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Effect of mushroom (*Agaricus bisporus*) waste in place of deoiled rice bran on production performance, egg quality and nutrient utilization in Rhode Island Red laying hens

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Abstract
A feeding experiment was planned to investigate the effect of mushroom (*Agaricus bisporus*) waste in place of deoiled rice bran on production performance, egg quality and nutrient utilization in Rhode Island Red laying hens. 12 weeks duration feeding trial was conducted on seventy-two, 28 week old laying chickens i.e., 18 birds per treatment having three replicates of 6 birds each. Hens of T_1 (control) group were fed with basal diet containing deoiled rice bran as one of the feed ingredients, whereas in treatment groups T_2, T_3 and T_4, deoiled rice bran was replaced with mushroom waste at 1.5%, 4%and 5%, respectively. The laying hens' performance was assessed by recording weekly average feed intake, daily egg production, feed conversion ratio and feed cost of egg production. Results showed that the overall average egg production was found significantly ($p \leq 0.05$) higher in treatment groups T_3 and T_4 than control group. The egg quality parameters in terms of yolk cholesterol and triglycerides were significantly ($p<0.05$) reduced in T_3 and T_4 groups as compared to T_1 and T_2 groups. Nutrient utilization in terms of DM, CP, EE & OM utilization showed significant ($p<0.05$) improvement in T_3 and T_4 as compared to $T_1$and T_2 groups. The feed cost/ dozen eggs was significantly lowered in T_3 and T_4 as compared to T_1. Conclusion is that mushroom (*Agaricus bisporus*) waste in place of deoiled rice bran can be replaced @ 4% in diet of RIR laying hens without any adverse effect on performance and is beneficial for improving egg quality and nutrient utilization.

Keywords: Egg production, mushroom waste, nutrient utilization, Rhode Island red

1. Introduction

India's poultry sector in the past 20 years has undergone a major statistical progress as well as a full transformation of its entire structure and operation. In 2022, the Indian poultry market had grown to a size of USD 28.18 billion. The total poultry population in India is 851.81 million which is increased up by 16.81% from last census (Livestock Census, 2019) [14]. The egg production in India is 129.60 billion eggs per year which is 3rd in world egg production. About 65-75% of poultry production expenses accounts to poultry feeding. There is an urgent need to look for novel alternative protein feedstuffs and to investigate how effective they are for feeding poultry in order to lower the cost of poultry production.

Mushrooms have natural advantages in terms of their dietary superiority over the rest of the vegetarian diet: (a) good protein content (20%-30% of dry matter) with all the essential amino acids, making them capable of substituting for meat; (b) chitinous wall to act as a source of dietary fiber. (c) high vitamin B content; (d) low fat content; and (e) virtually no cholesterol (Khan *et al.*, 2018) [10]. Mushrooms have been reported to have many useful functions including antitumor, anticancer, antihypertensive, cholesterol lowering effect, antioxidant properties, anti-inflammatory, immune-modulatory function, as well as anti-bacterial, antiviral and antifungal activities on human and animal health (Brugnari *et al.*, 2018) [6]. The presence of essential nutrients in mushrooms which are nutritional requirements of poultry, implies mushrooms could be utilized in diet to improve growth performance and health of poultry. Presently, researchers have become interested in the role of mushrooms in poultry production systems (Mahfuz *et al.*, 2019) [16]. A very good supply of protein, readily usable energy, essential amino acids like methionine (Tang *et al*., 2016) [22] and bioactive compounds with therapeutic potential can be found in mushroom waste.

The fungus *Agaricus bisporus* popularly called button mushroom is indigenous to grasslands in North America and Europe. It contains high levels of dietary fibre, antioxidants, vitamins like thiamine, ascorbic acid, and vitamin D2, as well as minerals and ergothioneine (ET) and polyphenols. It has immunomodulating, antioxidant, anti-cancer, anticholesterolemic, antiglycemic, anti-inflammatory and anti-microbial properties. Likewise, tyrosinase and ergothioneine have been extracted from *Agaricus bisporus* mushroom, which has made this mushroom worth considering more for nutritional and medicinal purposes (Usman *et al.*, 2021) [23].

The quality of deoiled rice bran sold in local markets is questioned, in order to keep the price low, sawdust and rice husk are frequently added. The need for alternate feed materials to replace deoiled rice bran in poultry diets has increased, therefore, mushroom waste can be employed in place of deoiled rice bran. Hence, the alternative use of agro-industry as feedstuffs in animal feeding industry represents an important source of protein, vitamins, minerals and antioxidants (Roy and Fahim, 2019; Mutlag *et al.*, 2017) [18, 17]. In addition, mushroom also have different types of essential amino acids (Smiderle *et al*., 2007; Kim *et al.*, 2009) [20, 11]. Numerous mushrooms were found to contain vitamin E and selenium, which can act as antioxidants (Bederska *et al.*, 2017) [4]. Nearly no work had been done on replacing deoiled rice bran with mushroom waste, therefore this study was carried out to evaluate the effect of replacing deoiled rice bran with mushroom (*Agaricus bisporus*) waste on feed intake, egg production, nutrient utilization and economics of egg production of Rhode Island Red laying hens.

2. Materials and Methods

The present experiment was conducted at Instructional Poultry Farm of the GBPUA&T, Pantnagar, Uttarakhand after approval of IAEC. Total 72 laying hens which were 28 weeks old were used for 12weeks in the study. The chemical composition of mushroom (*Agaricus bisporus*) waste and deoiled rice bran were found comparable and is presented in Table 1.

Table 1: Chemical composition of mushroom (*Agaricus bisporus*) waste and deoiled rice bran (% dry matter basis)

Particulars	Mushroom waste	Deoiled rice bran
Crude protein	12.75	13.00
Ether extract	2.71	1.22
Crude fibre	10.90	10.25
Total ash	11.50	13.21
Nitrogen free extract	62.14	62.32

All of the laying hens were divided into four treatment groups, each of which had three replicates and each of which contained six hens. Completely randomized design (CRD) was employed for study. Four treatments were, control (T_1): basal diet, (T_2): Incorporation of 1.5% mushroom waste by replacing deoiled rice bran in basal diet, (T_3): Incorporation of 4% mushroom waste by replacing deoiled rice bran in basal diet, (T_4): Incorporation of 5% mushroom waste by replacing deoiled rice bran in basal diet. The experimental layers were housed in deep litter with a 16-hour lighting facility. *Ad-libitum* water was provided and feed was offered every morning at 8:00 am. Four experimental diets for laying birds were prepared as specification recommendations of BIS (2007) [5]. The AOAC (2003) [3] technique was used for the proximate analysis of the experimental diet. The nutrient composition of ingredients of different diets that was used in the experiment for laying birds are shown in the table 2.

Table 2: Part composition of diets of different treatment groups (kg/100 kg)

Ingredients	T_1	T_2	T_3	T_4
Yellow Maize	57	57	57	57
Deoiled Rice bran	6.5	5	2.5	1.5
Rice polish	4.5	4.5	4.5	4.5
Mushroom waste powder	-	1.5	4	5
Groundnut cake-solvent extracted	09	09	09	09
Soyabean meal	18	18	18	18
Marble powder	03	03	03	03
Dicalcium Phosphate	01	01	01	01
DL- methionine	0.15	0.15	0.15	0.15
Choline Chloride	0.10	0.10	0.10	0.10
Mineral mixture	0.10	0.10	0.10	0.10
Common salt	0.40	0.40	0.40	0.40
Hepatocare	0.10	0.10	0.10	0.10
Vitamin Premix	0.10	0.10	0.10	0.10
Toxin binder	0.05	0.05	0.05	0.05
Total	100	100	100	100

Daily feed intake was recorded and residual feed have been noted weekly in replicates. For various treatment groups, the management conditions were similar**.** For a period of 12 weeks, eggs were collected twice daily in the morning and evening and recorded replicate wise. At the ending of the feeding trial, a metabolic trial involving six birds from each treatment was carried out for a period of seven days in the present study to assess the nutrient utilization. In this seven-day trial period, four days were regarded as the adaption phase, followed by three days for collection. Utilizing the actual purchase prices of the feed components employed in the experimental feed formulation, the cost of feed was calculated. Daily observations were used to compute the average dozen egg output.

The experimental data obtained were analysed statistically (Snedecor and Cochran, 1994) [21] by using general linear model procedure. Difference between treatments means were compared using Tukey's Multiple Range Test. Statistical significance was declared at $p\leq 0.05$.

3. Results & discussions

3.1 Production performance

The overall egg production, feed intake and feed conversion ratio in Rhode Island Red laying hens fed diet containing mushroom (*Agaricus bisporus*) waste in place of deoiled rice bran during entire experimental period are presented in Table 3. The laying hens did not show any significant difference ($p\geq0.05$) in the daily feed intake and FCR during the overall period (28-40weeks) among different treatment groups T_1, T_2, T_3 and T_4, however, the overall egg production T_3 and T_4 differ significantly ($p<0.05$) with T_1, although between T_3 and T_4 groups non-significant difference was recorded. The above findings were in agreement to Hwang *et al.* (2012) [9] who showed that when shiitake mushroom fed to layers, egg production was increased significantly ($p\leq0.05$) in treatment group as compared to control group, whereas feed intake and FCR were non-significant. Mahfuz *et al.* (2018) [15] who fed mushroom *Flammulina veluptis,* reported no significant difference ($p\geq0.05$) in feed intake in the entire experimental period in layers. The results reported by Lee *et al.* (2015) [13]

also showed no significant difference ($p \geq 0.05$) in feed intake in the overall experimental period in laying hens fed mushroom (*Pleurotus eryngii*) stalk residue. Yang *et al.* (2021) [26] found that the feed conversion ratios had no significant change ($p \geq 0.05$) in layers fed diet supplemented with mushroom (*Agaricus bisporus*) waste. It may be interpreted from table that feeding (*Agaricus bisporus*) waste did not have any effect on feed intake, as very little variation in feed intake in layers observed at this stage of laying, whereas overall egg production improved due to mushroom waste incorporation in diet of laying hens.

Table 3: Production performance of Rhode Island Red laying hens from 28-40 weeks fed diet incorporated with mushroom (*Agaricus bisporus*) waste

Period (28-40weeks)	Treatments				P-value
	T1	T2	T3	T4	
	Basal diet(control)	Diet containing 1.5%mushroom waste	Diet containing 4% mushroom waste	Diet containing 5%mushroom waste	
Feed intake(g)	120.39±0.30	120.35±0.12	119.95±0.03	120.26±0.16	0.944
Egg production(%)	62.50^a±0.33	63.49^{ab}±0.90	65.81^b±0.71	65.27^b±0.37	0.049
FCR (kg/dozen egg)	2.32±0.84	2.28±0.98	2.19±0.11	2.22±0.11	0.373
FCR(per kg egg mass)	3.47±0.11	3.45±0.14	3.22±0.17	3.28±0.16	0.462

a and b mean values bearing different superscripts in a row differ significantly, ($p \leq 0.05$)

3.2 Egg quality parameters

3.2.1 Egg albumen quality

The average values of albumen height, albumen weight, albumen percentage and Haugh unit are presented in Table 4. There was no significant difference ($P \geq 0.05$) in albumen quality among the different treatment groups. The present findings are in agreement Kim *et al.* (2014) [12] who showed non-significant difference ($p \geq 0.05$) among the treatments Haugh unit in layers.

Table 4: Average values of albumin quality and Haugh unit of Rhode Island Red laying hens fed diets incorporated with mushroom (*Agaricus bisporus*) waste by replacing deoiled rice bran

Parameters	Treatments				P-value
	T1	T2	T3	T4	
	(Basal diet)	(Basal diet containing 1.5% mushroom waste)	(Basal diet containing 4% mushroom waste)	(Basal diet containing 5% mushroom waste)	
Albumen height (mm)	6.60±0.10	6.63±0.02	6.70±0.28	6.68±0.44	0.607
Albumen weight (gm)	32.85±0.19	33.56±0.11	33.56±0.17	33.72±0.44	0.058
Albumen weight (%)	59.36±0.33	59.34±0.25	59.09±0.06	59.78±0.25	0.319
Haugh unit	83.13±0.07	82.68±0.13	82.47±0.06	82.56±0.25	0.059

3.2.2 Egg yolk quality

The average values of egg yolk quality of Rhode Island Red layers in terms of egg yolk weight, yolk weight percent, yolk index, yolk colour, egg yolk cholesterol and yolk triglyceride during the metabolic trial period when fed diet incorporated with mushroom (*Agaricus bisporus*) waste replaced by deoiled rice bran is presented in Table 3. Egg yolk quality in terms of egg yolk weight, yolk weight percent, yolk index and yolk colour showed no significant difference whereas in terms of yolk cholesterol and yolk triglyceride it differs significantly ($p<0.05$) among different treatment groups with significant decrease in T_3 and T_4 as compared to T_1 and T_2 groups, although T_3 and T_4 differed non-significantly. The present findings are in accordance with reports by Wang *et al*. (2015) [25] claimed that groups which were supplemented with 10.0 and 20.0g/kg dried mushroom *Cordyceps militaris* waster medium showed significantly decreased egg cholesterol compared to the control group at 9-12 weeks but non-significant difference in yolk weight, yolk index and yolk colour. Similarly, Lee *et al.* (2015) [13] reported eggs' cholesterol content of the 1.0% and 2.0% *Pleurotus eryngii* stalk residue (PESR) groups was significantly lower than that of the control group at 5-8 weeks. Similarly, dietary inclusion of *Flammulina velutipes* mushroom stem waste at a level of 4% enhanced the egg quality of laying hens (Chen *et al.*, 2020) [7]. (Wang *et al.*, 2019) [25] experiment demonstrated that *Flammulina velutipes* stem base had increased hens egg quality under heat stress. The reason for above findings may be that *Agaricus bisporus* have statins (lovastatins) that normalize the plasma triglyceride and cholesterol levels, (Elkichaoui, 2016) [8]. These results suggest that mushroom in diet of laying hens may affect lipid synthesis as well as decreased cholesterol content in eggs. The average values of egg yolk quality of Rhode Island Red laying hens fed diets incorporated with mushroom (*Agaricus bisporus*) waste by replacing deoiled rice bran are presented in table 5.

Table 5: Average values of egg yolk quality of Rhode Island Red laying hens fed diets incorporated with mushroom (*Agaricus bisporus*) waste by replacing deoiled rice bran

Parameters	Treatments				P-value
	T1	T2	T3	T4	
	Basal diet (control)	Basal diet containing 1.5% mushroom waste	Basal diet containing 4% mushroom waste	Basal diet containing 5% mushroom waste	
Yolk weight (gm)	17.22±0.16	17.12±0.18	17.42±0.09	17.16±0.22	0.637
Yolk weight (%)	31.12±0.26	31.09±0.26	30.66±0.12	30.35±0.45	0.356
Yolk index (%)	43.82±0.30	43.39±0.56	43.77±0.11	43.14±0.79	0.762
Yolk colour	4.83±0.22	5.06±0.11	4.81±0.04	4.94±0.31	0.790
Yolk cholesterol (mg/g)	14.43^a±0.09	14.43^a±0.25	13.60^b±0.41	13.56^b±0.15	0.048
Yolk triglyceride (mg/g)	203.61^b±0.12	202.30^{ab}±0.66	200.40^a±1.47	199.29^a±0.70	0.034

a and b mean values bearing different superscripts in a row differ significantly, *($p \leq 0.05$)

3.3 Nutrient utilization

The average values of nutrient utilization of Rhode Island Red layers in terms of dry matter, crude protein, ether extract and organic matter during the metabolic trial period when fed diet incorporated with mushroom (*Agaricus bisporus*) waste replaced by deoiled rice bran is presented in Table 6. Nutrient utilization in terms of dry matter, crude protein, ether extract and organic matter utilization differ significantly (P<0.05) among different treatment groups with significant improvement in T_3 and T_4 as compared to T_1 and T_2 groups, although T_3 and T_4 differed non-significantly. The findings in harmony with that of Yang *et al.* (2021) [26] reported CP digestibility for hens treated with (*Agaricus bisporus*) stem residue diet was prominently higher than those in the control treatment as the result differs significantly ($p \leq 0.05$). Abro *et al.* (2016) [1] reported significant difference ($p \leq 0.05$) in digestibility of ether extract, organic matter and crude protein when mushroom (*Pleurotus ostreatus*) fed to broiler chickens. Shang *et al.* (2016) [19] similarly reported crude protein digestibility of broiler chicken significantly ($p \leq 0.01$) improved by feeding *Hericium caput-medusae* mushroom. The reason for above findings may be that the protein (high in amino acids such as methionine) and carbohydrate in mushroom are more easily absorbed by birds, resulting in the improvement of nutrient digestibility.

Table 6: Nutrient utilization (%) in Rhode Island Red laying hens fed diets incorporated with mushroom (*Agaricus bisporus*) waste

Particulars	Treatments				P-value
	T_1	T_2	T_3	T_4	
	Basal diet(control)	Diet containing 1.5%mushroom waste	Diet containing 4% mushroom waste	Diet containing 5% mushroom waste	
Dry Matter	$68.04^{a}\pm1.05$	$70.86^{ab}\pm0.90$	$73.50^{b}\pm0.31$	$72.82^{b}\pm0.28$	0.039
Crude Protein	$80.11^{a}\pm0.59$	$82.79^{ab}\pm0.53$	$84.40^{b}\pm0.12$	$84.18^{b}\pm0.44$	0.048
Ether Extract	$80.65^{a}\pm0.63$	$81.08^{a}\pm0.49$	$84.48^{b}\pm0.33$	$83.97^{b}\pm0.46$	0.029
Organic Matter	$71.39^{a}\pm0.94$	$73.96^{ab}\pm0.92$	$76.15^{b}\pm0.35$	$75.64^{b}\pm0.87$	0.043

a and b mean values bearing different superscripts in a row differ significantly, ($p \leq 0.05$)

3.4 Economics of egg production

The average values of economics of egg production in terms of feed cost per dozen eggs during the entire experimental period (28-40 weeks) in which laying hens were fed mushroom (*Agaricus bisporus*) waste in place of deoiled rice bran is presented in Table 7. The highest feed cost/dozen egg (Rs) in laying hens was in T_1 (61.94 Rs) the control group whereas the lowest was in T_3 (57.36 Rs) the group containing 4% mushroom (*Agaricus bisporus*) waste by replacing deoiled rice bran. The research findings are comparable with that of Adentunji and Adejumo (2019) [2] who reported that mushroom (*Pleurotus sajor-caju*) waste is cost effective in broiler chicks.

Table 7: Economics of egg production of Rhode Island Red laying hens fed diets incorporated with mushroom (*Agaricus bisporus*) waste

Parameters	Treatments				P-value
	T_1	T_2	T_3	T_4	
	Basal diet(control)	Diet containing 1.5% mushroom waste	Diet containing 4%mushroom waste	Diet containing 5%mush room waste	
Average dozen egg	4.37±0.049	4.44±0.02	4.60±0.01	4.65±0.09	0.064
Cost /kg feed (Rs)	25	24.79	24.45	24.32	
Average feed intake(kg)	10.84±0.02	10.82±0.01	10.79±0.03	10.82±0.02	0.246
Total feed cost (Rs.)	$270.83^{c}\pm0.42$	$268.39^{b}\pm0.33$	$263.89^{a}\pm0.08$	$263.21^{a}\pm0.40$	0.001
Feed cost/dozen egg (Rs.)	$61.94^{b}\pm0.77$	$60.42^{ab}\pm0.37$	$57.36^{a}\pm0.17$	$57.75^{a}\pm1.12$	0.005

a, b and c mean values bearing different superscripts in a row differ significantly, ($p \leq 0.05$)

4. Conclusion

From the above findings, it can be concluded that mushroom (*Agaricus bisporus*) waste in place of deoiled rice bran can be replaced @ 4% in diet of Rhode Island Red laying hens without any adverse effect on performance and is beneficial for improving egg production and nutrient utilization. Also, mushroom waste @ 4% may be used as cheaper source of alternative feedstuff in layers.

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6. Conflict of Interest

Not available.

7. Financial Support

Not available.

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