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Production and bromatological analysis of the oyster mushroom (*Pleurotus ostreatus* (Jacq. ex Fr.) P.Kumm.) grown with cocoa, banana, coconut and African palm husk substrates

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Abstract: Oyster mushroom (*Pleurotus ostreatus* (Jacq. ex Fr.) P.Kumm. (1871) is a rich food source. It is cultivated on compost and plant waste material. Choosing adequate substrate is essential for oyster production as the substrate can change oyster production in terms of mass and metabolite composition. The different medium substrates for oyster production including T1 (PDA, potato-dextrose-agar), T2 (CCA: PDA + Cocoa Shell), T3 (APR: PDA + African Palm Rachis), T4 (BP: PDA + Banana Peel), T5 (CCO: PDA + Coconut Peel) were used. Based on mycelial diameter, CCO treatment was the best treatment with growth measures of 66.83 mm at 168 hours. CCA treatment with 164.13 g kg^{-1} yield had the highest production that was significantly different from other treatments. For APR treatment, trace production was observed. The bromatological analysis determined that the highest levels of crude total protein were obtained in CCO treatment (30.08 %) while CCA treatment exceeded significantly dry matter (94.05 %), ethereal extract (6.52 %), crude fiber (12.34 %), non-nitrogen matter (56.15 %) and titratable acidity (3.32 %). The substrates with more lignocellulosic compounds like banana and coconut residues are better for producing oyster with a higher percentage of total protein, while substrates that retain moisture like cocoa residues lead to an excellent production. It is recommended to keep fibrous residues moist constantly when they are used in oyster production because of their low absorbent capacity as they quickly lose moisture.

Key words: lignocellulosic compounds; PDA; protein; waste material; fruiting body

Produktivnost in bromatološka analiza ostrigarja (*Pleurotus ostreatus* (Jacq. ex Fr.) P.Kumm.) rastočega na ostankih kakavovca, kokosove palme, bananovca in oljne palme

Izvleček: Ostrigar (*Pleurotus ostreatus*) je bogat vir hranil. Goji se na kompostu in ostankih predelave različnih rastlin. Izbira primernega substrata je odločilna za njegovo produktivnost, ker ta vpliva na maso pridelka in njegovo sestavo. Za gojenje so bili izbrani različni substrati in sicer : T1 (PDA, krompirjev dekstrozni agar), T2 (CCA: PDA + ostanki kakavovca), T3 (APR: PDA + osrednja listna rebra oljne palme), T4 (BP: PDA + olupki banan), T5 (CCO: PDA + lupine kokosa). Na osnovi izmerjenega premera micelija je bilo obravnavanje CCO najboljše z izmerjeno hitrostjo rasti 66,83 mm v 168 urah. Obravnavanje CCA je imelo s 164,13 g kg^{-1} največji pridelek, ki se je značilno razlikoval od drugih obravnavanj. Obravnavanje APR je dalo najslabši pridelek. Bromatološka anliza je pokazala največjo vsebnost celokupnih beljakovin pri obravnavanju CCO (30,08 %) med tem, ko je imelo obravnavanje CCA značilno večjo vsebnost suhe snovi (94,05 %), eternega izvlečka (6,52 %), vsebnosti netopnih vlaknin (12,34 %), vsebnost ne dušičnih spojin (56,15 %) in večjo titrabilno kislost (3,32 %). Gojišča z večjim deležem lignoceluloznih spojin kot so ostanki banan in kokosovega oreha so boljši za pridelavo ostrigarjev z večjim odstotkom beljakovin med tem, ko so substrati, ki obdržijo večjo vlažnost kot so ostanki kakavovca odlični za večji pridelek ostrigarja. Priporočamo, da se ostanki, ki vsebujejo vlaknine držijo pri gojenja ostrigarja stalno vlažni, ker zaradi njihove majhne absorpciske sporobnosti hitro izgubijo vodo.

Ključne besede: lignocelulozne spojine; PDA; beljakovine; odpadki, trosnjaki

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1 INTRODUCTION

In agriculture lots of wastes of plant origin are generated, while several have around 70 % cellulose and lignin. These agro-industrial wastes with a high lignocellulosic content are barely degraded but in the nature, there are a large number of microorganisms that use such compounds as a source of nutrition and some of such microorganisms are used as a food alternative in the world (Del Socorro Fernandez Uribe, 2014). In many cases plant residue wastes are burned or disposed in sanitary landfills where slow degradation biopolymers such as cellulose and lignin remain for years with almost no alterations.

The production of higher fungi, especially that of the oyster mushroom is a very attractive production alternative made from agro-industrial residues of high fiber content because of its unique ability to degrade lignocellulosic residues and its rich protein quality and quantity. Development of efficient technologies for the cultivation of this basidiomycete is increasingly required in order to apply modern methods toward a greater production (Pineda-Insuasti et al., 2013).

This fungus, in addition to presenting nutritional benefits, has a bioremediation capacity. It has a potent lignocellulolytic enzymes such as phenol oxidases (laccase) or heme peroxidases (lignin peroxidase (LiP), manganese peroxidase (MnP) and versatile peroxidase) as well as cellulose-hydrolysing enzymes, i.e. cellulases basically divided into endo-β-1,4-glucanase, exo-β-1,4-glucanase I and II, and β-glucosidase, all allowing it to detoxify, bioconvert, and bioremediate resistant pollutants (Adebayo & Martínez-Carrera, 2015). The ability of strains of *P. pulmonius* to biotransform herbicide molecules such as atrazine and insecticides like endosulfan has been reported demonstrating its importance in environment protection. Additionally, regarding to the medicinal beneficial effects, *P. ostreatus* presents anticancer activity, immunomodulatory, antiviral, antibiotic, anti-inflammatory attributes and decrease in cholesterol levels (Garzón Gómez & Cuervo Andrade, 2008)tallo de maíz, aserrín y sobras de café de consumo humano. Se evaluó el efecto de los cuatro sustratos de forma individual y en mezclas sobre la producción del hongo y en mezclas sobre la producción del hongo a través de indicadores como la eficiencia biológica, el rendimiento, el número de días en periodo de incubación, el número de días para la aparición de primordios, la frecuencia y el porcentaje de peso de cada cuerpo fructífero y la productividad. El rendimiento de los sustratos que tuvieron café tanto individualmente como en las mezclas varió entre los 265g a 409g y fueron significativamente más altos ($p < 0,05$.

There are many ways to cultivate this fungus species like hanging bags, wooden or stainless-steel slabs. As an advantage, there is a great diversity of organic materials that also can be used as a substrate of the fungus cultivation such as paper, coffee pulp, corn cob and husk, bean shell, leaf litter, grass, bagasse of sugar cane, cotton stalk, leaves and many others those are normally considered as plant wastes (Aguilar-Rivera & de Jesús-Merales, 2010; Rambey et al., 2019; Tesfay et al., 2019; Tsegaye & Tefera, 2017). Moreover, this production activity is 100 % natural and allows the use of by-products derived from the processes of transformation of agricultural products (Cruz et al., 2010).

In a complete production cycle of the fungus, the substrate is used as culture medium, i.e. the residue may be utilized after harvest as a food supplement for cattle, as *P. ostreatus* accelerates the degradation of lignin (Ardon et al., 1998). It also increases digestibility and provides mycelial protein or compost ability to convert it into organic fertilizer for incorporation into the productive cycle of agricultural crops (Del Socorro Fernandez Uribe, 2014).

In this article, a comparative study of production of the oyster mushroom (*P. ostreatus*) on different medium substrates including the residues of cocoa, banana, coconut and African palm rachis is presented. The findings suggest that these substrates, generally available in tropical regions, are efficient to be used in producing oyster mushroom in agroindustry and human consumption.

2 MATERIALS AND METHODS

2.1 LOCATION

The present research was carried out in the laboratory of Bromatology and Nutritional Metabolism ("RUMEN" standing for its abbreviation in Spanish) of the Experimental Campus "La María", belonging to the Universidad Técnica Estatal de Quevedo (UTEQ), located in the 7½ km of the road from Quevedo to El Empalme.

2.2 RESEARCH MATERIALS AND SUBSTRATES

This research work was divided into two phases. The first phase included the radial growth of oyster fungus inoculated in different culture media. The second phase was devoted to analyze the production and chemical composition of the mushrooms cultivated on agricultural waste (cocoa shell and coconut husk) and agro-industrial waste (African palm rachis and banana peel).

2.3 PREPARATION OF CULTURE MEDIA

Four culture media were obtained from cocoa shell, African palm rachis, banana peel and coconut peel. Hundred grams of each of the four materials were chopped, washed and placed in four aluminum containers separately, then 1 l of distilled water was added to each container. These containers were put on fire allowing water to boil for 30 minutes. The boiled content of each container as culture medium base was filtered with gauze and cotton to prevent the passage of any impurity. The filtered liquid was placed in the flasks containing 20 g of agar and 20 g of dextrose, and then these solutions of the different stubble were dissolved.

To prepare PDA (potato-dextrose-agar) medium, 200 g of peeled potato were sliced in squares and these pieces were boiled to obtain a solution, which was passed to a flask containing 20 g of agar and 20 g of dextrose. The four prepared solutions were subjected to boil for 30 minutes so that the agar and dextrose were diluted uniformly. Solutions were sterilized in autoclave at 121 °C and ~1 bar for 30 minutes. In total, five culture media were obtained: PDA (Potatoes dextrose agar), CCA (cocoa peel), APR (African palm rachis), BP (banana peel), CCO (coconut peel). In the biosafety cabinet 15 ml of each medium was deposited in the Petri dishes and allowed to solidify.

2.4 DETERMINATION OF RADIAL GROWTH CURVE

The PDA invaded by the mycelium of fungus was cut into pieces with 4 mm diameter, which were taken from the Petri dishes previously inoculated by fungus. They were used to obtain inoculums and planted in the center of a 90 mm Petri dish. The Petri dishes contained 15 ml of the culture medium and incubated at 28 °C. A calibrator that measures the diameter of fungi (mm) during its growth time was used to estimate radial growth speed. Measurements of the growth diameter of the fungal mycelium were made every 24-hour.

2.5 FUNGUS SEED FOR FERMENTATION IN SOLID MEDIUM

Wheat grains selected for preparing fungus spawn were washed and soaked for 24 hours in potable water, with the aim of reaching to between approximately 50 and 60 % moisture. After this time, they were washed with abundant water. The grains were allowed to drain until being already very dry. Four hundred g of each were weighed and put in the wide-mouth glass jars.

The jars were subjected to sterilization by autoclave at 121 °C and ~1 bar for 30 minutes. Once the bottles were cold, the PDA pieces with mycelium of approximately 3 x 3 cm were cut and 6 to 8 pieces were placed throughout the jar with as much coverage as possible. Mycelium-contained part of PDA pieces was placed in direct contact with the grains aseptically. The bottles were labeled with date, type of fungus, type of grain and were taken to the incubator at 28 °C for an approximate period of 3 weeks.

2.6 FERMENTATION ON SOLID MEDIUM

The cocoa, banana, coconut and African palm rachis peel were chopped to an approximate diameter of ± 2 cm to facilitate the invasion of the fungus in FMS (Fermentation in a solid medium). One kg of each substrate including cocoa peel, banana peel, and African palm rachis and coconut shell was washed three times to remove impurities. Substrate mass was recorded for the control. They were put on the canvas for heat treatment. Seventy litter (70 l) of drinking water and 1400 g of lime (2 % of the total water) were deposited in the tank, and the temperature was kept at 100 °C for 1 hour.

After this time, the substrate was allowed to drain and was expected to cool to approximately 25 °C. Then it was weighed and put in bags including 1 kg of media. It was inoculated with the grain spawn of oyster in 10 % (100 g) of the wet mass of substrate, covered by a black cover to have more darkness. All containers were taken to the incubation chamber provided with artificial light and irrigation system for 21-day incubation.

2.7 MUSHROOM PRODUCTION IN INCUBATION CHAMBER

The cultivated mushrooms on substrates were incubated for 21 days at 29 °C and relative humidity remained approximately 96 % . After the total colonization of residues developed, the plastic covers were removed and artificial light was supplied to induce mushroom fruiting in order to subsequently weigh production and perform physical and chemical analysis immediately.

2.8 EXPERIMENTAL DESIGN AND TREATMENTS

A completely randomized experimental design with

five treatments and six repetitions was used for the first phase of the investigation. In the second phase, a completely randomized experimental design was used with four treatments and six repetitions. For the first phase, five treatments consisting of PDA culture medium plus agricultural by-products were evaluated. Whilst, for the second phase the productive performance and nutritional content were determined, for which the same treatments were evaluated, except for T1 (PDA) (Table. 1).

2.9 VARIABLES UNDER STUDY

For the first phase radial growth was estimated. For the second phase, productive yield of mushrooms, moisture, dry matter, fat, fiber, pH, acidity, non-nitrogen elements and protein were measured.

2.9.1 Moisture content determination

The total moisture measurement was carried out on the fungal samples, the remaining content of this step was ground in a Thomas Willy mill adapted to a 2 mm sieve and were sterilized at a temperature of 135 °C for 2 hours, following weighed by an analytical balance to record their dry weight.

2.9.2 Hygroscopic moisture determination

One g of milled mushroom sample was deposited in a crucible and subjected to 65 °C for 48 hours, next weighed to obtain the percentage of hygroscopic moisture with the following formula (Equation 1) according to the provisions of Association of Official Analytical Chemists (AOAC) (AOAC, 2012).

$$M = \frac{M2-M1}{M} x\ 100 \qquad \text{Equation 1}$$

Where:
M = Moisture
M_0 = Sample Mass (g)
M_1 = Crucible mass plus sample after drying (g)
M_2 = Crucible mass plus sample before drying (g)

Table 1: Treatments evaluated in radial growth in the research phases. I and II demonstrate the first and the second phase, respectively

Treatments	Description	Phase of the investigation
T1	PDA	PDA-I
T2	PDA + Cocoa shell (CCA)	CCA-I, CCA-II
T3	PDA + African palm rachis (APR)	APR-I, APR-II
T4	PDA + Banana peel (BP)	BP-I, BP-II
T5	PDA + Coconut shell (CCO)	CCO-I, CCO-II

2.9.3 Dry matter content determination

To calculate the dry matter content, the Equation 2 was used:

$$TDM = 100 - TM \qquad \text{Equation 2}$$

Where:
TM = Total Moisture
TDM = Total Dry Matter

2.9.4 Organic matter content determination

To carry out the analysis of organic matter content, with the same sample that remained from the hygroscopic moisture analysis, a muffle was placed at a temperature of 600 ºC for a period of 3 hours, after this time it was weighed in order to obtain the percentage of ash using the following formula (Equation 3):

$$C = 100 - (\frac{M_2-M_1}{M_0} x\ 100) \qquad \text{Equation 3}$$

Where:
C = organic matter content
M_0 = Dry sample mass (g)
M_1 = Mass of empty crucible (g)
M_2 = Crucible mass plus calcined sample (g)

2.9.5 Protein content analysis

In order to perform the analysis of protein content a modified Kjeldahl method was used (AOAC, 2012). For this analysis 300 mg of fungal samples were weighed in the dry state and deposited in the digester tubes and a copper catalyst tablet and 5 ml of sulfuric acid 98 % were added to each tube and then the tubes were placed in the programmed digester with the following times: 150 °C for 30 minutes, 280 °C for 30 minutes and 400 °C for 45 minutes, after this process the digested samples were

cooled for 45 minutes. In the distillation process, 10 ml of distilled water was added to each tube and the tubes were placed with the digested sample in the distiller that automatically injected into each tube 40 ml of boric acid solution (80 g of boric acid in 2000 ml of distilled water) and 40 ml of sodium hydroxide solution 6.25M (500 g of sodium hydroxide in 2000 ml of distilled water), where approximately 90 ml of distillate was deposited in a 300 ml flask and took 4 minutes. In the titration process, to the solution product of distillation process, 3 drops of indicator solution (100 ml of 98 % ethanol ,75 mg of bromocresol Green and 100 mg of red methyl) were added, and also a 0.1 N solution of sulfuric acid (2.77 ml of sulfuric acid in 1000 ml of distilled water) added to each tube until a red wine color was obtained.

2.10 DATA REGISTERING AND STATISTICAL ANALYSIS

The Excel program was used for the registration and ordering the data. For the statistical analysis, as well as for the comparison between treatments, ANOVA one way and the Tukey multiple range test ($p < 0.05$) were employed using R studio software version 4.0.

3 RESULTS AND DISCUSSION

3.1 RADIAL GROWTH OF *P. OSTREATUS* GROWN IN DIFFERENT CULTURE MEDIA

The radial growth of the oyster fungus (*P. ostreatus*) inoculated in different culture media is shown in Table 3, where the analysis of variance indicated that there were no significant differences between treatments ($p < 0.05$) at 24 and 48 hours of growth. At 72, 96, 120, 144, and 168 hours there were statistical differences and CCO treatment was the best treatment with 14.00, 24.83, 46.16, 60.16 and 66.83 mm of radial growth in time intervals, respectively. Oyster degraded the available substrates independently and after 72 hours it seems that it reached to a degradation point where substrates were decomposed. This is somehow in accordance with a previous study in which the author reported oyster mycelia grown on a mix of coconut and sawdust were thick, dense and comparatively compact compared to sawdust as control (Vetayasuporn, 2007) taking into account that the substrates were not identical in the compared studies APR treatment showed a difference at 72 and 96 hours with 14.00- and 23.00-mm growth in each interval time. The best radial growth response in CCO treatment was due to the fact that the substrate is rich in lignocellulosic compounds, which causes the fungus to have greater growth (Obodai et al., 2003). del Pilar Rios et al. 2010, in their research evaluated the productive parameters of *P. ostreatus* spawn propagated in different culture media, in which it has been mentioned that substrates with high cellulose and lignin content provide the necessary nutrients for growth of fungus decreasing incubation time (del Pilar Rios et al., 2010). This was also reported by other authors who indicated that rice straw is a good alternate substrate for growing oyster mushroom due to its high cellulose, fiber and lignin (Obodai et al., 2003). The authors used substrates based on cane bagasse and wheat bran extract, obtaining values that were confirmed by the other authors as well, who carried out the evaluation of the growth and production of biomass of three strains of the genus *Pleurotus* in a PDA medium prepared with different solutions of corn residue, achieving greater measures in the radial growth using stubble and corn husk (Rojas Ledesma & Quintana Zamora, 2015). Although degradation was done in different conditions in the above-mentioned studies, the main decomposed substrates were rich in cellulose, fiber and lignin and these coherent results suggest that degradation ability of oyster depends on the available metabolites of used substrate. In our study, this is confirmed by different results for *P. ostreatus* growth for varied substrates.

Rojas Ledesma and Quintana Zamora developed the study of radial growth and biomass production of the species *P. sapidus* (Schultzer) Kalchbrenner inoculated in various culture media using peanut shells (*Arachis hypogaea* L.) and *Cajanus cajan* (L.) Huth., obtaining inferior results, attributing their results due to the little or almost no contribution of linocellulite substances present in these wastes (Rojas Ledesma & Quintana Zamora, 2015).

3.2 PRODUCTION OF THE OYSTER MUSHROOM (*P. OSTREATUS*) GROWN ON SUBSTRATES OF COCOA PEEL, BANANA, AFRICAN PALM RACHIS AND COCONUT SHELL

The production of *P. ostreatus* mushrooms harvested in different agricultural by-products is shown in Table 4, where it can be seen that the crop residue on which the highest production was obtained was CCA treatment with 164.13 g ($p < 0.05$), while in APR treatment there was no mushroom growth because in this material there was an accelerated loss of moisture and high temperatures due to its non-absorbent fibrous characteristic, similar to those obtained in the CCO treatment that similarly achieved a lower production associated with this effect.

Table 3: Radial growth of *P. ostreatus* inoculated in different culture media

Variables Hours	Growth diameter (mm)					p
	T1 PDA	T2 CCA	T3 APR	T4 BP	T5 CCO	
24	4.00 ± 0.63 a	3.66 ± 0.52 a	3.83 ± 0.41 a	3.88 ± 0.41 a	3.66 ± 0.52 a	0.7639
48	5.16 ± 0.75 a	6.66 ± 3.14 a	6.33 ± 2.87 a	5.00 ± 0 a	4.66 ± 0.52 a	0.3268
72	10.66 ± 1.75 ab	9.00 ± 0.89 ab	14.00 ± 5.48 a	7.83 ± 0.75 b	14.00 ± 5.48 a	0.0162
96	17.50 ± 2.88 ab	17.16 ± 1.33 ab	23.00 ± 10.62 a	11.83 ± 0.75 b	24.83 ± 8.93 a	0.0129
120	30.50 ± 6.83 b	26.83 ± 2.23 bc	34.83 ± 5.85 ab	15.66 ± 0.82 c	46.16 ± 14.13 a	<.0001
144	50.66 ± 11.48 ab	37.00 ± 3.1 bc	49.50 ± 13.1 ab	20.16 ± 0.98 c	60.16 ± 14.69 a	<.0001
168	59.66 ± 9.39 ab	52.33 ± 4.97 bc	61.50 ± 9.57 ab	41.33 ± 3.27 c	66.83 ± 11.58 a	0.0002

T1 PDA = Potato dextrose agar; T2 CCA = cocoa shell; T3 ARP = African palm rachis; T4 BP = banana peel; T5 CCO = coconut shell. Averages with equal letters do not differ statistically, according to Tukey ($p < 0.05$)

This is in accordance with Pineda et al.(2013) who indicated that after 30 °C there is a degradation of growth and therefore low production, demonstrating that *P. ostreatus* has a better growth at temperatures below 20 °C while at temperatures above 30 °C its growth stops or slows. In addition, banana have been used and suggested as a good substrate for oyster production as it has lignocellulosic compounds those accelerate oyster growth (Bonatti et al., 2004). This is confirmed by our findings as banana-based medium is the second one whose oyster production was higher.

These results were similar to those obtained by Quintana Zamora et al.(2018), who obtained 163.75, 132.75 and 114.75 g in production of oyster mushroom species (*P. ostreatus* and *P. sapidus*) in crop media with agricultural residues of soybeans, rice and corn kernels, respectively. However, other authors obtained a greater production of up to 761 g evaluating the growth and production of *P. ostreatus* on different agro-industrial residues using byproducts of cape gooseberry, pea shell and cob of corn (López-Rodríguez et al., 2008). Romero et al. 2010, evaluated the productive capacity of *P. ostreatus* using dehydrate banana leaf (*Musa paradisiaca*(Roatan) and achieved superior results for wheat straw substrate with more than 200 g kg^{-1} compared to other substrates, such as wheat straw (*T. aestivum* L.), barley straw (*H. vulgare* L.), bean straw (*P. vulgaris* L.) and corn stubble (*Z. mays* L.) (Romero et al., 2010).

Table 4: Production of *P. ostreatus* mushroom harvested in different agricultural by-products

Variable	T2 CCA	T3 APR	T4 BP	T5 CCO	p
Production in grams	164.13 ± 46.43 a [1/]	----------	142.03 ± 21.99 a	45.03 ± 21.25 b	0.0001

[1/] Averages with equal letters do not differ statistically, according to Tukey ($p < 0.05$)

Table 5: Chemical composition of *P. ostreatus* grown in different agricultural substrates

Variable	T2 CCA	T3 APR	T4 BP	T5 CCO	p
DM	5.94 ± 0.47 b[1/]	----------	13.61 ± 1.49 a	12.66 ± 0.26 a	<.0001
Mo	94.05 ± 0.47 a	----------	86.38 ± 1.49 b	87.34 ± 0.26 b	<.0001
EE	6.52 ± 0.18 a	----------	6.31 ± 0.24 a	5.30 ± 0.49 b	<.0001
CP	19.05 ± 0.68 c	----------	21.23 ± 1.24 b	30.08 ± 0.71 a	<.0001
CF	12.34 ± 0.32 a	----------	10.08 ± 0.33 b	7.86 ± 0.42 c	<.0001
NNE	56.15 ± 0.97 a	----------	48.24 ± 2.35 b	43.21 ± 1.06 c	<.0001
pH	6.65 ± 0.15 a	----------	6.60 ± 0.06 a	6.55 ± 0.08 a	0.2426
TA	3.32 ± 0.12 a	----------	2.78 ± 0.29 b	2.91 ± 0.22 b	0.0021

Mo = Moisture; DM = Dry matter; EE = Ethereal Extract; CP = Crude protein; CF = Crude fiber; NNE = Non-nitrogen elements; pH = Hydrogen potential; TA = Titratable acidity; P = Probability; [1/] Averages with equal letters do not differ statistically, according to Tukey ($p < 0.05$)

3.3 CHEMICAL COMPOSITION OF *P. OSTREATUS* RODUCED IN DIFFERENT AGRICULTURAL RESIDUES

Table 5 shows the results of the chemical composition of mushrooms grown in agricultural residues of coconut, banana and cocoa. There is a statistical difference between the treatments in the analyses of moisture, dry matter, ethereal extract, crude protein, and nitrogen-free elements, while there is no statistical difference between treatments for titratable acidity analysis. *Pleurotus* fungi are considered to have a high percentage of excellent protein value. The fungi cultivated in CCO residues obtained better percentage of protein of 30.08 %.

Paucara Fernández (2014) evaluated the production of the *P. ostreatus* fungus on different types of substrates (barley Tamo, Vicia Tamo, oatmeal straw and paramo straw) enriched by ground cob, barley bran and calcium carbonate. He obtained similar results in protein content as seen in treatments CCA and BP, but inferior to the result of treatment CCO that was the most superior with 30.08 %. On the other hand, Quinrana Zamora et al. 2018 carried out the production of oyster mushrooms (*P. ostreatus* and *P. sapidus*) in crop media with agricultural residues of soybeans, rice and corn kernels, achieving results similar to those obtained in the present study (Quintana Zamora et al., 2018). However, combination of different agricultural wastes and plant residues might be a better solution for oyster production while varied substrates provide different compounds for mushroom growth and yield (Tsegaye & Tefera, 2017).

4 CONCLUSIONS

Oyster is a rich protein source. It grows on natural media that are plant-based substrates. Different substrates result in varied oyster yield and metabolite composition. This study was done to find a good substrate as oyster growing medium from plant-waste compostable materials. A medium based on PDA and coconut shell was the best substrate with the most oyster radial growth and protein content. Oyster grown on cocoa husk produced more dry matter and crude fiber compared with the other studied substrates.

In the radial growth phase of *P. ostreatus* on the PDA medium combined with coconut shell solution, greater speed in its growth was seen and therefore the production of fungal biomass. The substrate presented a higher output was the cocoa-based, since this unlike the rest of the residues, conserves a higher moisture. Based on our results, it seems that a mixture of different substrates can be more efficient as oyster growth medium. However, it remains to further study to formulate the substrates to obtain acceptable media for oyster production.

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