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# Influence of Mushroom Grown on Yam Peel, Palm chaff, Sawdust, and Oil Palm Empty Bunch as Poultry Feed Admixture for Broiler Chicks Growth Enhancer

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**ABSTRACT**: This study explores the viability of utilizing mushrooms (*Pleurotus ostreatus*) grown on diverse organic wastes as an economical and nutrient-rich feed for poultry production. Hence, the objective of this paper was to investigate the effect of mushroom grown on yam peel, palm chaff, sawdust, and oil palm empty bunch as poultry feed admixture for broiler chicks'growth enhancer using appropriate standard methods with thirty (30) broiler chicks on three diets for six weeks: Mushroom Poultry Feed (MPF); Commercial Poultry Feed (CPF), and Mixed Feed (MPF + CPF) respectively. Data obtained show that MPF-fed chickens exhibited a lower growth rate than chickens fed with CPF and MPF + CPF, signifying relatively less efficient weight gain. However, no significant differences were observed among feeding treatments ($p > 0.05$). The digestibility of MPF, CPF, and MPF + CPF was 81.06%, 82.93%, and 85.86% respectively, suggesting the potential of mixed feed to provide superior nutrients for growth and energy. Regarding chicken meat composition, significant differences ($p < 0.05$) were found in proximate composition, vitamins, and minerals among various feed treatments, emphasizing their interplay. However, the feed type did not significantly impact vitamin content ($p > 0.05$), highlighting variations more attributable to vitamin types than feed treatments. These findings highlight the potential of valorizing organic waste through mushroom cultivation for sustainable and economically viable poultry feed production.

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The cultivation of mushrooms on organic waste substrates aids in reducing environmental impact (Vinci *et al.*, 2023; Baptista *et al.*, 2023; Banasik *et al.*, 2019). Diverting organic waste from landfills helps mitigate greenhouse gas emissions, minimizes pollution risks, and reduces reliance on conventional feed sources, which often necessitate intensive use of fertilizers and pesticides (Nordahl *et al.*, 2023; Adewole, 2022; Meyer *et al.*, 2020; Sharma *et al.*, 2019). Various organic waste materials can be used for mushroom cultivation (Grimm *et al.*, 2021; Mahari *et al.*, 2023; Grimm and Wösten, 2018). For instance, agricultural waste, such as wheat straw, sawdust, rice straw, and sugarcane bagasse, is an abundant and low-cost source of organic waste that can be utilized for the cultivation of different mushroom species (Ab Rhaman *et al.*, 2021; Mahari *et al.*, 2020; Atila, 2019; Sadh *et al.*, 2018). Municipal solid waste is another type of organic waste that can be valorized using mushroom cultivation. Cesaro (2021) and Sharma *et al.* (2020) highlighted the potential of using municipal solid waste for mushroom cultivation, which not only reduces the waste volume but also generates income and provides employment opportunities. Furthermore, industrial waste, such as brewery waste, paper mill waste, and textile waste, can also be used as a substrate

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for mushroom cultivation (Bonato *et al.,* 2022; Kumla *et al.,* 2020). The potential for valorizing organic waste through mushroom cultivation is vast, and many other waste materials can be utilized for this purpose. For instance, the use of coffee waste as a substrate for mushroom cultivation has been investigated in several studies. Chai *et al.* (2021) and Carrasco-Cabrera *et al.* (2019) demonstrated that coffee waste could be used to cultivate oyster mushrooms, and the resulting mushroom biomass had high protein content, making it a potential source of feed for livestock. Similarly, the utilization of urban green waste for mushroom cultivation has been explored as a means of diverting this waste stream from landfills. Hu *et al.* (2022) and Mahari *et al.* (2020) investigated the use of green waste compost as a substrate for oyster mushroom cultivation and found that the resulting biomass had high nutritional value, indicating its potential for use as animal feed. The economic feasibility analysis of using waste-grown mushroom-based feed is crucial for poultry farmers (Hatvani *et al.,* 2022; Umor *et al.,* 2021). If proven cost-effective, it could increase profitability in poultry production. Additionally, this approach supports a circular economy by demonstrating the value derived from organic waste materials, creating economic opportunities in waste valorization (Pandey *et al.,* 2020; Lange *et al.,* 2020).

Hence, the objective of this paper was to investigate the effect of mushroom grown on yam peel, palm chaff, sawdust, and oil palm empty bunch as poultry feed admixture for broiler chicks' growth enhancer.

## MATERIALS AND METHODS

*Development of mushroom tissue culture:* A solution of 70% ethanol and 5% sodium hypochlorite in distilled water for sterilizing the equipment and workspace was prepared as described by Petrova *et al.* (2019). After sterilizing the workspace and equipment, the potato dextrose agar (PDA) medium used for cultivating the *Pleurotus ostreatus* was prepared and sterilized using a pressure cooker as described by Xu *et al.* (2021) and Hou *et al.* (2019). The potato dextrose agar (PDA) was prepared using 200 g of fresh, locally available potato and industrially produced agar and glucose. The potato was washed, sliced, and added to 1 liter of boiling water in a brass flask. The mixture was boiled for 15 minutes and then filtered using a piece of cheesecloth to obtain potato broth. To this broth, 20 g of glucose and 20 g of agar were added, and the volume was made up to 1 liter with water. The mixture was then sterilized in a pressure cooker for 30 minutes, and 25 ml of the resulting PDA was poured aseptically into petri dishes. The PDA was then allowed to cool before inoculation and incubation. A small piece of fresh tissue from a healthy fruiting body of *Pleurotus ostreatus* obtained from the University of Port Harcourt Demonstration Farm was collected using sterile forceps and inoculated on the PDA medium. Afterward, the inoculated culture medium was incubated in a sterile environment at a temperature range of between 20 and 25°C for a period of 10 to 14 days or until the mycelium had grown over the surface of the medium.

*Production of mushroom spawn:* The grain-based medium used for sub-culturing the *Pleurotus ostreatus* in larger amounts was prepared and sterilized as described by Xu *et al.* (2021) and Hou *et al.* (2019). Sorghum, maize, and rice grains were manually cleaned to remove debris. The cleaned grains were soaked in tap water overnight and then boiled in a stainless-steel pot. After soaking and boiling the grains were drained to remove the excess water. Next, wheat bran was added at a rate of 10% and chalk ($CaCO_3$) at a rate of 2% on a dry weight basis of the grains. The additives were mixed evenly and thoroughly with the grains. The grain-based medium was then filled into heat-resistant glass bottles, which were plugged with cotton wool and sterilized using a pressure cooker for 30 minutes. After sterilization, the bottles were allowed to cool for approximately six hours and inoculated with the mycelial culture of *Pleurotus ostreatus* that was maintained on potato dextrose agar (PDA). The inoculated bottles were then incubated at room temperature (25-28°C) and humidity levels between 70-80% for about 14-21 days, or until the mycelium fully colonized the grains inside the bottles. The bottles containing the spawns were stored in a cool, dry place until they were ready to be used for cultivating the mushroom on the organic waste materials. When the spawns were ready, they were transferred onto the organic wastes so that mushrooms could shoot out.

*Experimental design for cultivating the mushroom on waste substrates:* To determine the effect of organic waste substrates including yam peel, palm chaff, sawdust and oil palm empty bunch on the growth of *Pleurotus ostreatus*, the mushroom was cultured on different amounts and combinations of the substrates using the completely randomized block design (CRBD) shown in Table 1 (Wachira *et al.,* 2022; Prasad *et al.,* 2021). The independent variables included the type and amount of the organic waste, while the dependent variables included growth parameters such as the number of primordial formations, number of fruiting, cap diameter, height, girth, and biological efficiency of the mushroom. The cap diameter, girth, and height of the mushroom were monitored and determined using a caliper with a meter rule (Rakib *et al.,* 2020).

**Table 1:** Experimental design for cultivation of *Pleurotus ostreatus* on waste substrates

| Treatment | Label | Replications | | |
|---|---|---|---|---|
| Treatment 1 | A | A1 | A2 | A3 |
| Treatment 2 | B | B1 | B2 | B3 |
| Treatment 3 | C | C1 | C2 | C3 |
| Treatment 4 | D | D1 | D2 | D3 |
| Treatment 5 | A+B | A+B1 | A+B2 | A+B3 |
| Treatment 6 | A+C | A+C1 | A+C2 | A+C3 |
| Treatment 7 | A+D | A+D1 | A+D2 | A+D3 |
| Treatment 8 | C+B | C+B1 | C+B2 | C+B3 |
| Treatment 9 | C+D | C+D1 | C+D2 | C+D3 |
| Treatment 10 | A+B+C | A+B+C1 | A+B+C2 | A+B+C3 |
| Treatment 11 | B+C+D | B+C+D1 | B+C+D2 | B+C+D3 |
| Treatment 12 | A+B+C+D | A+B+C+D1 | A+B+C+D2 | A+B+C+D3 |

*A = Saw Dust; B = Yam Peel; C = Oil palm empty bunch; D = Palm chaff*

*Processing of mushroom into powder:* To process the oyster mushroom (*Pleurotus ostreatus*) from the different set-ups into powder form, several steps were taken as described by Aditya and Jarial (2022) and Akter *et al.* (2022). First, the fresh mushrooms were meticulously cleaned to remove any dirt or damaged areas. Next, they were blanched in hot water at 32°C for three minutes, which contained 3% salt and 0.01% citric acid. The mushrooms were then drained and dried in an oven at a temperature of 105°C for 3 hours. Once fully dried, the mushrooms were milled in the laboratory using an industrial electric blender and passed through a 60-inch mesh sieve (British Standard Screen). Finally, the resulting composite mushroom powder was packaged in a low-density polyethylene bag, labeled, and stored in a refrigerator at 4°C until needed.

*Experimental design for feeding broiler chicks:* A total of 30 one-day-old broiler chicks were randomly allocated into three (3) treatment groups, with 30 chicks per group. Each group was fed one of the three (3) experimental diets 75kg of MPF, 75kg of CPF and 75kg of the admixture (37.5kg MPF and 37.5kg CPF) as shown in Table 2 for 6 weeks, with feeding treatment 3 (FT3), a conventional commercial poultry feed, serving as the control as shown in Table 2.

**Table 2:** Experimental set-up for feeding broiler chicks for meat production

| Feeding Treatment (FT) | Code | Amount of Feed (kg) | No. of Broiler Chicks |
|---|---|---|---|
| Mushroom-based poultry feed (MPF) | FT1 | 75.0 | 10 |
| MPF: CPF (50:50) | FT2 | 75.0 (=37.5 + 37.5) | 10 |
| Commercial poultry feed (CPF) | FT3 | 75.0 | 10 |

*Preparation of mushroom-based poultry feed:* The chicken feed for each feeding treatment was prepared according to the recipe and ratio of ingredients. 75kg of MPF, 75kg of CPF and 75kg of the admixture (37.5kg MPF and 37.5kg CPF) as shown in Table 2 were used. To create the mushroom-based poultry feed, the powdered mushroom was used to formulate the poultry feed as shown in Table 3.

**Table 3:** Composition of the formulated mushroom-based poultry feed (MPF)

| S/N | Feed composition | Proportion (%) |
|---|---|---|
| 1. | Yam peel | 36.0 |
| 2. | Palm chaff | 30.0 |
| 3. | Dried mushroom | 30.0 |
| 4. | Broiler eggshell | 3.0 |
| 5. | Salt (NaCl) | 1.0 |

Formulation of the poultry feeds was carefully crafted to ensure optimal nutrition for the birds. Fresh yam peel and palm chaff were collected within and around the University of Port Harcourt main campus in Choba. After collecting the wastes, they were sun-dried, cleaned to remove debris, and powered using an electric blender. After blending, the wastes were mixed in a large container. Next, the powdered mushroom, dried powdered broiler eggshell, and salt were combined with the powdered wastes and thoroughly mixed to produce a homogeneous mixture of the mushroom-based poultry feed free of clumps or lumps. Next, samples of the prepared mushroom-based feed were collected to determine its proximate composition and bio-safety profile. Afterward, the feed was stored in a dry, cool location to prevent spoilage.

*Pasteurization of the formulated mushroom-based poultry feed:* Sterilization of the mushroom-based poultry feed was conducted using the method described by Coe *et al.* (2022) and Steghöfer *et al.* (2021). The formulated feed was sterilized through pasteurization using plantain leaves to encase the mushroom-based poultry feed in spherical forms. These plantain-wrapped feed units were subsequently enveloped in foil paper to shield against moisture and prevent any contact between the aluminium foil and the mushroom-based poultry feed. To eradicate any potentially existing bacteria and fungi organisms within the feed, they underwent a heat treatment process in an autoclave at 60°C for 30 minutes, performed twice over two days.

## RESULTS AND DISCUSSIONS

*Growth Patterns and Feed Efficiency in Broiler Chickens:* The result in Fig. 1 shows the average weight (in kilograms) of broiler chickens over six weeks across three different feeding treatments including Mushroom Poultry Feed (MPF), Commercial Poultry Feed (CPF), and a combination of both (MPF + CPF). Initially, at week 0, all treatment groups had an identical average weight of 0.05 kg. However, as the weeks progressed, we observed distinct weight patterns. Notably, the broilers fed with MPF exhibited slightly slower increase in average weight compared to those on CPF, with the MPF + CPF group displaying the highest weight. This trend was consistent throughout the six weeks. At the end of the trial, the MPF broilers weighed 2.68 kg, while the CPF broilers and MPF + CPF broilers weighed 2.82 kg and 3.58 kg respectively. The ANOVA provided a statistical analysis of the average weights of broiler chickens across different feeding treatments (MPF, CPF, and MPF + CPF) over six weeks. For the "Rows" source of variation, the p-value was very small (1.56542E-08), which was much less than the conventional alpha level of 0.05. This indicated that there were significant differences in average weights across the different weeks. For the "Columns" source of variation, the p-value was also very small (0.000790577), which was less than 0.05. This suggested that there were significant differences in average weights among the different feeding treatments (MPF, CPF, MPF + CPF). Overall, the ANOVA indicated that both time (weeks) and feeding treatment significantly influenced the average weights of broiler chickens. The observed differences were unlikely to be due to random chance and were therefore considered statistically significant.

The result in Fig. 2 shows the growth rate (in kilograms per day) of broiler chickens under the three feeding treatments. The growth rate was an important metric for assessing the rate at which the chickens were gaining weight. Across the six weeks, we observed a progressive increase in growth rate for all groups. Interestingly, the MPF broilers displayed a consistently lower growth rate compared to the CPF broilers and MPF + CPF broilers. This implied that while the MPF may have offered nutritional benefits, it might not have been as efficient in promoting rapid weight gain in broiler chickens compared to commercial feed. Notably, the growth rates tended to converge as the birds aged, indicating that the initial differences in growth rates may have diminished over time. The ANOVA provided a statistical analysis of the growth rates (in kg/day) of broiler chickens across different feeding treatments (MPF, CPF, and MPF + CPF) over six weeks. For the "Rows" source of variation, the p-value was 0.010988747, which was less than the conventional alpha level of 0.05. This indicated that there were significant differences in growth rates across the different weeks. For the "Columns" source of variation, the p-value was 0.379241168, which was greater than 0.05. This suggested that there were no significant differences in growth rates among the different feeding treatments (MPF, CPF, MPF + CPF). Overall, the ANOVA indicated that the growth rates of broiler chickens significantly varied across different weeks, but there were no significant differences in growth rates among the different feeding treatments. This implied that the growth rates were more influenced by time (weeks) rather than the specific feeding treatment.

The Feed Conversion Ratio (FCR) depicted in Fig. 3 quantified the feed's efficiency in converting into body weight gained by the broilers. A lower FCR indicated a more efficient conversion. Across the six weeks, we observed that the FCR tended to increase, which was expected as the birds grew and required more feed for maintenance and growth. Interestingly, the FCR values for the MPF broilers were consistently higher compared to the CPF broilers and MPF + CPF broilers. This suggested that the MPF may not have been as efficient in terms of feed conversion, potentially indicating that more feed was required to achieve the same level of weight gain compared to the commercial feed. The ANOVA provided a statistical analysis of the feed conversion ratios (FCR) of broiler chickens across different feeding treatments (MPF, CPF, and MPF + CPF) over six weeks. For the "Rows" source of variation, the p-value was very small (8.04632E-08), which was much less than the conventional alpha level of 0.05. This indicated that there were significant differences in FCR across the different weeks. For the "Columns" source of variation, the p-value was also very small (5.34716E-05), which was less than 0.05. This suggested that there were significant differences in FCR among the different feeding treatments (MPF, CPF, MPF + CPF). Overall, the ANOVA indicated that both time (weeks) and feeding treatment significantly influenced the feed conversion ratios of broiler chickens.

The observed differences were unlikely to be due to random chance and were therefore considered statistically significant.

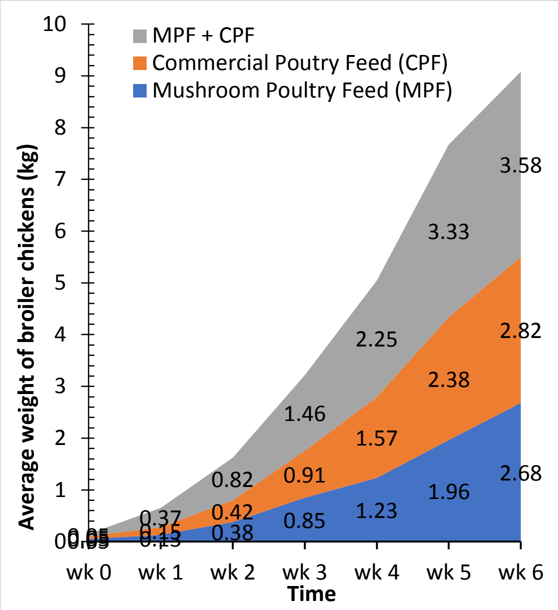


**Fig. 1**: Temporal dynamics of chicken weights in the feeding treatments

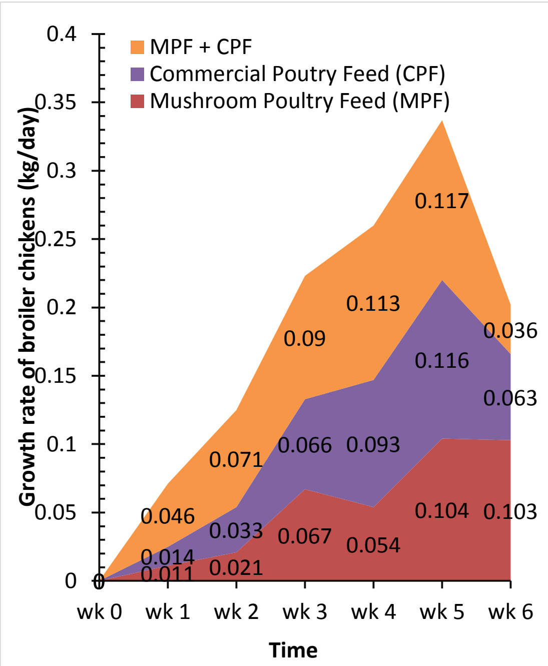


**Fig. 2**: Temporal dynamics of chicken growth rates in the feeding treatments

The findings above, concerning the growth patterns and feed efficiency of broiler chickens, yielded valuable insights. The analysis of average weights over six weeks revealed distinct growth patterns across feeding treatments. Broilers fed with Mushroom Poultry Feed (MPF) exhibited slightly slower growth compared to those on the mixed feed (MPF + CPF group), while the Commercial Poultry Feed (CPF) group, showed intermediate growth. Furthermore, examining growth rates, we observed a progressive increase for all groups over six weeks. Notably, MPF-fed broilers displayed a consistently lower growth rate compared to CPF-fed broilers and those on a combined diet.

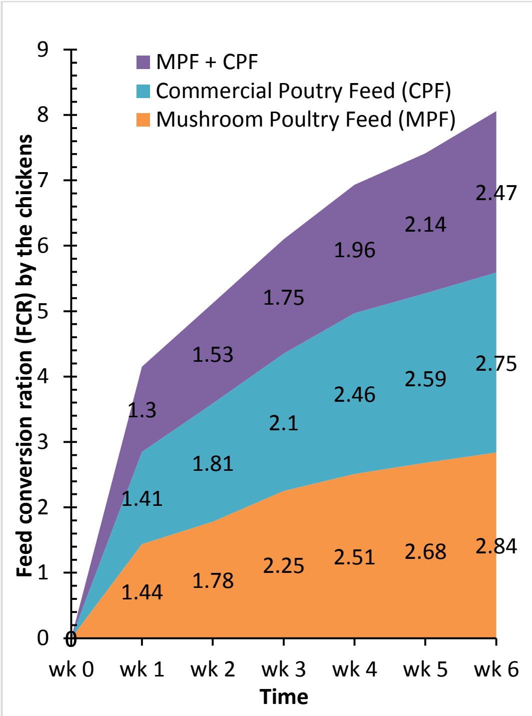


**Fig. 3**: Temporal dynamics of FCR by chickens in the feeding treatments

This suggested that while MPF offered nutritional benefits, it may not have been as efficient in promoting rapid weight gain in broiler chickens compared to the commercial feed and the mixed feed. This consistent trend indicated that feeding treatment significantly influenced broiler growth in terms of weight gain over time. Moreover, analysis of the Feed Conversion Ratio (FCR) revealed important information about feed efficiency. The consistently higher FCR values for MPF-fed broilers compared to CPF-fed broilers and the combined group implied that more feed may have been required to achieve the same level of weight gain with MPF. This indicated a potential difference in feed conversion efficiency. Overall, these results emphasize the significance of both feeding treatment and time in influencing broiler growth dynamics and feed efficiency. The observed differences were statistically significant and not likely due to random chance. These findings are crucial for making informed decisions regarding broiler feeding strategies.

Some studies including Berger et *al.* (2021), Kumar *et al.* (2021), and Aftab *et al.* (2018) support our findings regarding the significantly positive influence of feeding treatment and time on broiler growth patterns and feed efficiency, emphasizing the importance of considering both factors in poultry farming. However, other studies provide alternative perspectives on the relationship between feeding treatment and broiler growth, suggesting potential areas for further investigation. For example, a study by Fesseha *et al.* (2021) demonstrated significant positive effects of probiotics on the growth patterns and feed efficiency of broiler chickens. In addition, the findings of Atela *et al.* (2019) showed that a multi-strain probiotic administered via drinking water enhances feed conversion efficiency in indigenous chickens. Moreover, Cardinal *et al.* (2019) showed that an antibiotic growth-promoting diet significantly enhanced the rate of feed intake, weight gain, and feed conversion of broiler chickens. While our study identified distinct growth patterns in broiler chickens fed with different treatments, it's important to consider potential interactions between feed composition, genetic factors, and environmental conditions that may have contributed to these patterns.

*Nexus between Growth Patterns and Feed Efficiency in the Chickens:* The correlation coefficients between the growth parameters provided valuable insights into the relationships among these key indicators in broiler chickens fed with different treatments (Figure 4). For the broiler chickens fed with the mushroom poultry feed (MPF Broiler Chickens), there was a very strong positive correlation (0.9443) between average weight and growth rate. This implied that as the average weight of the broiler chicks increased, their growth rate also increased. This was an expected and positive relationship, indicating that heavier chicks tended to grow faster. Similarly, there was a strong positive correlation (0.8034) between average weight and feed conversion ratio (FCR). This suggested that as the average weight of the broiler chicks increased, their feed conversion ratio also increased. While this may have seemed counterintuitive, it implied that heavier birds may have required more feed to achieve the same level of growth. Furthermore, there was a very strong positive correlation (0.8605) between growth rate and feed conversion ratio.

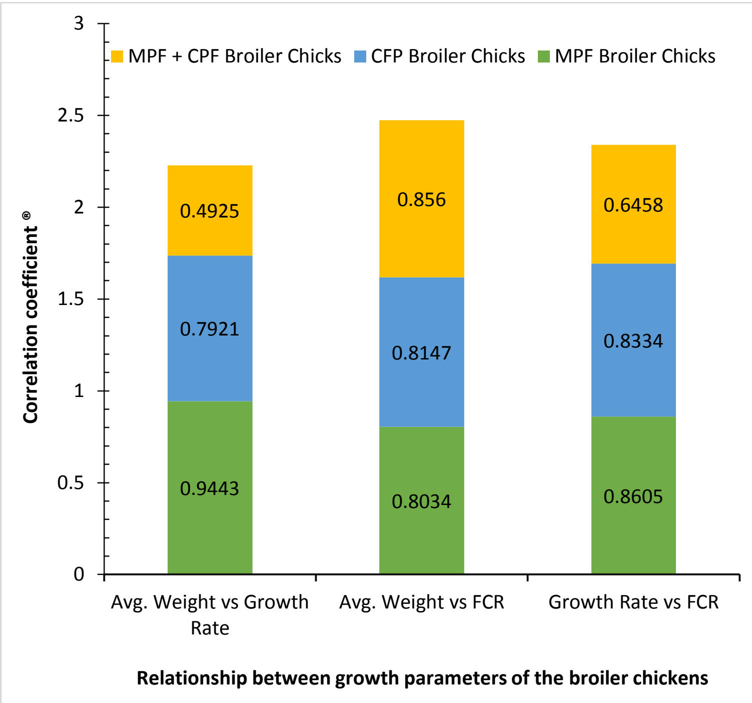


**Fig. 4:** Nexus between growth parameters of chickens in the feeding treatments

This indicated that broiler chickens with higher growth rates tended to have higher feed conversion ratios. It implied that birds with rapid growth rates may have required more feed to sustain that growth (Fig. 4.). For the broiler chickens fed with the mushroom poultry feed and the commercial poultry feed (CPF Broiler Chickens), there was a strong positive correlation (0.7921) between average weight and growth rate. Similar to the MPF group, this suggested that as the average weight of the broiler chicks increased, their growth rate also increased. Similarly, there was a strong positive correlation (0.8147) between average weight and feed conversion ratio (FCR). Again, this indicated that as the average weight of the broiler chicks increased, their feed conversion ratio also increased. Furthermore, there was a very strong positive correlation (0.8334) between growth rate and feed conversion ratio. Similar to the MPF group, this implied that broiler chickens with higher growth rates tended to have higher feed conversion ratios (Fig. 4).

For the broiler chickens fed with the mushroom poultry feed and the mixed poultry feed (MPF + CPF Broiler Chickens), there was a moderate positive correlation (0.4925) between average weight and growth rate. This suggested that the relationship between average weight and growth rate was not as strong in the MPF + CPF group compared to the other two groups. However, there was a very strong positive correlation (0.856) between average weight and feed conversion ratio (FCR). This implied that as the average weight of the broiler chicks increased, their feed conversion ratio also increased. This correlation was even stronger in this group compared to the other two. Moreover, there was a moderate positive correlation (0.6458) between growth rate and feed conversion ratio. This implied that broiler chickens with higher growth rates tended to have higher feed conversion ratios, but the relationship was not as strong as in the other two groups (Fig. 4.).

Overall, these correlations (Fig. 4.) highlighted the complex interplay between growth parameters and feed efficiency in broiler chickens. They emphasized the need for a balanced approach when formulating diets, considering factors like feed type and bird weight to optimize growth dynamics and feed utilization in poultry production. Our observations on the correlations between growth parameters in broiler chickens fed with different treatments are consistent with the findings of Li *et al.* (2020), Prakash *et al.* (2020), and Yi *et al.* (2018), indicating strong associations between average weight, growth rate, and feed conversion ratio. However, the findings from the study of Chen *et al.* (2021), Marchesi *et al.* (2021), and Shah *et al.* (2019) introduce additional considerations for understanding the genetic architecture and host-microbiome interaction of these relationships, potentially complementing our findings.

*Conclusions:* Cultivating *Pleurotus ostreatus* on different primary waste substrates resulted in mushrooms with varying nutritional profiles. These findings hold paramount importance for leveraging waste-grown mushrooms as a potent dietary component, particularly in poultry farming, where specific nutrient content is pivotal for broiler chick development. The MPF demonstrated a favorable nutritional profile for poultry farming, but adjustments are recommended to align it with established standards. The biosafety results provide confidence in the suitability of the pasteurized MPF for poultry consumption. The study demonstrated that the mixed feed (MPF + CPF) provided enhanced growth dynamics and feed efficiency in broiler chickens, potentially leading to higher profitability for poultry farmers. These findings hold practical implications for both producers and consumers, providing a basis for informed feed selection to enhance the nutritional quality of poultry products.

*Declaration of Conflict of Interest:* The authors declare no conflict of interest.

*Data Availability Statement:* Data are available upon request from the first author or corresponding author.

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