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INCREASE IN THE PRODUCTION OF PLEUROTUS OSTREATUS IN URBAN AND AGROINDUSTRIAL WASTE FROM ACATZINGO, PUEBLA

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Abstract: The objective of this work was to increase the production of Pleurotus ostreatus, using mixtures of agroindustrial residues (sawdust and pine shavings [AP], corn cob [OM], corn stubble [RM] and bean straw [PF]) from the Acatzingo region, Puebla, with coffee grounds [PC] from homes and cafeterias in the city of Puebla. Five treatments were designed: T1, T2, T3 and T4 with 50% PC and 50% of each of the aforementioned residues, and T5 (mixture of PC, AP, OM, PF, and RM in proportions of 50, 20, 10, 10 and 10% respectively). Production was determined from indicators such as crop cycle, total fresh weight, biological efficiency (EB) and production rate. Resulting the most effective treatment with respect to EB followed T5 (97%), managing to increase these values up to 234% for T1. In addition, a production rate between 1.65% to 3.32% (T1 and T3) was obtained, with an average crop cycle of 64 days in three harvests. Resulting the most effective treatment with respect to EB followed T5 (97%), managing to increase these values up to 234% for T1. Therefore, the addition of coffee grounds to said substrates for the production of P. ostreatus is a sustainable alternative to produce nutritious food.
Keywords: edible mushrooms, sustainable, coffee grounds, biological efficiency.

INTRODUCTION

Edible mushrooms have been highly appreciated by many populations around the world for many years, both for their sensory (mainly for their taste), nutritional and medicinal properties, as well as for their economic and ecological value, resulting in a profitable technology for producing rich foods. in proteins and at the same time reduce environmental contamination, since due to their complex enzymatic system, such as laccases, lignocellulite peroxidases, quinone reductases, among others, they are capable of degrading a wide variety of lignocellulosic substrates, mainly residues from agricultural activities and livestock, as well as the timber industry, and the manufacturing industry, which add up to approximately 200 types (POPPE, 2000). However, only approximately 300 species are edible, and only 30 have been domesticated, and ten commercially cultivated (BARNY, 2009). Therefore, the production of fungi, including yeasts, is considered the second most important commercial microbial technology in the world (PATHAK et al., 2009).

In Mexico, the consumption of mushrooms has been practiced since ancient times, and is currently the main biotechnological resource, which is denoted by the significant advances in its production and consumption, since according to studies by Martínez-Carrera and his work team, in In 2007, it was the largest producer of edible mushrooms in Latin America, generating around 58.9% of the total production, ranking 16th worldwide. While in 2011 it was also ranked as the main exporter, mainly white mushrooms, although worldwide it is number 13; In addition, the commercial production of edible, medicinal and functional mushrooms was approximately 62,374 tons. Likewise, in 2016, the production chains of these products generated 25,000 jobs and 62,000 annual tons of commercial products. The same thing happened with per capita consumption, since in the period from 1990 to 1997 it increased by 209 % (from 0.112 kg to 0.346 kg), while in the period from 2000 to 2011, it increased to 0.600 kg, which which represents a growth of approximately 10%, however, this is still little compared to Germany where it is 3.5 kg. Likewise, it was determined that, in 2003, 49.4 % of urban consumers of different social levels acquired edible mushrooms, increasing to 59.2 % in 2007. Currently, it constitutes an emerging agri-food chain developed on a small and large scale, since that there is an interaction between small rural producers and large producing companies, which is why in technological terms it is a profitable, controlled, intensive chain, efficient in the use of water, and that adapts to climate change; In addition, in social and economic terms it is competitive, ecological, and generates sources of work, that is, it is sustainable (MARTÍNEZ- CARRERA et al., 2000; MARTÍNEZ- CARRERA et al., 2007; CRUZ, 2016).

Pleurotus ostreatus is known in Mexico as "mushroom fungus", "oyster fungus", "maguey fungus", "white fungus", "stubble fungus", coffee pulp fungus" (GUZMAN, 1997), and in the world as "hiratake", "shimeji", "houbitake" (MIZUNO and ZHUANG, 1995; BONONI et al., 1995; RÜHL et al., 2008). It is the second most cultivated mushroom both in Mexico and worldwide. In addition, it is the most studied for various reasons, since it is a food of excellent quality, both for its sensory, nutritional and functional properties. It is also very profitable, since it presents high rates of biological efficiency, which is due to its relatively easy development as a result of its great capacity to degrade a wide spectrum of lignocellulosic substrates, mainly agricultural by-products, several of which are toxic to humans. environment (OBODAI et al., 2003), which is due to the low specificity of their lignolytic enzymes (KALMIS and SARGIN, 2004); In addition, it does not require a lot of care and resources for its production, since it is only necessary to pasteurize the substrates and not sterilize them as is the case with other mushrooms; Similarly, it can develop even without controlled conditions (SÁNCHEZ, 2010). For this reason, a large number of works have been carried out to take advantage of the residues of each region according to the primary and secondary activities carried out in them, such as waste from: *Simmondsia chinensis, Jatropha macrocarpa* and wheat straw in: La Rioja, Argentina (FRACCHIA *et al.*, 2009); on banana leaf (*Musa paradisiaca* l., cv. Roatan) dehydrated and wheat straw, barley straw, bean straw and corn stubble from the Martínez de la Torre area, in the state of Veracruz, Mexico (ROMERO et al., 2010); in gooseberry capacho, pea shell and corn cob from the department of Cundinamarca, Bogotá, Colombia (LÓPEZ-RODRÍGUEZ et al., 2008); even in other urban waste such as disposable diapers and with grass (DELFÍN-ALCALÁ and DURÁN DE BAZÚA, 2003), and coffee grounds in mixtures with sugarcane bagasse, corn stalk, and sawdust (GARZÓN-GÓMEZ and CUERVO-ANDRADE, 2008), among others.

On the other hand, in the city of Puebla (Mexico) and in several municipalities of the state, in recent years the establishments that offer coffee as a beverage in different presentations have increased to a great extent, ranging from self-service centers and grocery stores convenience, such as "Oxxo", to nationally and internationally recognized places such as "Starbucks", "Itallian Coffe", "Punta del Cielo", etc., as well as rural and culturally set cafeterias such as "Panela Canela", "Café Culture", among others, which add up to 468 according to data recorded on the internet. An alternate result of this great activity is the generation of a large amount of waste such as disposable cups, straws, "coffee grounds" (waste product from coffee preparation), etc. The latter being a problem when they are deposited in drainage dumps, despite the fact that they have been used as fertilizer for gardens, and that some initiatives have been created for their management, such as the project "Posos para su jardín Starbucks" and "Poso para la tierra", in addition to the fact that people have tried to reuse them at home, for example to stain wood, to make air fresheners and soaps mainly; and in the same way in the industry, which uses them for the production of biogas and for the treatment of residual waters.

The objective of this work was to evaluate mixtures of four agro-industrial residues (sawdust and pine shavings, corn cob, corn stubble and bean straw) from the Acatzingo region, Puebla with coffee grounds from homes and cafeterias in the city of Puebla, since various works indicate that mixtures of substrates are more efficient than by themselves, coffee grounds being an alternative little studied for this purpose, which will be compared with the data previously obtained in said substrates alone to determine the degree of improvement of said mixtures based on performance parameters such as biological efficiency, culture cycle time, total weight of fresh mushrooms produced, and production rate.

MATERIALS AND METHODS

EXPERIMENTAL PHASE

Five treatments were designed: T1, T2, T3 and T4 with 50 % PC and 50 % of each of the agro-industrial residues (sawdust and pine shavings [AP], corn cob [OM], corn stubble [RM] and bean straw [PF]) and T5 (mixture of coffee grounds (PC), with the rest of the residues (AP, OM, PF and RM) in proportions of 50, 20, 10, 10 and 10 % respectively.). For this, the following procedure was carried out:

1) All materials were dried in the sun until constant weight.

2) Each substrate was manually chopped to a particle size between 1 and 2 cm, with the exception of pine sawdust.

3) The substrates were weighed and the mixtures were made.

4) Each substrate mix was pasteurized in water at 85°C for 45 min.

5) It was allowed to cool, and 2 kg of substrate and 50 g of activated mycelium or seed were weighed, to obtain a 4% homogeneous inoculation, obtaining bags of 2050 g of substrate inoculated with the commercial strain CP-50 of P. ostreatus. acquired from the Edible Fungi Genetic Resources Center (CREGENHC) of the Puebla Campus Postgraduate College, for which 15 x 25 cm polypaper bags were used, previously perforated with a sterile dissection needle and with a template to cover a 2 % surface.

6) The bags were tied to close them, and placed on the shelves (with latticed bases for greater aeration).

7) Fruiting was carried out at room temperature and humidity, and in the dark for a period of 20 to 30 days, irrigating the floor with drinking water three times a day, and ventilating for one hour every eight hours to maintain low CO2 levels and maintain the necessary illumination produced by daylight.

8) Each mixture was made with four replicates for each treatment with two replicates for each production period.

ANALYSIS OF RESULTS

Production was determined from indicators such as crop cycle time (CC = period from the start of the colonization of the substrate until the end of fruiting), the total fresh weight (PF = weight obtained from fresh mushrooms until the last harvest), the biological efficiency (EB = weight of fresh fungi per 100 g of dry substrate) and the production rate (TP = EB for the time elapsed from inoculation to the last harvest).

Analysis of variance (ANOVA) and Tukey’s multiple comparison test ($\alpha = 0.05$) were performed to determine the differences between treatments using the XLSTAT statistical software.

RESULTS AND DISCUSSION

CROP CYCLE

The 160 inoculated bags (32 of each treatment shown in Table 1) were randomly distributed on the shelves to determine the different stipulated performance parameters. In general, the ANOVAs showed that all the production parameters obtained for the five treatments were significantly different ($p < 0.05$) among them, however, when performing the Tukey test in some parameters they were significantly the same ($p < 0.05$) as indicated. will detail below.

Thus, the treatment with the shortest incubation time was T3 with 22 days, while the latest was T2 with 38 days, which was finally reflected in the average culture cycle time of 55.25 and 72.56 days, respectively (Table 2), so the best treatment due to its shorter production time is T3 with 55 days, followed by T4 and T5 with 62 days on average; which may be due to the additional carbon provided by the fat, since bean straw has the highest content (1.8%) compared to the cob and corn stubble (0.8% and 1.4%, respectively (PICCIONI, 1970), given that this element is essential for its rapid development.

Treatment	Mix	% of each substrate
T1	AP-PC	50-50
T2	OM-PC	50-50
T3	PF-PC	50-50
T4	RM-PC	50-50
T5	AP-OM-PF-RM-PC	20-10-10-10-50

Table 1. Characteristics of each treatment.

Treatment	Average	Deviation	Difference Between Groups
T1	66.53	4.16	b,c,d,e
T2	72.56	5.27	c,d,e
T3	55.25	4.54	d,e
T4	63.28	3.44	
T5	60.91	3.95	

Table 2. Crop cycle time (days) obtained in each treatment

TOTAL FRESH WEIGHT

Regarding the fresh weight obtained after three harvests, it can be observed (Table 3) that the treatment that gave the highest yield was T5, although there is no statistically significant difference ($p < 0.05$) with T2, T3 and T4, except with T1, which can be explained in the same way as for the crop cycle, since in both cases they are related to development and growth due to carbon availability. In addition to the fact that carbon is also increased by coffee grounds, since coffee beans contain polysaccharides of different types, as well as fats in a proportion of 13.4 to 20%, made up of free fatty acids; triglycerides (75%) formed from linoleic and enpalmitic acids; unsaponifiable lipids (20% to 25%); diterpenes where palmitic acid predominates; sterols (2.2%); and cholesterol (0.044% to 0.11%) (PUERTA-QUINTERO, 2011).

Treatment	Average	Deviation	Difference Between Groups
T1	1108.9	67.16	b,c,d,e
T2	1555.4	80.29	
T3	1822.6	91.73	
T4	1880.2	100.6	
T5	1968.6	97.48	

Table 3. Fresh weight of mushrooms (g) obtained in three harvests

BIOLOGICAL EFFICIENCY

The greatest BE was for T5 as can be seen in Table 4, however, there is no significant difference ($p < 0.05$) with T4, which is followed by T3. This is explained by the relationship that exists in the value of the carbon-nitrogen ratio in the substrates (C:N), since the lower this value, the BE will be higher (SÁNCHEZ et al., 2002), which It is verified with the C:N data given by PICCIONI (1970), who reports that bean straw has a value of 40.7 and corn cob 71.3, and it is presumed that sawdust and pine shavings are higher when they contain a less amount of N

Comparing the values obtained in the present work in relation to the previous one (CALDERÓN-FERNÁNDEZ et al, 2016), it is observed that these values were increased by adding the coffee grounds in T1, T2, T3 and T4, achieving increases of 231.35 %, 154.16 %, 126.67% and 112.37% respectively (Figure 1), and in the case of T5 it can be seen that the synergy is greater, which was to be expected due to the nitrogen contained in the coffee grounds, since both the Almond coffee, like roasted coffee, contain this element in a proportion, which goes from 1.30% to 3.23% of the dry weight of the grain, in addition to 11% to 13.5% of proteins, of which 50% are albumins (soluble in water) and 50% globulins (insoluble in water), as well as free amino acids (PUERTA-QUINTERO, 2011); which contributes to decrease the C:N ratio and therefore to increase the BE.

In addition, these data are consistent with those obtained by GARZÓN-GÓMEZ and CUERVO-ANDRADE (2008), who mixed different agro-industrial substrates with coffee grounds in different proportions, being 25% by volume (equivalent to 50% by weight) They obtained higher BE compared with the substrates alone, with their mixtures without coffee grounds, with those that had a greater or lesser percentage of 25% in volume of coffee grounds, and even with the coffee grounds alone; Therefore, this proportion seems to be the most efficient in these substrates.

Finally, it can be said that all the substrates had an acceptable productive quality, since the EB was greater than 50% in all the treatments (PATRA and PANI, 1995).

Treatment	Average	Deviation	Difference Between Groups	Average
T1	54.09	3.28	b,c,d,e	Of soil substrate *
T2	75.88	3.92	c,d,e	49.22^{OM}
T3	88.91	4.47	e	70.19^{RM}
T4	91.72	4.91		81.65^{PF}
T5	96.03	97.48		-

Table 4. Biological efficiency (%) obtained in each treatment and in the substrate alone *

* AP: : sawdust and pine shavings, OM: corn cob, RM: corn stubble, and PF: bean straw. Obtained in a previous study (Calderón-Fernández et al, 2016).

PRODUCTION RATE

The production rate obtained for each treatment is shown in Table 5, observing that there is a significant difference ($p < 0.05$) between all of them, the highest being that of T3, which is evident, since in the case of the cycle of crop this presented the lowest value, in addition to the fact that, in the case of EB, for T3 and T4 there was no significant difference ($p < 0.05$), and the same for T4 and T5, which turned out to be the best with respect to this parameter.

Therefore, according to all the results obtained, T3 is the best, since it has a shorter cultivation cycle time (55 days) and the highest production rate (3.32%) with practically 146 g of fresh mushrooms less than the highest (1968.6 g for T5, but with an investment of 5 more days), which is equivalent to $10 if a commercial value of $70 per kg of fresh mushroom is taken into account.

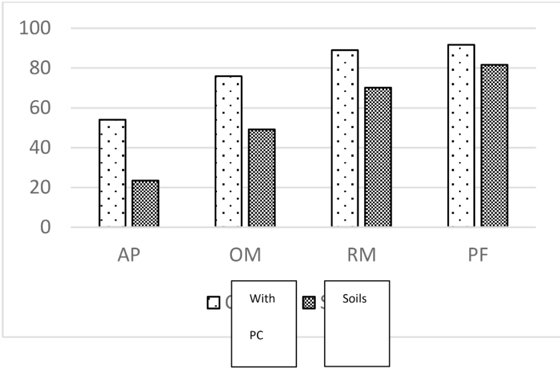

Figure 1. Comparison of the EB obtained from the substrates alone and those added with coffee grounds (PC)

Treatment	Average	Deviation	Difference Between Groups
T1	1.654	0.086	b,c,d,e
T2	2.138	0.085	c,d,e
T3	3.319	0.112	d,e
T4	2.995	0.117	E
T5	3.218	0.113	

Table 5. Production rate (%) obtained in each treatment

CONCLUSIONS

The mixtures of coffee grounds with pine sawdust, corn cob, bean straw, and corn stubble were an adequate alternative for the production of *Pleurotus ostreatus* in the backyard of the homes of the municipalities of the Acatzingo region of the state of Puebla (Mexico), since not only the agro-industrial waste generated in said region is used, but also those generated in the city of Puebla, such as the dregs of coffee, which at the rate that the commercial establishments that produce them are growing, can create a problem if they are not handled properly. With these mixtures formed with an equal proportion of each agroindustrial residue and with coffee grounds, it was possible to increase the BE from 112.37% to 231.35% compared to the substrates alone, highlighting this last value, which corresponded to pine sawdust, which by itself it had an efficiency of less than 50%, so, this way it does not have an acceptable productive quality. Concluding that the mixture of bean straw with coffee grounds was the best option, since it presented a crop cycle of 6 to 18 days less compared to the other mixtures, so that in less than two months (55 days) it can be have the total production of mushrooms; In addition, it presented the best biological efficiency taking into account the largest amount of fungi produced in the shortest time.

With which the high profitability of Pleurotus ostreatus is verified once again, by presenting biological efficiency values greater than 54% in uncontrolled conditions and with low economic and personal resources, as are those of the vast majority of small producers and households in the mentioned region.

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