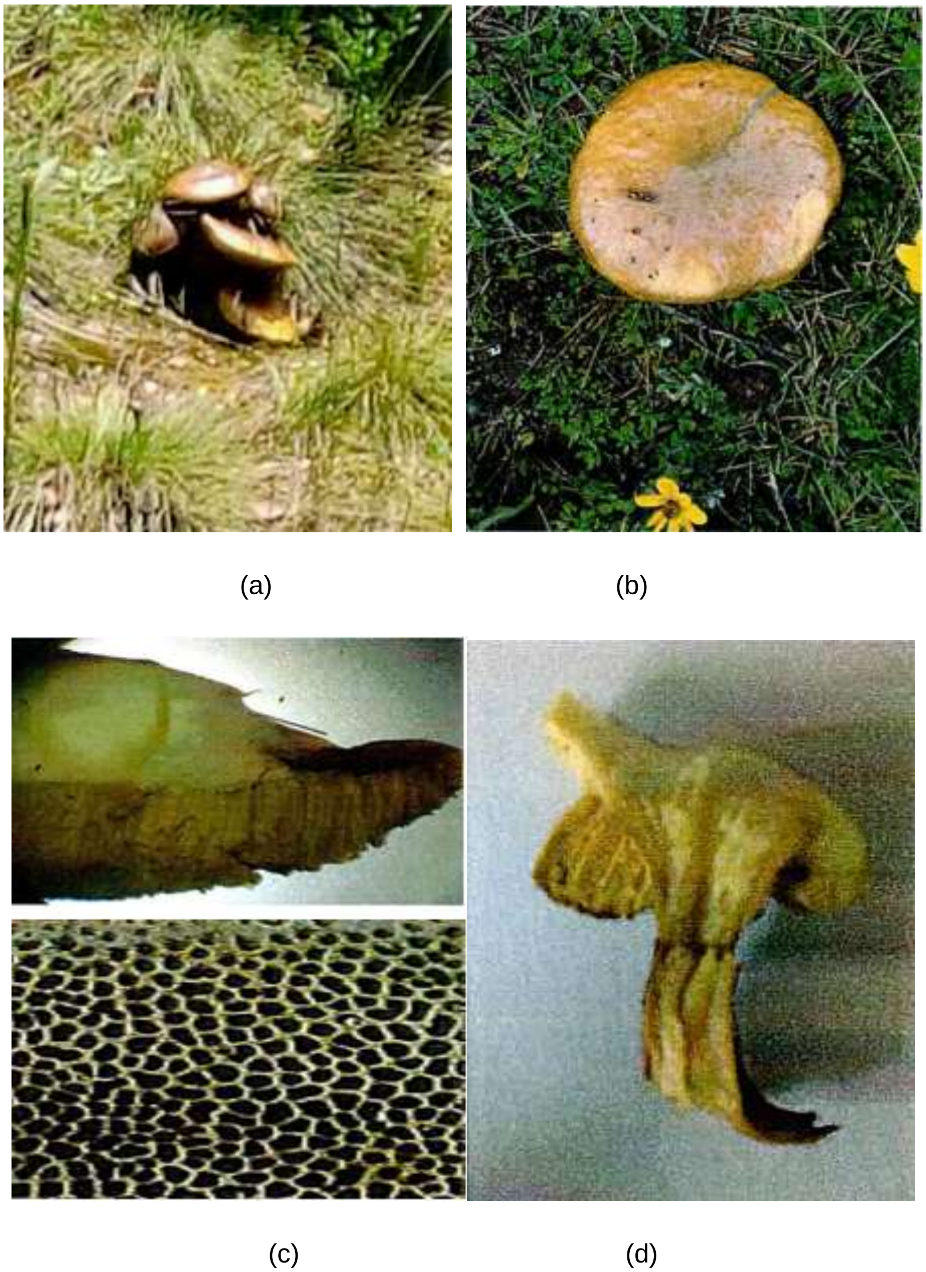
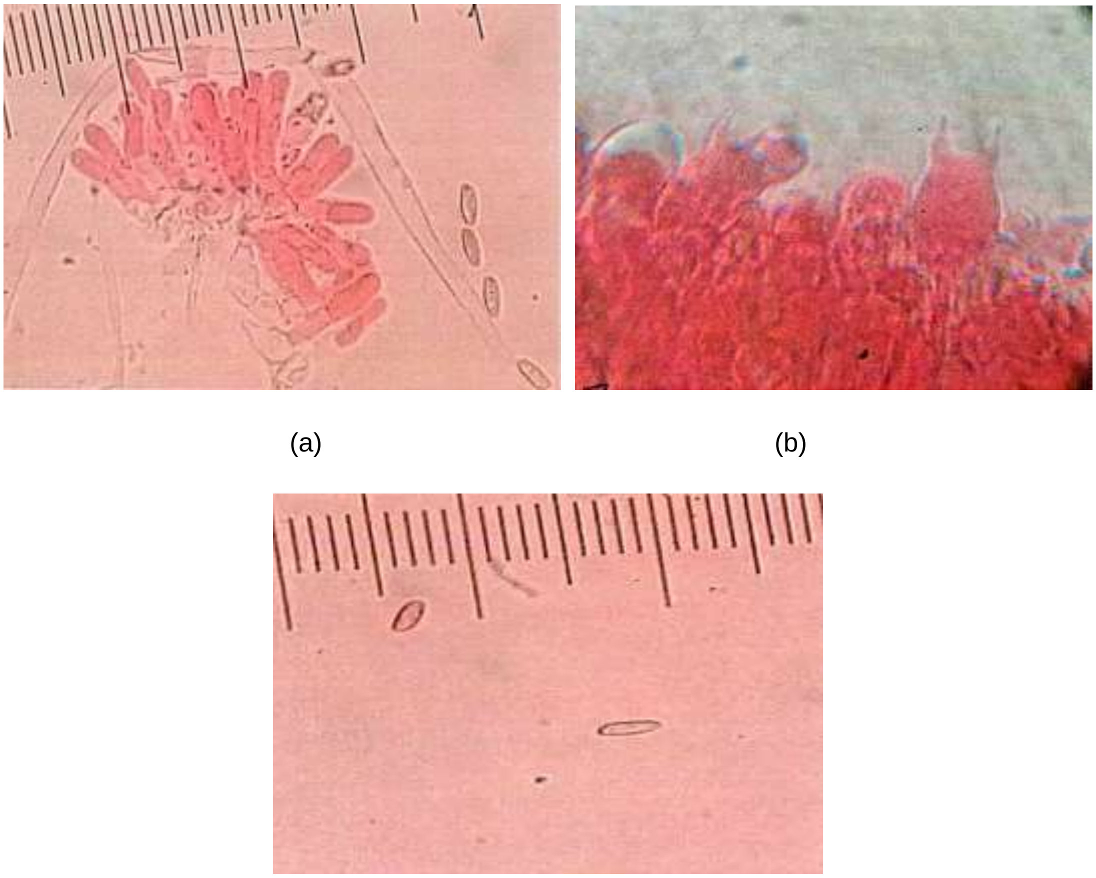



**Figure 2:** Morphological characteristics of the mushroom *Suillus luteus*, a species identified in the forests of *Pinus radiata* (A) Fruiting body, (B) Cap, (C) Detail of the Tubes and Pores (10X), (D) Longitudinal section of the Stipe.

Microscopic analysis shows that mature basidia are bat-shaped, with the proximal end being thin and the distal end wider, while the color is similar to that of the hyphae, i.e., yellow. Each of the basidia produces four sterigmas (Figure **3a**). From the distal end of the basidia arise four sterigmas, which support one spore per sterigma (Figure **3b**). The spores presented by the mushroom have an elliptical shape, between 7 and 10 microns long by 3 to 4 wide, thick-walled and smooth, without ornamentation and have a yellow pigmentation (Figure **3c**) [19].



(a) (b)

(c)

**Figure 3:** Microscopic characteristics of the mushroom *Suillus luteus*, species identified in *Pinus radiata* forests (a) Basidia (400X), (b) Basidia with stigma (400X), (c) Spores (1000X)

### 3.1.2. Mushroom Laccaria laccata

The identified fungi of the *Laccaria laccata* species have a brownish-pink coloration with a pycelium of pinkish, dull to finely decurrent lamellae, scattered with lamellulae, a somewhat sinuous curved cylindrical stem, with a subulbose base, whitish towards the base, smooth or grooved. Also, they do not present ring, have a not appreciable odor and sweet taste, have a diameter of 5 - 60 mm, hemispherical, convex to flat-convex, reddish-brown, orange brown to pinkish-brown, hygrophanous flesh color, striated, with small scales, brittle, margin striated by transparency, sometimes grooved, characteristics reported in studies [20].

The stipe present in this mushroom is fibrous and has a height of 5 to 10 cm and a width of 0.6 to 1 cm (Figure **4**). Microscopic analysis shows that the hymenium has scattered lamellae and contains lilac or pink lamellulae. Basidia are 38 by 10 microns in size, 4-spored, claviform. Pleurocystidia variable in shape, cylindrical, ventricose to lageniform. Cheilocystidia of the same shape and size as the pleurocystidia, and fibulae are also present. In general, the characteristics of Laccaria described in the present work coincide with those of [21] [22].

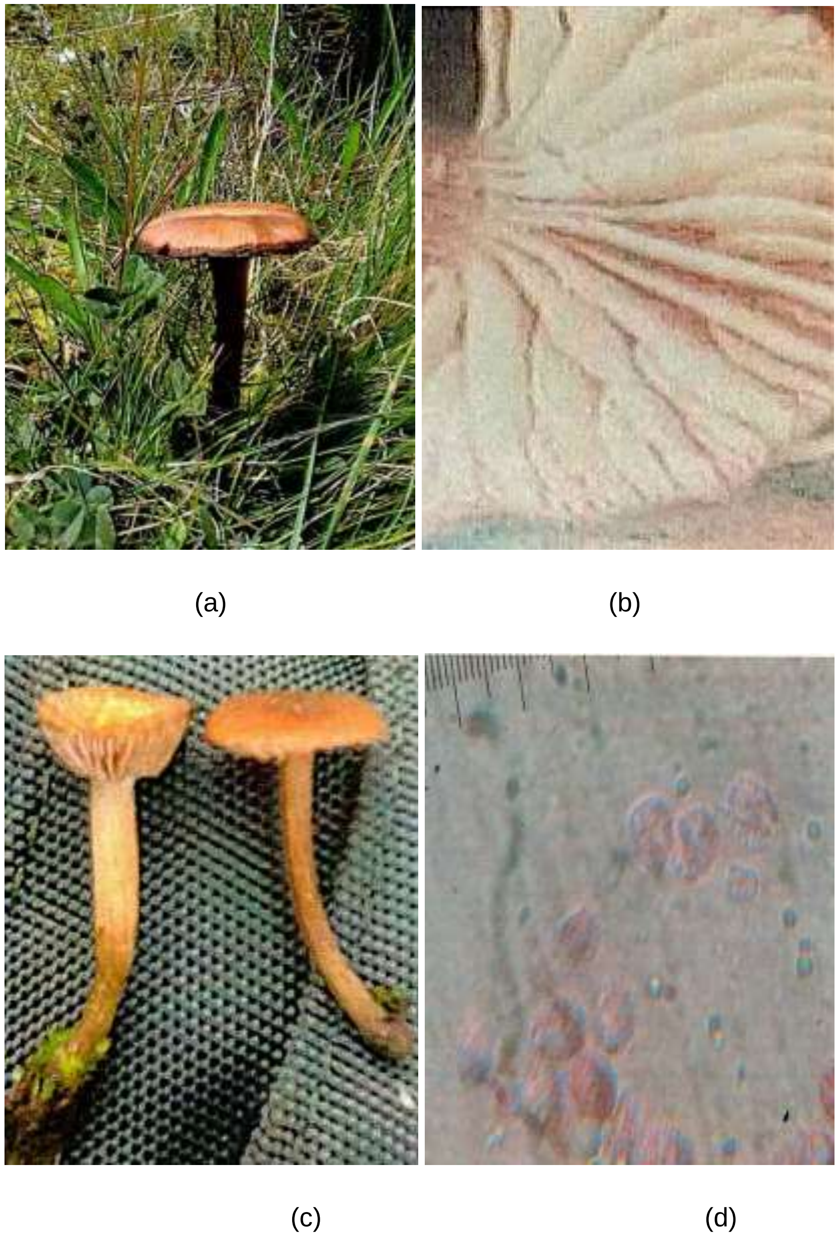



**Figure 4:** Morphological and microscopic characteristics of the fungus Lacearía laccata, species identified in *Pinus radiata* forests (A) Fruiting body, (B) Hymenium lamellae, (C) Stipe (10X), (D) Spores (1000X)

### 3.2. Accounting For The Mushrooms Suillus Luteus In Communities

Among all the species identified, *Suillus luteus* is the most collected by the communities of Cuyuni and Yuracmayo, due to its characteristics of larger size and fleshy consistency. This type of preference is a pattern that has been observed in mushroom collection in other studies developed [6] [23].

Table **1** shows that there is a statistical difference between the different groups of *Suillus luteus* and *Pinus radiata* forests with different growth ages (GL = 4, N = 750, $\alpha$ =0.05 and P=0.000), being more frequent in *Pinus radiata* older than 7 years, due to a strong mycorrhizal association where the optimization of a fungus-plant symbiosis is clearly effective [24].

On the other hand, the fungus had an incidence on the aerial development of the plants, enhancing the plants to develop greater photosynthetic activity, producing a great variability in the number of mushrooms per *Pinus radiata* tree ($p < 0.05$).

**Table 1: Parameters related to the quantity of the fungus *Suillus luteus* in the Cuyuni and Yuracmayo forests.**

| Sizes of *Suillus luteus* Mushroom | Ages of pine (*Pinus radiata*) forests associated with the mushroom. | Standard deviation | Minimum quantity of mushrooms | Maximum quantity of mushrooms | Non-parametric test (a) | | |
|---|---|---|---|---|---|---|---|
| | | | | | Average range | H | *P* |
| Size_10cm | Pine <3years | 2.389 | 0 | 8 | 85.08 | 34.36 | *0* |
| | Pine 3-7years | 4.649 | 0 | 19 | 123.04 | | |
| | Pine >7years_ParA | 2.573 | 1 | 10 | 147.08 | | |
| | Pine >7years_ParB | 5.279 | 0 | 20 | 160.91 | | |
| | Pine >7years_ParC (b) | 2.455 | 0 | 8 | 111.39 | | |
| Size_15cm | Pine <3years | 1.418 | 0 | 5 | 87.27 | 32.88 | 0 |
| | Pine 3-7years | 4.149 | 0 | 19 | 130.75 | | |
| | Pine >7years_ParA | 1.863 | 0 | 8 | 136.87 | | |
| | Pine >7years_ParB | 4.431 | 0 | 15 | 163.63 | | |
| | Pine >7years_ParC (b) | 2.342 | 0 | 9 | 108.98 | | |
| Size_20cm | Pine <3years | 0.507 | 0 | 2 | 77.81 | 49.82 | *0* |
| | Pine 3-7years | 2.927 | 0 | 15 | 141.45 | | |
| | Pine >7years_ParA | 1.088 | 0 | 6 | 120.86 | | |
| | Pine >7years_ParB | 3.839 | 0 | 16 | 169.7 | | |
| | Pine >7years_ParC (b) | 1.637 | 0 | 6 | 117.68 | | |

(a) Kolmogorov-Smirnov, Lilliefors significance correction ($p<0.05$).

(b) Forest belonging to the community of Yuracmayo

Annual fluctuations and changes in climatic conditions have a direct effect on *Suillus luteus* production within pine forests generally associated with changes in rainfall or fire passage. [25] observed higher correlations between fungal production and host tree width. Likewise, [26] observed a significant positive relationship between tree growth and fungal fruiting in a pine ecosystem, productivity findings similar to conditions in the Cusco region. According to the results reported by [27] there are positive correlations between wood width growth and fungal biomass, being a relationship sensitive to precipitation events, resulting in a greater synchrony between both, confirming the abundance of mushroom (Figure **5**, Figure **6** and Figure **7**) associated with *Pinus radiata* older than 7 years in the community of Cuyuni (plot A and B), but of considerable contrast in the community of Yuracmayo (plot C). This may be due to the slope factor where the forest is located, which produces runoff that does not favor the fungus-plant association [28].

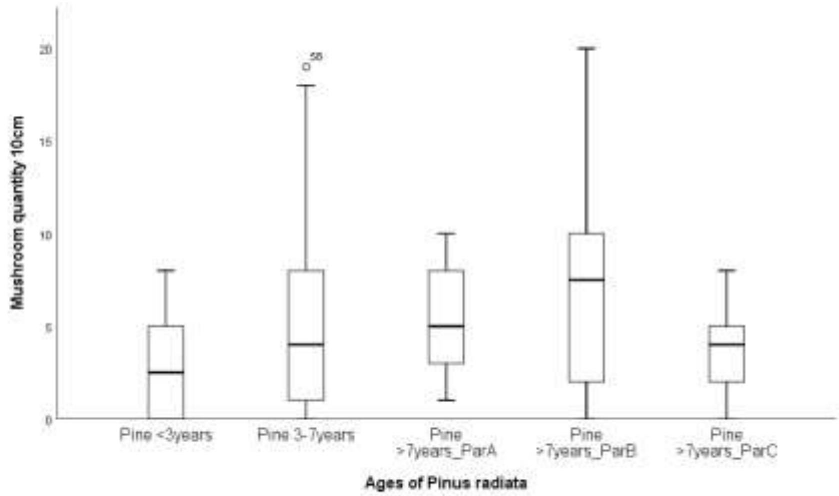



**Figure 5:** Distribution of the amount of *Suillus luteus* fungus with 10 cm diameter cap on *Pinus radiata* forests in the communities of Cuyuni and Yuracmayo

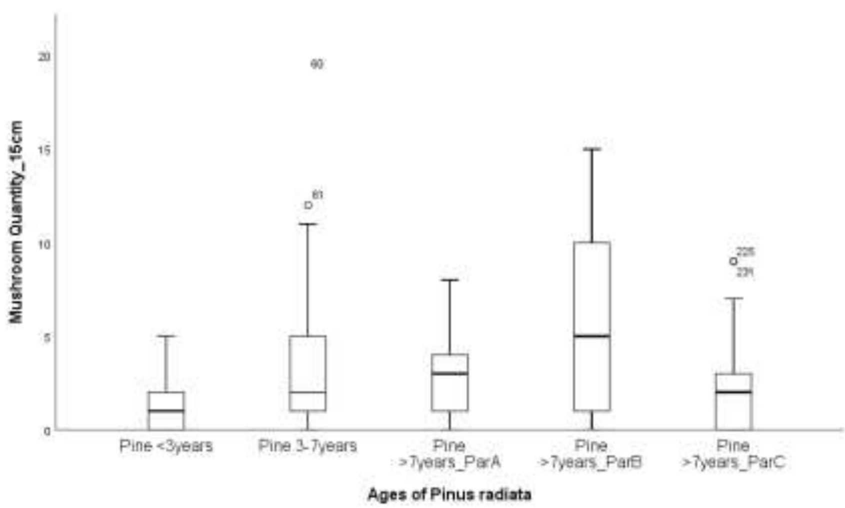



**Figure 6:** Distribution of the amount of *Suillus luteus* fungus with 15 cm cap diameter on *Pinus radiata* forests in the communities of Cuyuni and Yuracmayo

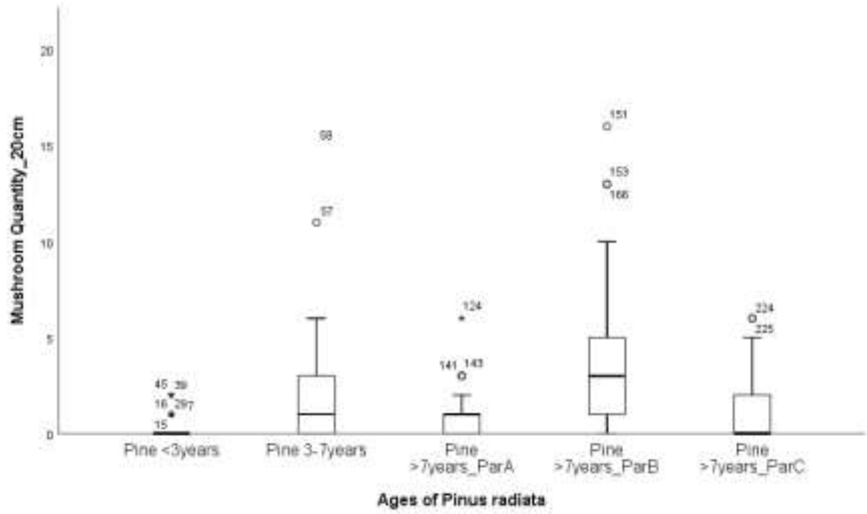



**Figure 7:** Distribution of amount of mushroom *Suillus luteus* with 20 cm diameter cap on *Pinus radiata* forests in the communities of Cuyuni and Yuracmayo

### 3.3. Productivity Of *Suillus Luteus* In The Pine Forests

The estimated average production of the total mushrooms collected was 523.6 kg, during the months of February - March with an average of 8.7 kg/day. This value is related to that reported by [6] in communities in Mexico with averages of 4 to 6 kg/day. Mushrooms associated with young pines have the highest fresh weight (Figure **8**).

It is quite possible that a large quantity of edible wild mushrooms was found for sale, at least in the rainy season, in the large market of Cusco or private companies. The geography of the traditional commercialization of edible wild mushrooms in Peru is still far from being fully understood.

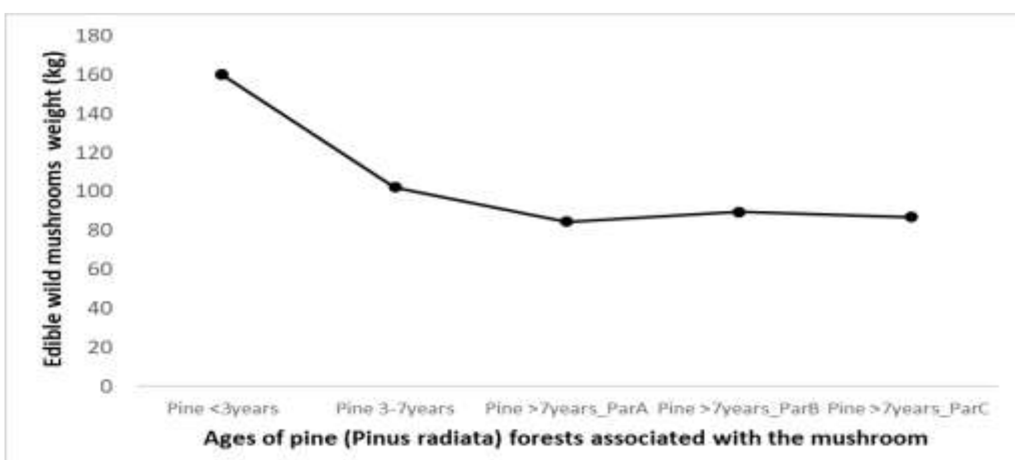



**Figure 8:** The sum total of fresh weights collected.

## CONCLUSION

The species *Suillus luteus* and *Laccaria laccata*, in symbiotic growth with Pinus radiata, were identified in forests of the peasant communities of Cuyuni and Yuracmayo in the district of Ccatca, province of Quispicanchi, Cusco Region. Between these species, the *Suillus luteus* mushroom, is the most important for its abundance and food utility, with respect to *Laccaria laccata*. The abundance of *Suillus luteus* mushroom is related to *Pinus radiata* trees older than 7 years of life, estimating a production of 523.6 kg of fresh fungus of *Suillus luteus* in one harvesting season.

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