

Effect of fermented rice bran and chitosan on duck livestock productivity

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ABSTRACT

This study examined how adding fermented rice bran and chitosan to duck diets affects hematological profiles, blood cholesterol, egg cholesterol, enzyme activity, and fatty acid content in duck meat and eggs. The research employed an experimental design with a Completely Randomized Design (CRD) with four treatments: R0 = 45% corn + 35% concentrate + 20% unfermented rice bran; R1 = 45% corn + 35% concentrate + 20% fermented rice bran; R2 = 45% corn + 35% concentrate + 19.5% fermented rice bran + 0.5% chitosan; R3 = 45% corn + 35% concentrate + 17.5% fermented rice bran + 2.5% chitosan, with five replications. The results showed that fermented rice bran and chitosan increased hematocrit levels, hemoglobin, erythrocyte, and leukocyte counts. They also affected blood glucose and cholesterol levels, meat cholesterol, and eggs from Tegal ducks. Some treatments significantly reduced cholesterol. Additionally, treatments influenced enzyme activity; R3 exhibited increased amylase and protease activity and decreased lipase activity. Blood glucose levels decreased in treatments R2 and R3, and blood cholesterol levels were reduced in R2, with specific treatments showing significant reductions. The combined use of fermented rice bran and chitosan impacted the fatty acid composition of duck eggs and meat. Overall, this study demonstrates that incorporating fermented rice bran and chitosan into duck diets can improve health parameters and enhance the quality of duck products.

Introduction

Food health and food security are the main priorities in efforts to enhance public welfare. Duck eggs, an important protein source for the health of the Indonesian people, require further research to boost their functional value. Besides being a popular food ingredient, duck eggs are also believed to have therapeutic benefits in some communities (Manin et al., 2024). The high fat and cholesterol levels in duck eggs have become a barrier to acceptance by modern consumers. The egg yolk contains about 65% complex lipoprotein. Egg yolk lipids comprise 70-75% triglycerides, 20-25% phospholipids, and 40% cholesterol. Duck's cholesterol levels are higher than chickens (Nisa et al., 2017). Efforts to improve the quality of duck eggs are common. Various studies reported by Artonang et al. (2024) and Adriani et al. (2024) indicate that adding fermented rice bran and chitosan to duck feed can reduce egg fat and cholesterol levels. Additionally, it can boost the content of unsaturated fatty acids, which is vital for enhancing the nutritional quality of duck eggs and meat. The study's results (Sahara et al., 2016) showed that bran fermentation with an inoculum volume of 7 ml and a fermentation duration of 3 days yielded 13 types of unsaturated fatty acids and omega-3.

Rice bran is a by-product of rice milling, obtained from the outermost layer of rice, specifically between the rice grains and the brown rice husk (Sukma, 2010). Rice bran contains many nutrients, including 36.9% carbohydrates, 11.54% protein, 9.89% fiber, 3.82% fat, and 5.88 mg of vitamin B15 (Hidayah et al., 2024). The benefits of vitamin B15 include lowering blood cholesterol levels and supporting protein synthesis (Hidayati, 2016). Fermented rice bran has been shown to increase levels of unsaturated fatty acids (Yosi et al, 2014; Sahara, 2019), while chitosan can bind fat and cholesterol in the digestive tract (Hasri, 2010; Muhammad et al., 2023).

Consuming unsaturated fatty acids decreases triacylglycerol circulation in poultry and limits lipid availability for egg yolk formation (Loh et al., 2007). Therefore, this study explores how fermented rice bran and

chitosan in duck diets impact hematological profiles, blood and egg cholesterol levels, enzyme activities, and fatty acid content in duck meat and eggs.

Studying the effects of these treatments can offer valuable insights into developing healthier and more nutritious functional duck egg products, as well as supporting food security and public health overall. The research aimed to enhance the quality of duck livestock products, such as meat and eggs.

Materials and methods

Research design

This study employed an experimental design with a Completely Randomized Design (CRD) featuring four treatments and five replications. Each replication consisted of two ducks serving as an experimental unit. The study involved 40 adult female Tegal ducks. The current study included:

R0= 45% corn + 35% concentrate + 20% unfermented rice bran.

R1= 45% corn + 35% concentrate + 20% fermented rice bran.

R2= 45% corn + 35% concentrate + 19.5% fermented rice bran + 0.5% chitosan.

R3= 45% corn + 35% concentrate + 17.5% fermented rice bran + 2.5% chitosan.

The ducks were given a basic ration for one week and continued for the first 4 weeks. Treatment rations were given at the beginning of week 5 (Table 1). Drinking water was provided ad libitum

Preparation of the cage and duck maintenance

The cage was cleaned, whitewashed, and disinfected. The ducks received sugar water during the first four hours. Ankle bracelets were put on as markers. Drinking water was supplied twice a day. Maintenance was

Table 1. Chemical Content (%) of Research Rations.

Treatment	Water*	Ash*	fat*	Protein*	Crude fiber*	ADF**	Crude fiber**	Lignin**	GE**	Ca**	P**
R0	10.25	15.15	4.46	13.6	3.77	15.39	8.91	5.52	3524	2.27	0.62
R1	10.96	16.63	2.98	14.88	4.43	15.52	7.42	7.1	3697	2.59	0.70
R2	9.3	18.54	8.61	15.82	4.81	17.27	0.21	15.88	4036	3.44	0.84
R3	9.17	16.35	8.31	15.99	3.58	17.03	0.36	16.22	4068	3.99	0.99

*Analysis results of the Research on Biological Resources and Biotechnology at the Research and Community Empowerment Institute, Bogor Agricultural University. **Analysis Results from the Laboratory of Feed Science and Technology, Faculty of Animal Husbandry, Bogor Agricultural University. R0 = 45% corn + 35% concentrate + 20% unfermented rice bran, R1 = 45% corn + 35% concentrate + 20% fermented rice bran, R2 = 45% corn + 35% concentrate + 19.5% fermented rice bran + 0.5% chitosan, R3 = 45% corn + 35% concentrate + 17.5% fermented rice bran + 2.5% chitosan.

performed over two months. The parameters measured included blood hematology (hematocrit, hemoglobin, erythrocyte count, leukocyte count) using the method Campbell (2015), blood cholesterol, and egg cholesterol, were measured using the method described by AOAC (2000). Duck meat chemistry was determined following AOAC (1990) standards. Enzyme activity (amylase, lipase, and protease) was measured using a spectrophotometer, following Mahardikaningrum and Yuanita's (2012) method to assess fatty acid content in meat and eggs.

Sampling and analysis

Blood samples were collected from the vena porta externa using the 3 ml tube containing EDTA solution, for hematology and cholesterol analysis, and meat and duck egg samples were taken for chemical analysis. Enzyme activity was measured using a spectrophotometer following the Randox KIT protocol, and fatty acid content was calculated using the GC-MS method (Brands et al., 2021), GC-MS with EXPEC 3700 model of Hangzhou EXPEC Technology Co., Ltd.

Data analysis

Data were analyzed using variance analysis and appropriate statistical tests. The SPSS computer program was used for data analysis. If there was a significant difference between treatments, Duncan's Multiple Range Test was used for further study. However, without statistical testing, the fatty acid profile data from GC-MS analysis for meat and eggs were presented descriptively based on the number and types of fatty acids identified.

Results

Giving chitosan and fermented rice bran affects hematology data, blood glucose data, and blood cholesterol. The research data (Table 2) shows that treatment R3 results in a higher hematocrit level in the Hematocrit data. Hemoglobin (Hb) treatments R0, R1, and R2 have similar statistical values, but there is an indication of increased Hb levels in R3. Erythrocyte data show an upward trend in treatment R3, suggesting the

potential for enhanced red blood cell production with a combination of fermented rice bran and chitosan. Leukocyte data indicate that treatments R1, R2, and R3 have increased leukocytes compared to the control group R0, reflecting a more active immune response in the treatment groups. Treatment R2 showed the lowest average blood glucose, indicating the combination of fermented bran and chitosan's positive potential for controlling blood glucose levels. Treatment R1 had the lowest blood cholesterol levels, while R3 had the highest.

Table 3 shows that the study's average cholesterol content of Tegal duck meat ranged from 1.08 to 7.61 mg/dg. Giving fermented bran and chitosan in the ration had a significant effect ($P < 0.05$) on cholesterol levels in meat and had no significant impact on cholesterol in eggs. There was an increase in meat cholesterol levels in treatments R1, R2, and R3. The cholesterol level of meat R0 was significantly the lowest ($P < 0.05$). Treatment R1 did not differ from R2 and R3 ($P > 0.05$).

Effect of chitosan and fermented rice bran administration on the chemical content of Tegal duck meat

The analysis showed that administering chitosan and fermented rice bran in duck diets affected the chemical composition of duck meat, particularly in terms of dry matter, water content, and crude fat. According to the data in Table 3, adding chitosan and fermented bran increases the dry matter content in duck meat. Using chitosan and fermented bran reduces the water content in duck meat. Treatment with these supplements influences the crude fat content in duck meat, with treatment R1 increasing crude fat.

Effect of chitosan and fermented rice bran on amylase, lipase, and protease enzyme activity in the digestive tract of Tegal ducks

The study's results showed that fermented bran and chitosan can increase amylase enzyme activity in the digestive tract of Tegal ducks. The amylase enzyme activity obtained from the ration ranged from 866.0805 to 3636.8040 U/ml.

The administration of fermented bran and chitosan was indicated to slow down the activity of the lipase enzyme in the digestive tract of Te-

Table 2. Average hematology levels (hematocrit, haemoglobin, erythrocytes, and leucocytes), glucose, and blood cholesterol with the administration of chitosan and fermented rice bran.

Parameter	Treatment			
	R0	R1	R2	R3
Hematocrit (%)	41.40±1.05 ^{ab}	40.00±1.25 ^a	40.0±1.15 ^a	44.00±1.10 ^b
Hb (g% %)	12.08±0.50 ^{ab}	12.28±0.10 ^{ab}	11.72±0.15 ^a	12.66±1.05 ^b
Erythrocytes (x10 ⁴ /mm ³)	232.00±3.05	241.00±2.36	244.80±2.65	250.00±3.01
Leucocytes (x10 ² /mm ³)	426.40±2.22 ^a	487.4±2.06 ^b	493.4±3.08 ^b	502.6±2.95 ^b
Blood glucose (ml/dl)*	30.42±1.15 ^{bc}	42.07±1.55 ^c	15.04±0.75 ^a	25.74±1.25 ^{ab}
Blood cholesterol (ml/dl)	4.82±0.12 ^{ab}	2.91±0.02 ^a	5.08±0.42 ^{ab}	7.02±0.07 ^b

*) Analysis results of the physiology and biochemistry laboratory Faculty of Animal Husbandry UNPAD. R0 = 45% corn + 35% concentrate + 20% unfermented rice bran, R1 = 45% corn + 35% concentrate + 20% fermented rice bran, R2 = 45% corn + 35% concentrate + 19.5% fermented rice bran + 0.5% chitosan R3 = 45% corn + 35% concentrate + 17.5% fermented rice bran + 2.5% chitosan; a, b The average followed by D different superscripts notes i indicates a significant difference ($P < 0.05$)

gal ducks, so that it appeared to decrease compared to the control. The lipase enzyme activity obtained from administering fermented bran and chitosan in the ratio ranged from 0.7250-3.1175 U / ml.

The role of fermented bran and chitosan treatment is to stimulate protease enzymes in hydrolyzing proteins. The protease enzyme activity obtained from administering fermented rice bran and chitosan in the ratio is 0.083-4.7 U / mg.

Effect of chitosan and fermented rice bran on the types of fatty acids in Tegal duck eggs

Table 4 shows the amount of fatty acids from treatments R0 to R1, R2, and R3. This study's results show that the treatment increased the variety of fatty acid types in duck eggs. The distribution of fatty acid types detected in each treatment is as follows: treatment R0 has 16 fatty acids, R1 has 26 kinds, R2 has 33 types, and R3 has 26 kinds.

Effect of chitosan and fermented rice bran on the types of fatty acids in Tegal duck meat

The amount of fatty acids produced was almost the same between treatments (Tabel 5), the only possible differences being the specific types of fatty acids and their relative proportions.

Discussion

The percentage of hematocrit is directly proportional to the total erythrocytes, so the increasing number of erythrocytes will increase the hematocrit rate (Viastika et al., 2022). This indicates the positive potential of fermented bran and chitosan in increasing the number of red blood cells in duck blood. Haemoglobin (Hb). This suggests that giving fermented bran may better affect Hb levels in duck blood. According to Ali et al. (2013), hemoglobin is a complex compound of globin formed by four subunits, each containing a heme group conjugated to a polypeptide.

Hidayati et al. (2016) found that the average number of red blood cells in poultry is 1.25-4.50 million/mm³. Wardiny et al. (2012) found that the number of erythrocytes is influenced by age, gender, hormones, hypoxia (lack of oxygen), activity, nutrition, egg production, race, environmental temperature, and climate factors. Leucocyt. Leukocytes act as the body's defense system, protecting the body from disease agents such as

viruses, bacteria, and blood parasitic protozoa (Sari et al., 2021).

The hematology results show that fermented bran and chitosan in the R3 treatment significantly impact hematological parameters, especially higher hematocrit and a more active immune response. Effect of giving chitosan and fermented bran on blood glucose and blood cholesterol. Blood Glucose. It is suspected that in this process, chitosan can also interact with carbohydrates, including glucose. As a result, glucose absorption from the digestive tract into the blood may be inhibited. Meanwhile, R1 has the highest average, but it is not significantly different from the control treatment. This demonstrates a significant difference between the treatment groups. Chitosan has antimicrobial, biocompatible, and biodegradable properties, and easily interacts with organic substances such as proteins and fats (Destrianingtyas et al., 2024). Its nature, which makes it easy to react with organic substances, is thought to influence the glucose content in the blood.

Blood Cholesterol. This demonstrates that fermented bran can effectively lower blood cholesterol levels in ducks. Fermented bran boosts unsaturated fatty acids that contain sterols. Sterols help inhibit cholesterol absorption into the bloodstream and promote its excretion, thereby reducing overall cholesterol absorption (Sukma, 2010). The R2 treatment positively influenced blood glucose levels, while the R1 treatment significantly decreased blood cholesterol levels. These results suggest combining fermented bran with chitosan could enhance ducks' overall health and blood quality. According to Ayman et al. (2022), chickens fed COS @ 262 g / ton significantly reduced serum total cholesterol, triglycerides, LDL cholesterol, and VLDL cholesterol. However, more research is necessary to fully understand the mechanisms behind these effects and their implications for duck health.

The study's results on the effect of giving chitosan and fermented bran on cholesterol in the meat and eggs of Tegal ducks show that the average cholesterol content of Tegal duck meat ranges from 1.08 to 7.61 mg/dg. The results indicate that fermented bran and chitosan treatment significantly influence duck meat's cholesterol levels. Treatment R0 has a relatively low average meat cholesterol of 1.80 dg, while treatment R3 has the highest average of 7.61 dg.

Although there was no significant difference between treatments R1 and R2, treatment R3 showed a notable increase. Several factors, including genetics, nutrients, drugs, and bacteria, influence cholesterol deposition in meat and eggs. Cholesterol in egg yolk can vary, reaching up to 25% of the cholesterol from feed and consumed fat (Muliani, 2014). This indicates that the combination of fermented bran and chitosan in treat-

Table 3. Average chemicals content in duck meat, eggs and activity of amylase, lipase, and protease enzymes in the digestive tract of ducks with the administration of chitosan and fermented rice bran.

Parameter*	Treatment			
	R0	R1	R2	R3
Meat				
Cholesterol (dg)*	1.80±0.01 ^a	6.63±0.01 ^{bc}	5.94±0.01 ^b	7.61±0.01 ^c
Cholesterol (dg)	9.44±0.35	6.60±0.12	4.39±0.04	2.78±0.03
Dry matter (%)	26.11±3.05	27.48±3.06	27.70±2.17	27.81±1.74
Water (%)	72.60±3.03	71.18±3.85	71.39±3.05	70.96±4.04
Crude fat (%)	8.52±0.85	11.80±1.63	10.88±1.92	10.47±1.16
Egg				
Cholesterol (dg)	9.44±1.01	6.60±1.01	4.39±0.75	2.78±0.07
Enzyme Activity				
Amylase enzyme activity, U/mL	1930.33±12.05	1242.24±11.08	866.085±15.02	3636.80±13.13
Amylase enzyme lipase, U/mL	3.04±0.02	3.12±0.01	0.74±0.01	0.94±0.01
Amylase enzyme activity, IU/mg protein	1.06±0.01	0.83±0.01	1.82±0.01	4.70±0.02

*) Analysis results of the physiology and biochemistry laboratory, Faculty of Animal Husbandry, UNPAD. R0 = 45% corn + 35% concentrate + 20% unfermented rice bran, R1 = 45% corn + 35% concentrate + 20% fermented rice bran, R2 = 45% corn + 35% concentrate + 19.5% fermented rice rice bran + 0.5% chitosan R3 = 45% corn + 35% concentrate + 17.5% fermented rice bran + 2.5% chitosan.

Different superscripts in the same row indicate significant differences (P<0.05).

ment R3 may significantly affect duck meat cholesterol.

The egg cholesterol results in the R3 treatment showed the lowest value of 2.78 dg, while the R0 treatment had the highest level of 9.44 dg. This suggests combining fermented bran and chitosan in the R3 treatment may help reduce egg cholesterol levels. Chitosan can lower cholesterol and triglycerides by binding lipid micelles in the small intestine after eating fatty foods, a specific mechanism where chitosan inhibits fat digestion in the digestive tract (Maharani and Susanti, 2022)

The results of this study indicate that the R3 treatment, a combination of fermented rice bran and chitosan, can potentially reduce cholesterol in duck meat and eggs. Although the R0 treatment had the lowest meat cholesterol content, the R3 treatment significantly decreased egg cholesterol. These results indicate that the combination of fermented rice bran and chitosan may have a positive effect in controlling cholesterol

levels in duck products.

The data in Table 3 shows that adding chitosan and fermented rice bran increases the dry matter content in duck meat. This may be due to the interaction between these components and the metabolism of duck meat. The administration of chitosan and fermented rice bran tends to reduce the water content in duck meat. The livestock's age and the feed's nutritional content greatly influence the beef's water and fat content (Hidayati et al., 2016). The water and fat content of meat is greatly affected by the livestock's age and the nutritional content of its feed. The feed animals eat influences the chemical properties of the beef produced (Dewi, 2013). This may relate to the meat's water absorption and the impact of fermentation on its composition. The treatment involving chitosan and fermented rice bran influences the crude fat content in duck meat. Treatment R1 showed increased crude fat, possibly due to the interaction

Table 4. Fatty acids in duck eggs.

No	Treatment			
	R0	R1	R2	R3
Duck Egg				
1	Methyl myristoleate	Tetradecanoic acid, methyl ester (CAS	Tetradecanoic acid, methyl ester (CAS	Tetradecanoic acid, methyl ester (CAS
2	Methyl tetradecanoate	Pentadecanal-	Octadecanal	Pentadecanal-
3	9-Hexadecenoic acid, methyl ester, (Z)	9-Hexadecenoic acid, methyl ester, (Z)	9-Hexadecenoic acid, methyl ester, (Z)	9-Hexadecenoic acid, methyl ester, (Z)
4	9-Hexadecenoic acid, methyl ester, (Z)	Methyl hexadec-9-enoate	9-Hexadecenoic acid, methyl ester, (Z)	9-Hexadecenoic acid, methyl ester, (Z)
5	Hexadecanoic acid, methyl ester (CAS	Hexadecanoic acid, methyl ester (CAS)	Hexadecanoic acid, methyl ester (CAS)	Hexadecanoic acid, methyl ester (CAS)
6	Gamma-Linolenic acid, methyl ester	E,E,Z-1,3,12-Nonadecatriene-5,14-dio	cis-9-Hexadecenal	E,E,Z-1,3,12-Nonadecatriene-5,14-dio
7	9,12-Octadecadienoic acid (Z, Z)-, met	9-Octadecenoic acid (Z)-, methyl ester	9-Octadecenoic acid (Z)-, methyl ester	9-Octadecenoic acid (Z)-, methyl ester
8	9-Octadecenoic acid, methyl ester, (E)	Octadecanal	Oxirane, hexadecyl-	Heptadecanoic acid, methyl ester
9	9-Octadecenoic acid, methyl ester (CA	Heptadecanoic acid, methyl ester	Heptadecanoic acid, methyl ester	Gamma-Linolenic acid, methyl ester
10	cis-13-Octadecenoic acid, methyl ester	Gamma-Linolenic acid, methyl ester	Gamma-Linolenic acid, methyl ester	9,12-Octadecadienoic acid (Z,Z)-, met
11	Octadecanoic acid, methyl ester	9,12-Octadecadienoic acid (Z,Z)-, met	6,9-Octadecadienoic acid, methyl ester	9-Octadecenoic acid, methyl ester, (E)
12	5,8,11,14-Eicosatetraenoic acid, meth	9-Octadecenoic acid, methyl ester, (E)	9,12-Octadecadienoic acid (Z,Z)-, met	9-Octadecenoic acid (Z)-, methyl ester
13	cis-5,8,11-Eicosatrienoic acid, methyl	9-Octadecenoic acid (Z), methyl ester	9-Octadecenoic acid, methyl ester, (E)	Octadecanoic acid, methyl ester (CAS)
14	cis-13-Eicosenoic acid, methyl ester	Octadecanoic acid, methyl ester (CAS)	9-Octadecenoic acid (Z)-, methyl ester	6,9-Octadecadienoic acid, methyl ester
15	Methyl 4,7,10,13,16-docosapentaenoa	6,9-Octadecadienoic acid, methyl ester	9-Octadecenoic acid (Z)-, methyl ester	5,8,11,14-Eicosatetraenoic acid, meth
16	Cholest-5-en-3-ol (3.beta.)-, nonanoa	5,8,11,14-Eicosatetraenoic acid, meth	Octadecanoic acid, methyl ester (CAS)	Methyl 5,8,11-eicosatrienoate
17		cis-5,8,11-Eicosatrienoic acid, methyl	7,10-Octadecadienoic acid, methyl est	Methyl 8,11,14-eicosatrienoate
18		Methyl 8,11,14-eicosatrienoate	9-Hexadecenoic acid, methyl ester (Z)	cis-11,14-Eicosadienoic acid, methyl e
19		9,12-Octadecadienoic acid (Z,Z)-, met	5,8,11,14-Eicosatetraenoic acid, meth	cis-13-Eicosenoic acid, methyl ester
20		cis-13-Eicosenoic acid, methyl ester	Methyl 5,8,11-eicosatrienoate	Cholest-5-ene, 3-methoxy-, (3.beta.)-
21		Methyl 4,7,10,13,16-docosapentaenoa	Methyl 8,11,14-eicosatrienoate	Oleoyle chloride
22		4,7,10,13,16,19-Docosahexaenoic acid	cis-11,14-Eicosadienoic acid, methyl e	Methyl 4,7,10,13,16-docosapentaenoa
23		cis-7,10,13,16-Docosatetraenoic acid,	cis-13-Eicosenoic acid, methyl ester	4,7,10,13,16,19-Docosahexaenoic acid
24		Cholest-5-ene, 3-methoxy-, (3.beta.)-	Eicosanoic acid, methyl ester (CAS) Ar	cis-7,10,13,16-Docosatetraenoic acid,
25		Cholest-5-en-3-ol (3.beta.)-, nonanoa	Oleic anhydride	cis-5,8,11,14,17-Eicosapentaenoic aci
26		Cholest-5-en-3-ol (3.beta.)-, acetate	Methyl 4,7,10,13,16-docosapentaenoa	Cholest-5-en-3-ol (3.beta.)-, acetate
27			4,7,10,13,16,19-Docosahexaenoic acid	
28			cis-7,10,13,16-Docosatetraenoic acid,	
29			cis-5,8,11,14,17-Eicosapentaenoic aci	
30			Cholest-5-en-3-ol (3.beta.)-, nonanoa	
31			Cholesta-3,5-diene	
32			Cholest-5-en-3-ol (3.beta.)-, acetate	
33			5-Cholestene, 3. beta.-fluoro-	

GC-MS analysis results of UPI Bandung. R0 = 45% corn + 35% concentrate + 20% unfermented rice bran, R1 = 45% corn + 35% concentrate + 20% fermented bran, R2 = 45% corn + 35% concentrate + 19.5% fermented bran + 0.5% chitosan, R3 = 45% corn + 35% concentrate + 17.5% fermented rice bran + 2.5% chitosan

Table 5. Fatty acids in duck meat

No	Treatment			
	R0	R1	R2	R3
1		Dodecanoic acid, methyl ester	Dodecanoic acid, methyl ester	Dodecanoic acid, methyl ester
2	Tetradecanoic acid, methyl ester (CAS	Methyl tetradecanoate	Methyl tetradecanoate	Methyl tetradecanoate
3	9-Hexadecenoic acid, methyl ester, (Z	Cyclotrisiloxane, hexamethyl- (CAS) 1	Cyclotrisiloxane, hexamethyl- (CAS) 1	Cyclotrisiloxane, hexamethyl- (CAS) 1
4	Hexadecanoic acid, methyl ester	9-Hexadecenoic acid, methyl ester, (Z	9-Hexadecenoic acid, methyl ester, (Z	9-Hexadecenoic acid, methyl ester, (Z
5	Cyclotrisiloxane, hexamethyl- (CAS) 1	9-Hexadecenoic acid, methyl ester, (Z	9-Hexadecenoic acid, methyl ester, (Z	9-Hexadecenoic acid, methyl ester, (Z
6	9,12-Octadecadienoic acid (Z,Z)-, met	Hexadecanoic acid, methyl ester	Hexadecanoic acid, methyl ester	Hexadecanoic acid, methyl ester
7	9-Octadecenoic acid, methyl ester (CA	9,12-Octadecadienoic acid (Z,Z)-, met	9,12-Octadecadienoic acid (Z,Z)-, met	9,12-Octadecadienoic acid (Z,Z)-, met
8	9-Octadecenoic acid, methyl ester, (E)	9-Octadecenoic acid (Z)-, methyl ester	9-Octadecenoic acid, methyl ester (CA	9-Octadecenoic acid, methyl ester (CA
9	Octadecanoic acid, methyl ester	9-Octadecenoic acid (Z)-, methyl ester	9-Octadecenoic acid, methyl ester, (E)	9-Octadecenoic acid (Z)-, methyl ester
10	5,8,11,14-Eicosatetraenoic acid, meth	Octadecanoic acid, methyl ester	Octadecanoic acid, methyl ester	Octadecanoic acid, methyl ester
11		9,12-Octadecadienoic acid (Z,Z)-, met	5,8,11,14-Eicosatetraenoic acid, meth	5,8,11,14-Eicosatetraenoic acid, meth
12		5,8,11,14-Eicosatetraenoic acid, meth		
13		cis-11-Eicosenoic acid, methyl ester		

GC-MS analysis results of UPI Bandung. R0 = 45% corn + 35% concentrate + 20% unfermented rice bran, R1 = 45% corn + 35% concentrate + 20% fermented bran, R2 = 45% corn + 35% concentrate + 19.5% fermented bran + 0.5% chitosan, R3 = 45% corn + 35% concentrate + 17.5% fermented rice bran + 2.5% chitosan

between chitosan, fermented rice bran, and fat metabolism in the duck's body.

The study's results demonstrated that administering fermented rice bran and chitosan can enhance the activity of the amylase enzyme in the Tegal ducks' digestive tract. This suggests increased carbohydrate metabolism, which can benefit the ducks' health and digestive efficiency. The amylase enzyme plays a crucial role in breaking down carbohydrate molecules into simple forms, especially glucose, which is then absorbed by the small intestine for distribution to tissues or organs that require it. Well-known enzymes include amylase, lipase, and protease, hydrolytic enzymes that decompose macromolecular compounds of carbohydrates, fats, and proteins (Supriyatna et al., 2015; Kharazi et al., 2022; Mushawwir et al., 2023). According to the data in Table 3, the activity of the amylase enzyme increases with higher levels of fermented rice bran and chitosan. The fermented rice bran and chitosan treatment can support the amylase activity in hydrolyzing carbohydrates. Treatment R3 showed the highest amylase activity with 17.5% fermented rice bran and 2.5% chitosan. The combination of fermented rice bran and chitosan seems to have a synergistic effect, enhancing the activity of the amylase enzyme, which is vital for carbohydrate metabolism. The increase in amylase activity suggested that energy metabolism in Tegal ducks can operate more efficiently with fermented rice bran and chitosan treatment.

The administration of fermented rice bran and chitosan was shown to slow down the activity of the lipase enzyme in the digestive tract of Tegal ducks, resulting in a decrease compared to the control (Table 3). The reduction in lipase activity in treatments R2 and R3 may be due to adding chitosan to the duck feed. Chitosan, a polymer compound derived from chitin, is believed to influence digestive enzyme activity. Its nature allows it to bind fat (Hasri, 2010). Previous studies have demonstrated that chitosan can inhibit lipase activity by forming complexes with enzymes or substrates, thereby preventing the enzyme from interacting with its substrate. In this context, adding chitosan to the feed in treatments R2 and R3 may have disrupted lipase enzyme activity in the ducks' digestive tract.

The role of fermented rice bran and chitosan treatment is to enhance the activity of protease enzymes that break down proteins. Administering 17.5% fermented rice bran and 2.5% chitosan has been shown to increase protease enzyme activity in the digestive tract of Tegal ducks (Table 3). This suggests that protein digestion occurs smoothly. Chitosan molecules share the same N group as proteins, allowing them to bind and form many amino acid compounds. Chitosan is derived from chitin with its acetyl group removed, making it a D-glucosamine polymer capable of binding to proteins (Rahmania et al., 2022; Naban et al., 2024). Depending

on feed composition, this study finds significant differences in protease enzyme activity in ducks' digestive tracts. The results show that adding chitosan to duck feed, especially in treatments R2 and R3, shows a noticeable increase in protease enzyme activity.

Table 4 shows that the variety of fatty acids increased from treatment R0 to R1, R2, and R3. Treatment R2, in particular, exhibited the highest number and diversity of fatty acids." This indicates that adding chitosan and fermented rice bran to the feed (especially in R2 and R3) increased fatty acid variation.

Supplying antioxidants in feed influences fatty acid composition in livestock, and fatty acids impact oxidation (Lestari et al., 2020; Nurfauziah et al., 2024). The R2 treatment produced the highest fatty acid enrichment among the treatments. This indicates that combining bran fermentation with chitosan addition in feed can create a broader range of fatty acids. The increased fatty acids observed in the R2 treatment can potentially improve the nutritional quality of duck eggs. Different fatty acids can offer additional health benefits for consumers. The interaction between bran fermentation and chitosan can stimulate fatty acid synthesis in the animals' bodies, which is reflected in the fatty acid profile of the eggs. The combination of rice bran fermentation and chitosan may have a synergistic effect, increasing enzyme activity (Table 3), where both boost each other's effects in improving nutrient availability and animal metabolism.

The amount of fatty acids produced was nearly the same across treatments, with possible differences in specific types and proportions of fatty acids. There was a slight increase in fatty acids in the treatment compared to the control. This indicates that administering fermented rice bran and chitosan treatments can help increase fatty acids in the meat. As supported by research, chitosan's antibacterial and antioxidant properties influence fatty acids production. This is supported by research (Lestari et al., 2020).

The administration of *Pluchea indica* Less or *Cosmos caudatus* significantly affects ($P < 0.05$) MDA levels, fatty acid composition, and odor preference in cooked meat. The data in Table 4 indicated that combining chitosan and fermented rice bran in Tegal duck feed may influence duck meat's fatty acid composition by increasing certain fatty acids. This demonstrates the potential for nutritional changes in duck meat in response to the treatment.

Conclusion

Incorporating fermented rice bran and chitosan into duck diets improves hematological health, reduces blood and egg cholesterol, and

enhances enzyme activity and fatty acid profiles in duck meat and eggs. This combination can lower fat and cholesterol levels, lower unsaturated fatty acids, and influence enzyme activity in the digestive system. These results highlight the potential to produce healthier, more nutritious duck products, supporting food security and public health.

Conflict of interest

The authors have no conflict of interest to declare.

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