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Original Article

Possible effects of different types of agricultural wastes on food security and mushroom (*Pleurotus ostreatus*) production

Possíveis efeitos de diferentes tipos de resíduos agrícolas na segurança alimentar e na produção de cogumelos (*Pleurotus ostreatus*)

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Abstract

One of the new waters, and environmentally friendly agriculture initiatives in Peru is to encourage the utilization of agricultural waste, because low agricultural output is a threat to food security there. The purpose of this research was to evaluate the effect of harvest residues on the basidiocarp production of the fungus *Pleurotus Ostreatus*, in Acobamba-Huancavelica. The trial had a completely randomized design, and the treatments included T1, barley stubbles; T2, wheat stubbles; T3, pea stubbles; T4, broad bean stubbles; and T5, quinoa stubbles. The research was quantitative in nature, taking the form of an experiment with an applied, explanatory level of design. The recorded data was tabulated and analyzed with analysis of variance, as well as Tukey's test (α:0.05), for which the statistical software Infostat was used. The results are presented in tables and graphs for a better interpretation. As main results, it was obtained that the time (colonization), diameter (stem, pileus), length (stem) and weight (basidiocarps), present statistical differences between treatments showing significant enhancement in all parameters. Despite a numerical difference, a Tukey average comparison test revealed that there was no statistically significant difference between the averages for the variable time for fungus colonisation, suggesting that the treatment T5 in which quinoa substrate showed the greatest average. Treatment T4 in which broad bean stubbles were used gave the most low-average. In conclusion, increment in all parámeters were noted in all treatment of *Pleurotus basidiocarps ostreatus* under Acobamba conditions.

Keywords: edible fungus, nutrients, proteins, organic residue, *Pleurotus ostreatus*.

Resumo

Uma das novas iniciativas de águas e agricultura ecológica no Peru é incentivar a utilização de resíduos agrícolas, porque a baixa produção agrícola é uma ameaça à segurança alimentar no país. O objetivo desta pesquisa foi avaliar o efeito dos resíduos da colheita na produção de basidiocarpos do fungo *Pleurotus ostreatus*, em Acobamba-Huancavelica. O ensaio teve um delineamento inteiramente casualizado, e os tratamentos incluíram T1, restolho de cevada; T2, soqueiras de trigo; T3, restolho de ervilha; T4, restolho de fava; e T5, restolho de quinoa. A pesquisa foi de natureza quantitativa, assumindo a forma de experimento com um nível de *design* aplicado e explicativo. Os dados registrados foram tabulados e analisados com análise de variância, bem como teste de Tukey (α:0,05), para o qual foi utilizado o software estatístico Infostat. Os resultados são apresentados em tabelas e gráficos para melhor interpretação. Como principais resultados, obteve-se que o tempo (colonização), diâmetro (caule, píleo), comprimento (caule) e peso (basidiocarpos) apresentam diferenças estatísticas entre os tratamentos, mostrando melhora significativa em todos os parâmetros. Apesar da diferença numérica, o teste de comparação de médias de Tukey revelou que não houve diferença estatisticamente significativa entre as médias para a variável tempo de colonização do fungo, sugerindo que o tratamento T5 em que usou o substrato quinoa, apresentou a maior média. O tratamento T4, no qual foram usadas restolhos de fava, apresentou a média mais baixa. Em conclusão, incrementos em todos os parâmetros foram observados em todos os tratamentos de *Pleurotus basidiocarps ostreatus* nas condições de Acobamba.

Palavras-chave: fungo comestível, nutrientes, proteínas, resíduo orgânico, *Pleurotus ostreatus*.

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1. Introduction

Mushrooms have been consumed by humans for thousands of years; the ancient Greeks believed they gave strength to warriors, the ancient Egyptians valued them for their delicacy, and reserved them for ceremonial occasions, and the ancient Chinese called them "the elixir of life" due to their reputation as a nutritious food (Gaitán-Hernández, 2020). Mushrooms are widely cultivated around the world because of their excellent flavour and the fact that their fruiting bodies are fleshy. The carbs, proteins, vitamins, and minerals found in them are plentiful (Kour et al., 2022). Decomposing organic matter high in lignin, cellulose, and other complex carbohydrates is ideal mushroom growing material. Likewise, the cultivation of edible mushrooms is an activity that has acquired economic importance over the years in Asian countries and in Latin America, therefore, cultivating edible mushrooms has become for many a type of occupation that requires experience in the productive management as in its reproduction (Singh, 2023). Where it is also considered as an ecological bioconversion system, in which the most useless agricultural remains are used to later transform them into protein food that can be used for food. (Cybertruffle, 2019).

Many of the world's environmental and health issues can be traced back to the massive amounts of agro-industrial wastes created every year (Younas et al., 2023; Gondal and Tayyiba, 2022). The mushroom farming industry grew in response to the increasing demand for low-cost, high-nutrition food (Areche et al., 2022) and the shortage of protein in emerging nations. The oyster mushroom Pleurotus ostreatus grows quickly on a variety of agro-wastes, including quinoa stubbles, wheat stubbles, pea stubbles, broad bean stubbles, and barley stubbles. In the Andean region, Huancavelica in the province of Acobamba, barley, broad beans, quinoa, wheat and peas are grown; in an area of 3323, 1933, 344, 907 and 297 hectares respectively that generates large amounts of waste from their stems, called stubble, which is sometimes used by farmers as food for their animals. The others due to ignorance, they carry out the burning of stubble in the open field, causing negative environmental impacts for the ecosystem, causing the physical, chemical and biological degradation of the soil (Gondal et al., 2022; Jiang et al., 2022). Since the organic matter necessary to restore the productive capacity of the soil is removed (Gondal et al., 2023; Cotrina Cabello et al., 2023). On the other hand, Huancavelica is a region that reached a malnutrition rate of 40.1% above the national average. It is possible to contribute to its reduction through technological innovations in agriculture, through the production of edible mushrooms using agricultural stubble and thus contribute to improving the diet of families for all the benefits that the Pleurotus mushroom offers ostreatus. Hence the importance of knowing in which of the crop residues, used as substrate, allows to achieve better production responses of this fungus in the environmental conditions of Acobamba.

Among the alternative of exploitation or use of this type of waste is the cultivation of edible mushrooms *Pleurotus ostreatus*. So, the following question arises; What is the effect of crop residues on the production of basidiocarps of the fungus *Pleurotus Ostreatus,* in Acobamba-Huancavelica? The purpose of this research project was to determine the production capacity of the fungus *Pleurotus Ostreatus* from plant residues from different substrates composed of crop residues such as barley, wheat, quinoa, peas and broad beans. As limitations of the investigation, it was had; unfavorable environmental conditions, little theoretical information and lack of equipment to grind the trace of adequate size. The purpose of this research was to generate knowledge about the effect of crop residues on the production of the *Pleurotus fungus Ostreatus*, in Acobamba–Huancavelica

2. Materials and Methods

The research work was carried out in the environments of the Professional School of Agronomy Faculty of Agricultural Sciences of the UNH, with temperatures between 5° - 19°C, geographically located at 3423 meters above sea level, 12°50'37" S, and 74 °33´41.46" W, in the province of Acobamba Huancavelica Peru. In Acobamba, the summers are short, comfortable, and cloudy; the winters are short, cold, and partly cloudy; and it is dry year around. During the course of the year, the temperature generally varies from 5 °C to 19 °C and rarely drops below 2 °C or rises above 21 °C (Meteoblue, 2020).

2.1. Material used in the study

Material used in the study was Strain: *Pleurotus ostreatus* that were collected from UNH Peru. Extracts and culture media: Potato extract (solanum tuberosum) in distilled water (AD), potato-dextrose-commercial agar (PDA), wheat grain and vegetable remain of the crops. Inputs: Gelling agent (agar-agar), dextrose (carbon source). Elements: Sterilized canvas, labeled glass jars, aluminum foil, polypropylene bags, Petri dishes, test tube. Equipment: Laminar flow chamber, autoclave, pH meter, analytical balance, microwave, magnetic stirrer, incubator.

2.2. Research method

The research work was a quantitative approach, with an experimental design, which seeks to evaluate the productive capacity of the *Pleurotus oyster mushroom Ostreatus*, cultivated on lignocellulosic residues (crop residues) in the province of Acobamba, Huancavelica, Peru. Also, research work was explanatory level. Due to the interest in explaining the effect of crop residues on the production of the fungus *Pleurotus ostreatus*. It was carried out under a completely randomized design (CRD) (Figure 1), with five treatments, substrates based on five crop residues (barley, wheat, quinoa, broad bean, pea), with 4 repetitions, making a total of 20 experimental units (Gondal, 2023a). The treatments were composed of crop residue substrates, in which the activated mycelia were be sown in wheat grain including T1: Barley stubble, T2: wheat stubble, T3: Pea stubble, T4: Broad bean stubble, and T5: Quinoa stubble.

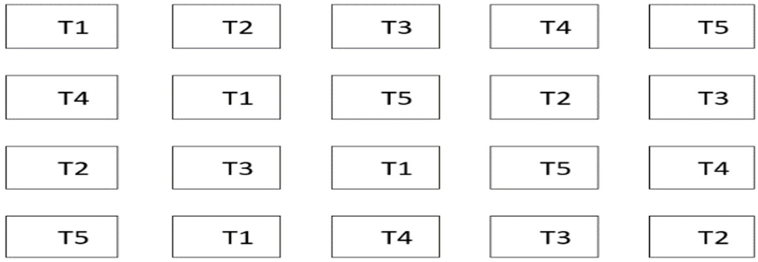

Figure 1. Sketch of the experiment under CRD design.

2.3. Population and sampling

The study population was made up of the mycelia and the cups of the fungus *Pleurotus ostreatus*. The sample size was 5 individuals per experimental unit. The sampling technique used to choose the sample elements of the study was random, for which smaller quadrants were established in each experimental unit as shown in Table 1.

2.4. Procedure

2.4.1. Colonization time

To determine the colonization time of the fungus mycelium to the substrates under study, it was necessary to evaluate daily, after 14 days after inoculation. Since as of the date the substrate bags could already be almost completely invaded, such is the case that, to decree the days of colonization, the substrate balls had to be completely invaded with fungal mycelium which could be distinguish with the naked eye since the bags were covered in a whitish way. For the statistical analysis, the time elapsed from the moment of inoculation to total colonization was considered. This activity was carried out in the incubation stage.

2.4.2. Production time

In the determination of the production time, the evaluation was on daily basis from the appearance of the primordia to decree and carry out the statistical analysis. It was taken into account from the moment of induction to fruiting until the days of harvest.

2.4.3. Mushroom stem and crown diameter

In the quantification of the diameter of the stem and the cap of the fungus, it was carried out daily from the moment of the appearance of the primordia until the moment of harvest, for which three basidiocarps per repetition were taken into account for their respective measurement using the vernier instrument, for statistical analysis the repetitions of each pull were averaged.

2.4.4. Stem length

The quantification of the length of the stem of the fungus was carried out as well as the diameter of the stem and crown, which were carried out in the fruiting stage in both parts.

Table 1. Techniques and instruments used in data collection

Variable	Technique	Instrument
Colonization time	Estimate	Calendar
Production time	Estimate	Calendar
Stem diameter	Measurement	Vernier
Pileus diameter	Measurement	Vernier
Stem diameter	Measurement	Vernier
stem length	Measurement	Vernier
number of basidiocarpos	Count	Numeration
Weight of individuals	Heavy	Analytical balance

2.4.5. Number of basidiocarps harvested

To determine the number of basidiocarps, a numerical count was made for each repetition at harvest times, then it was averaged for statistical analysis.

2.4.6. Basidiocarp fresh weight

This activity was carried out once the basidiocarps had acquired the appropriate size for harvesting. Analytical balance was used for weighing. For statistical analysis, it was averaged like the other activities mentioned above.

2.4.7. Data processing and analysis techniques

The recorded data was tabulated and analyzed with analysis of variance, as well as Tukey's test (α:0.05), for which the statistical software Infostat was used. The results are presented in tables and graphs for a better interpretation.

3. Results

Regarding the time for colonization in the lignocellulosic substrates of the fungus (*Pleurotus ostreatus*) between 15 and 19 days after inoculation (DDI) were noted and it was observed that there was no significant statistical difference between the treatments at a confidence level of 95% and showing that the treatments had no influence on the colonization of the fungus (Figure 2). Likewise, the coefficient of variation was 5.10%, considered excellent on the Calzada Benza rating scale.

Despite a numerical difference, a Tukey average comparison test revealed that there was no statistically significant difference between the averages for the variable time for fungus colonisation, suggesting that the treatment T5 in which quinoa substrate showed the greatest average. Treatment T4 in which broad bean stubbles were used gave the most low-average (Figure 2).

The time of formation of basidiocarps of the *Pleurotus Ostreatus* in the lignocellulosic substrates between 14 and 19 days after the induction of primordia formation (DDFP), it was observed that there was a significant statistical difference between the treatments at a confidence level of 95%. Results concluded that treatments do influence the basidiocarp formation of the fungus. Likewise, the coefficient of variation was 8.02%, considered excellent on the Calzada Benza rating scale. Regarding the comparison test of Tukey averages for the variable time for the formation of basidiocarps in production, it was evident that there was a statistical difference between the averages, showing that the treatment T4, broad bean substrate presenting the longest time of formation of basidiocarps with 18.50 days on average and treatment T3, pea substrate the shortest time with 14.50 days on average (Figure 3).

Tukey average comparison test for the variable time for the formation of basidiocarps in production, it is evident that there is a statistical difference between the averages, showing that the treatment T4, broad bean substrate presents the longest time of formation of basidiocarps with 18.50 days on average and treatment T3 = pea substrate the shortest time with 14.50 days on average (Figure 3).

Regarding the stem diameter of basidiocarps of *Pleurotus Ostreatus*, which fluctuate between 19.02 and 23.64 mm, concluding that there was no significant statistical difference between the treatments at a confidence level of 95%, that was, the treatments had no influence on the diameter of the fungus stem (Figure 4). Likewise, the coefficient of variation was 22.67%, considered regular on Calzada Benza 's rating scale. Tukey's test for the variable of the mean stem diameter in the basidiocarps of each treatment, where it is evident that there is no statistical difference between the means, despite observing a numerical difference, showing that treatment T5, Quinoa substrate, it was slightly higher than the other treatments with 23.64 mm in diameter on average. While the treatment that presented the smallest stem diameter in the production of basidiocarps was the treatment T2, Wheat substrate with 19.02 mm on average (Figure 4).

From the diameter of the pileus of basidiocarps of the *Pleurotus ostreatus*, in which the measurements fluctuate between 59.21 and 74.85 mm, concluding that there was no significant statistical difference between the treatments at a confidence level of 95%, that was, the treatments had no influence on the basidiocarp pileus diameter (Figure 5). Likewise, the coefficient of variation was 23.11%, considered regular on Calzada Benza 's rating scale (Figure 5).

From the diameter of the pileus of basidiocarps of the *Pleurotus ostreatus*, in which the measurements fluctuate between 59.21 and 74.85 mm, concluding that there was no significant statistical difference between the treatments at a confidence level of 95%, that was, the treatments had no influence on the basidiocarp pileus diameter.

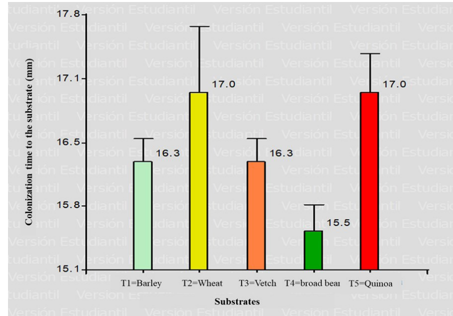

Figure 2. Comparison of means of the variable time for colonization between 15 and 19 DDI.

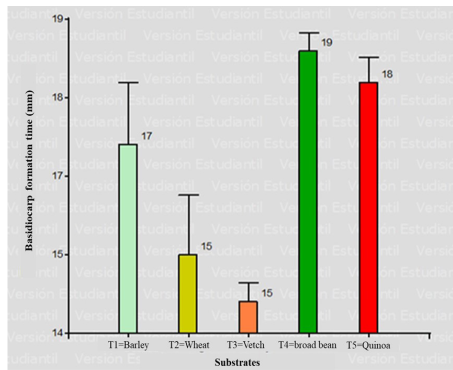

Figure 3. Comparison of means of the basidiocarp formation time variable.

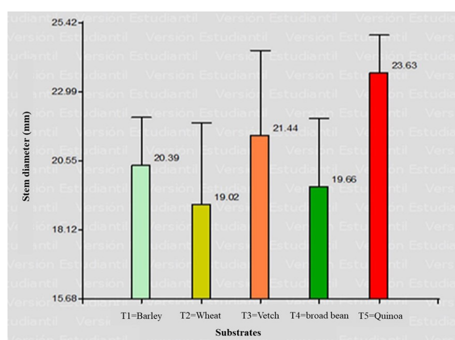

Figure 4. Comparison of means of the basidiocarp stem diameter variable.

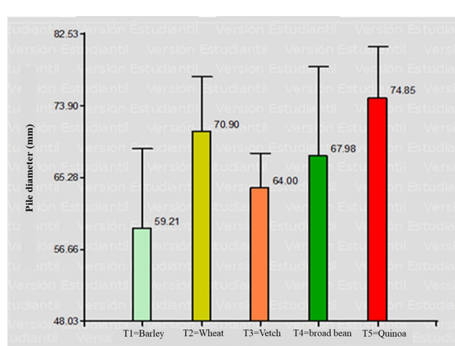

Figure 5. Comparison of means of the basidiocarp pileus diameter variable.

Likewise, the coefficient of variation was 23.11%, considered regular on Calzada Benza ‘s rating scale (Figure 5).

Tukey’s test for the variable of the mean diameter of the pileus in the basidiocarps of each treatment was appreciated, where it as evident that there was no statistical difference between the means, despite observing a numerical difference, showing that the treatment T5, substrate of quinoa, was slightly superior to the other treatments with an average diameter of 74.85 mm. While the treatment that presented the smallest diameter of the pileus in the production of basidiocarps was the treatment T1, Barley substrate with 59.21 mm on average (Figure 5).

From the length of the stem of basidiocarps of the *Pleurotus Ostreatus* where the measures that fluctuate between 59.21 and 74.85 mm. Concluding that there is no significant statistical difference between the treatments at a confidence level of 95%, that is, the treatments had no influence on the basidiocarp stem length. Likewise, the coefficient of variation was 23.11%, considered in Calzada Benza ‘s rating scale as regulated. Tukey’s test for the stem length variable in the basidiocarps of each treatment, where was evident that there was no statistical difference between the averages, despite observing a numerical difference, showing that the treatment T3, pea substrate, was lightly superior to the other treatments with 41.45 mm length on average (Figure 6). While the treatment that presented the shortest stem length in the production of basidiocarps was the treatment T1, barley substrate with 30.73 mm on average (Figure 6).

The quantity of the harvested basidiocarps of *Pleurotus Ostreatus*, fluctuate between 4.25 and 16.25 units on average. In conclusion, there was a significant statistical difference between the treatments at a confidence level of 95%, that was to say that the substrates of each treatment influenced the amount of basidiocarp at the time of harvesting. On the other hand, the coefficient of variation was 52.98%. Tukey’s test for the variable amount of basidiocarps harvested from each treatment, where it was evident that, if there is a statistical difference between the averages, showing that treatment T5, quinoa substrate was superior to the other treatments with 16.25 units harvested on average. While the treatment that presented the least amount of basidiocarps was the treatment T1=Barley Substrate with 4.25 units on average (Figure 7).

Of the weight of basidiocarps of the *Pleurotus Ostreatus* of the five treatments fluctuate between 65.04 and 168.46 grams on average. Concluding that there was no significant statistical difference between the treatments at a confidence level of 95%, that was, the treatments had no influence on the basidiocarp weight. On the other hand, the coefficient of variation was 43.64% (Figure 8). Tukey test for the variable weight of the basidiocarps of the oyster mushroom of each treatment, where it was evident that there was no statistical difference between the averages, despite observing a numerical difference, evidencing that the treatment T5, quinoa substrate, was slightly higher than the other treatments with 168.46 grams on average. While the treatment that presented the lowest weight of basidiocarps was the treatment T1, barley substrate with 65.04 grams on average.

4. Hypothesis Test Statistic: Analysis of Variance

In the analysis of variance Table 2 it was observed that in the source of treatments there was no statistical difference, this means that the substrates used did not influence the production of basidiocarps, and therefore the levels of production of the fungus were the same in all the substrates. From the analysis it was concluded that the null hypothesis is accepted, because the production averages are statistically similar.

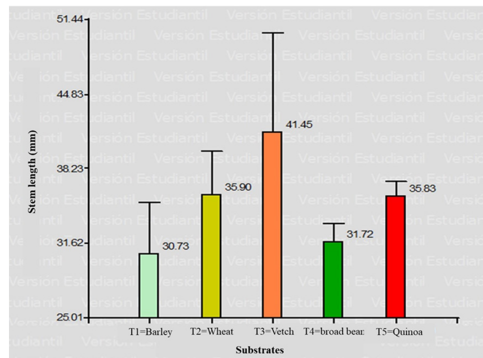

Figure 6. Comparison of means of the basidiocarp stem length variable.

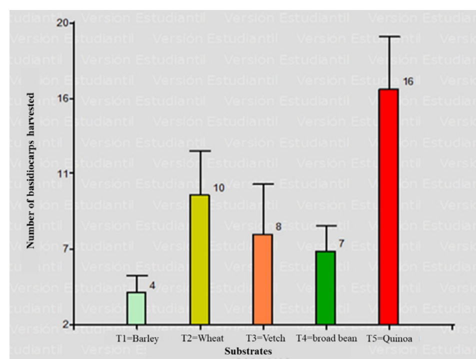

Figure 7. Comparison of means of the number of the basidiocarps harvested.

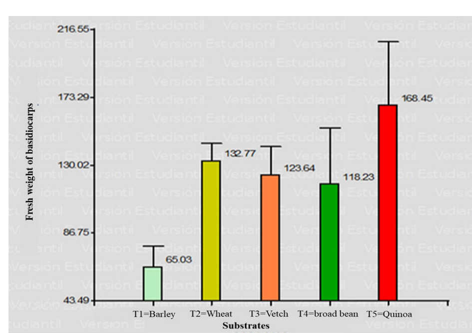

Figure 8. Comparison of means of the fresh weight of the basidiocarps

Table 2. Hypothesis test of the production of basidiocarps of the fungus *Pleurotus ostreatus* on substrates

V	SC	Gl	CM	F	p-value
Model	22140.77	4	5535.19	1.96	0.1518
Substrates	22140.77	4	5535.19	1.96	0.1518
Error	42255.46	Fifteen	2817.03		
Total	64396.22	19			

V represents the variance, SC represents the standard central limits, F represents the explained variance or unexplained variance.

4.1. Null hypothesis

Ho: Crop residues of quinoa, wheat, peas, broad beans and barley used as a substrate in the colonization and production of basidiocarps of the fungus *Pleurotus Ostreatus* do not present statistical differences. (Ho = μ1 = μ2 = μ3 = μ4 = μ5)

4.2. Alternative hypothesis

Ha: Crop residues of quinoa, wheat, peas, broad beans and barley used as a substrate in the colonization and production of basidiocarps of the fungus *Pleurotus Ostreatus* present statistical differences. (Ho = μ1 ≠ μ2 ≠ μ3 ≠ μ4 ≠ μ5).

5. Discussion

Regarding the purpose of the study, it was exposed to determine the production capacity of the fungus *Pleurotus Ostreatus*, from plant residues from different substrates composed of crop residues such as barley, wheat, quinoa, peas and broad beans. It was possible to show that all the substrates were beneficial in the productive part of the *Pleurotus fungus. Ostreatus*, with some differences between them such as colonization time, stem and crown diameter, stem length and basidiocarp weight, as shown in the results. This has a similarity with what was found by Quispe (2021) whose objective was *"Evaluate the production of the edible fungus (Pleurotus Ostreatus,), in four types of substrate, (potato substrate, barley, pine needles and sawdust) at the K'ayra Agronomic Center -San Jerónimo-Cusco"*, where he concluded to be able to evaluate both the yield, the number of basidiocarps, productivity rate and biological efficiency of the different substrates used for the production of the edible fungus (*Pleurotus Ostreatus*), evidencing that regarding the yield, the potato was the one that obtained the best result, the potato and barley (as a mixture) was the one that obtained the highest number of basidiocarps, in productivity rate, the barley stubble was the one that occupied the first place and with biological efficiency, barley was the one with the highest percentage with 139.07%. Indicate that the same between the differences could be shown that the fungus could be produced in all the substrates, but with differences.

6. Conclusions

It was possible to produce *Pleurotus basidiocarps ostreatus* in all the treatments under study under the Acobamba environmental conditions. In the determination of the variables such as time (colonization), diameter (stem, crown), length (stem) and weight (basidiocarps), there were no statistical differences between treatments, despite the fact that there was a numerical difference. The colonization time of the substrate was highest and smallest in case of quinoa and broad bean treatments respectively. In the time of formation of basidiocarps, treatment T4, broad bean substrate presents the longest time with 18.50 days on average and treatment and pea substrate the shortest time with 14.50 days, proving that pea stubble was more efficient. In the diameter of the basidiocarp stem in which quinoa substrate was slightly higher than the other treatments with 23.64 mm diameter on average and less was produced in wheat substrate with 19.02 mm. The largest crown diameter was obtained quinoa substrate and smallest diameter was observed in barley substrate with 59.21 mm on average. In the quantification of the number of basidiocarps, a statistically significant difference was observed between treatments, being in the treatment T5 in which quinoa substrate that allowed the highest production while the lowest production was presented by the treatment barley.

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