Research Article

Porang Glucomannan as a Prebiotic and Cholesterol Reducer in Broiler Chickens: Effects on Carcass Quality, Meat Cholesterol, and Immune Response

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Abstract | This study aimed to evaluate the effectiveness of porang glucomannan extract as a prebiotic and cholesterol-lowering agent in broiler chickens. The research was conducted in three stages: (1) glucomannan extraction using methanol and ethanol solvents for 2, 4, and 6 hours, followed by in vitro prebiotic test to observe the growth of probiotic bacteria (*Lactobacillus acidophilus* and *Lactobacillus casei*) and media pH; (2) *in vitro* Cholesterol-lowering activity test; (3) *in vivo* test using a completely randomized design (CRD) with 4 treatments and 5 replicates. Treatments consisted of (T0: control, T1: 0.2%, T2: 0.4%, T3: 0.6% glucomannan extract) with parameters: Carcass quality, meat cholesterol levels, and antibody titers of Newcastle Disease (ND) and Infectious Bursal Disease (IBD). The results showed that the best extract was obtained from ethanol solvent for 6 hours with the highest glucomannan content (57.29%) with the lowest calcium oxalate and in vitro anticholesterol test showed significant cholesterol reduction. In vivo tests showed that the highest carcass percentage in T2 (74.8%), the lowest abdominal fat weight in T3 (0.83%). Meat cholesterol levels decreased significantly ($P<0.05$) from 76.33 mg/100 g in T0 to 66.80 mg/100 g in T3. Immune response analysis showed that ND antibody titer decreased from 6.00 log2 (T0) to 4.10 log2 (T3), IBD increased from 2,162 (T0) to 5,195 (T3). However, higher doses of glucomannan (0.6%) unexpectedly lowered ND and IBD antibody titers. This finding suggests a potential immunomodulatory effect of glucomannan that requires further investigation. In conclusion, porang glucomannan extract has the potential as a natural feed additive that functions as a prebiotic, cholesterol lowering and carcass quality enhancer for broiler chickens with special attention to its effect on immune response.

Keywords | Glucomannan, Broiler chicken, Carcass quality, Cholesterol, Immune response

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INTRODUCTION

Porang tubers (*Amorphophallus oncophyllus* Prain), native to the Araceae family, grow abundantly in tropical regions such as Indonesia. They are known to have a high glucomannan content, accounting for approximately 45-65% of their dry weight (Perdinan *et al.*, 2023). Glucomannan is a water-soluble polysaccharide composed of D-glucose and D-mannose monomers linked by β-1,4 bonds. It can form gels, thicken, and improve texture (Amyranti et al., 2023). Although glucomannan can be extracted from other sources, such as konjac (*Amorphophallus*

konjac), porang has advantages, including its abundance in Indonesia, low calcium oxalate content, and high-quality extraction potential (Nurlela *et al*., 2021; Azhar *et al*., 2023). These characteristics make porang a promising yet underutilized source of functional fibre for animal feed. The glucomannan extraction process from porang tubers has been extensively studied to optimize yield and quality. Standard methods employ solvents, such as ethanol and water, in conjunction with sodium metabisulfite, to prevent oxidation. Characterization of the extracted glucomannan reveals that this compound can form gels and thicken to enhance food texture (Aryanti and Abidin, 2015).

Broiler chickens are one of the most economically valuable poultry commodities in the livestock industry. However, the high fat content of broiler chicken meat is a major consumer concern as it can contribute to increased blood cholesterol levels, posing risks to human health (Nursinah *et al*., 2013; Taulescu *et al*., 2010). Therefore, there is a need for innovations in feed formulation that support growth performance and produce chicken meat with lower cholesterol levels. One promising approach is the use of glucomannan from porang tubers as a natural feed additive in broiler chicken feed. Glucomannan, a water-soluble polysaccharide with β-1,4 bonds, cannot be digested by chicken digestive enzymes. This allows it to reach the lower digestive tract, where it functions as a prebiotic. In the large intestine, microbiota ferment glucomannan into short-chain fatty acids (SCFAs), which play a crucial role in strengthening the intestinal barrier, enhancing nutrient absorption, and supporting growth and feed conversion efficiency (Perdinan and Larasati, 2019).

Studies have shown that supplementing with 0.4% glucomannan can increase feed intake and body weight gain in broiler chickens, resulting in a feed conversion ratio (FCR) of 1.72 (Tafsin *et al*., 2024). Similar improvements were observed by Kamalzadeh *et al*. (2009), who reported increased body weight in broilers fed 1 g of glucomannan per kg of feed. Glucomannan contributes to maintaining a balanced gut microbiota by increasing the population of lactic acid bacteria (LAB) and suppressing the growth of pathogenic bacteria (Perdinan and Larasati, 2019). Additionally, glucomannan supplementation has been shown to increase SCFA concentrations and lower pH in the jejunum, thereby supporting a healthy gut environment (Perdinan and Larasati, 2019). These changes contribute to improved gut morphology, including an increase in villus length. This is directly linked to digestive efficiency and nutrient absorption (Chacher *et al*., 2017). Beyond its prebiotic function, glucomannan exhibits immunomodulatory properties. It can enhance macrophage activity and antibody production post-vaccination, thereby supporting the immune system of broiler chickens (Perdinan and Larasati, 2019). Several studies have confirmed the effectiveness of glucomannan in lowering cholesterol levels. Nugraheni *et al*. (2014) reported decreased total cholesterol levels in mice fed a high-fat diet supplemented with glucomannan. Khanifah *et al*. (2018) found that adding porang tuber to broiler feed improved protein digestibility and body weight. Annisa *et al*. (2021) stated that adding up to 1.2% porang tuber flour did not negatively impact the weight or length of the small intestine of broilers.

This study presents a novel approach by optimizing the glucomannan extraction process from porang tubers using different solvents (methanol and ethanol) and varying extraction times (2, 4, and 6 hours). The study also evaluates the use of glucomannan as a natural carbon source to support probiotic growth and reduce cholesterol levels. The novelty of this study lies in its integration of *in vitro* testing of prebiotic activity and cholesterol reduction with in vivo testing of carcass quality, meat cholesterol, and the immune response of broiler chickens.

MATERIALS AND METHODS

Animal ethics

The experimental protocol was approved by the Animal Research Ethics Committee of the Faculty of Mathematics and Natural Sciences at Universitas Sumatera Utara in Indonesia under the ethics number 0330/KEPH-FMIPA/2023. All procedures, including slaughter, were conducted by ethical standards for the humane treatment of animals.

Glucomannan extract preparation

Porang tubers were cut into thin slices (chips) and soaked with 5% (w/b) salt solution in the ratio of 1 kg tubers to 3 liters of water for 24 hours (Haryani and Hargono, 2008), then washed thoroughly with running water and drained and baked at 55°C for 12 hours. The dried chips were ground to powder form and sieved with an 80 mesh sieve to equalize the particle size. Extraction was carried out according to the treatment. A total of 50 grams of porang flour was put into a solution of ethanol (p.a) and methanol (p.a) with a ratio of sample and solvent (1 gram: 15 ml) then stirred constantly using a stirrer. The extraction was carried out at a constant temperature of ±25°C under stirring. The time used for extraction was 2, 4 and 6 hours. The mixture was then separated with filter paper. The remaining ethanol p.a and methanol p.a in the porang flour were evaporated using oven heating at 60 °C until the flour was dry. We included methanol as a control solvent to evaluate the effect of polarity on glucomannan yield. The glucomannan extraction method carried out in this study uses the method of Saputro *et al*. (2014) with

modifications. This research was conducted at the USU FP Flour House, FTIP Unpad Test Services Laboratory and USU FMIPA Chemistry Laboratory from April 2023 to December 2023. The research design used to examine the effect of solvent type and extraction time on glucomannan content from porang tubers is a factorial complete randomized design. The use of factorial RAL method has 2 factors, namely, the first factor is the type of solvent with 2 levels and the second factor is the extraction time with 3 levels, each level is carried out 3 times. The treatments are S1T1 (methanol solvent with 2 hours extraction time); S1T2 (methanol solvent with 4 hours extraction time); S1T3 (methanol solvent with 6 hours extraction time); S2T1 (ethanol solvent with 2 hours extraction time); S2T2 (ethanol solvent with 4 hours extraction time) and S2T3 (ethanol solvent with 6 hours extraction time).

Animals, diet treatment and management

One-day-old chickens (DOC) strain Lohman (MB 202) without sex separation amounted to 100 chickens originating from PT Japfa Comfeed Indonesia with an initial body weight of 47.35 ± 3.95 g/head were reared for 35 days. The research was conducted at the Research and Technology Laboratory of FP USU, Soil Biology Laboratory of FP USU, Medion Laboratory and Baru Village, Pancur Batu District, Deli Serdang Regency. This research took place from January 2024 to January 2025. Chickens were kept in 20 cages (1×1 m^2/unit), each containing 5 chickens, and were given basal feed enriched with glucomannan extract according to the treatment after an adaptation period of 1 week. Chickens were vaccinated against Newcastle Disease (ND) (days 1 and 14) and Infection Bursal Disease (IBD) (days 10 and 21). At the end of the rearing period, 60 chickens were slaughtered after fasting for 12 hours, and breast and thigh meat samples (100 grams each) were taken for cholesterol level analysis. This study used a completely randomized design with 4 treatments and 5 replicates. T0 (Basal ration + 0% glucomannan extract); T1 (Basal ration + 0.2% glucomannan extract); T2 = Basal ration + 0.4% glucomannan extract); T3 (Basal ration + 0.6% glucomannan extract). The feed was prepared based on the nutritional needs of starter and finisher phase broilers (National Standardization Agency, 2006). The composition of the ration given to starter and finisher phase broilers can be seen in Table 1.

Table 1: Formulation of broiler chicken rations in the starter and finisher phase (%).

Feed ingredients	Starter (8-21 day)	Finisher (22-35 day)
Corn meal	51.2	53.7
Rice bran	10	10
Soybean meal	24	23.5
Fish meal	10	8
Crude palm oil (CPO)	2	2
Calcium carbonate ($CaCO_3$)	1	1
Dicalcium phosphate (DCP)	1	1
L-Lysine	0.3	0.3
DL-Methionine	0.2	0.2
Premix	0.3	0.3
Amount (%)	100	100
Nutritional composition		
Metabolizable energy/ ME (kcal/kg)**	3,014.19	3,038.06
Dry matter / DM (%)*	91.17	91.17
Crude protein (%)*	21.01	19.08
Crude fat (%)*	4.83	3.93
Crude fiber (%)*	4.29	4.67
Calcium (%)**	1.26	1.21
Phosphorus (%)**	0.72	0.65
Lysine (%)**	1.54	1.44
Methionine (%)**	0.64	0.61

*Medion laboratory analysis results (2024); **Based on calculations.

Data collection

Analysis of glucomannan content in glucomannan extract using the 3,5-DNS method (Chua *et al*., 2012). Calcium oxalate content was analyzed using the permanganometric titration method (Handayani *et al*., 2020). The prebiotic test was conducted by measuring the pH of the media and the number of bacterial colonies after 24 hours incubation at 37°C. A decrease in pH and media turbidity indicates fermentation activity. Colony counts and pH measurements were performed in triplicate for each treatment. The number of colonies of *Lactobacillus acidophilus* and *Lactobacillus casei* was counted using the Total Plate Count (TPC) method according to the procedure of Ngatirah and Syaflan (2016). Anticholesterol activity analysis was performed using Lieberman-Burchard reagent with five different concentrations and three replications for each concentration (Noviani *et al*., 2021). Broiler carcass quality was measured through several parameters, namely live weight, slaughter weight, carcass weight, carcass percentage, abdominal fat weight, and abdominal fat percentage (Oktaviana *et al*., 2010; Subekti *et al*., 2012). Determination of meat cholesterol levels was carried out using the Liebermann-Burchard method (Tugiyanti and Susanti, 2020). Haemagglutination Inhibition (HI) test is one of the serological methods used to measure antibody titer against ND virus (Kitikoon *et al*., 2014). Enzyme-Linked Immunosorbent Assay (ELISA) test is used to detect the humoral immune response to IBD vaccination in broiler chickens (Alhajj *et al*., 2023). ND and IBD antibody titers were chosen as immune markers because they are commonly used in broiler studies to assess

the humoral immune response following vaccination. In summary, the entire research design process, from extraction to testing, is presented in Figure 1. Data were first tested for normality using the Shapiro-Wilk test and for homogeneity of variance using Levene's test. The data that met these assumptions were then analysed using one-way analysis of variance (ANOVA) with SPSS 27.0 software. If a significant difference was detected, Duncan's multiple range test was used to compare the means between treatments (Loto, 2022).

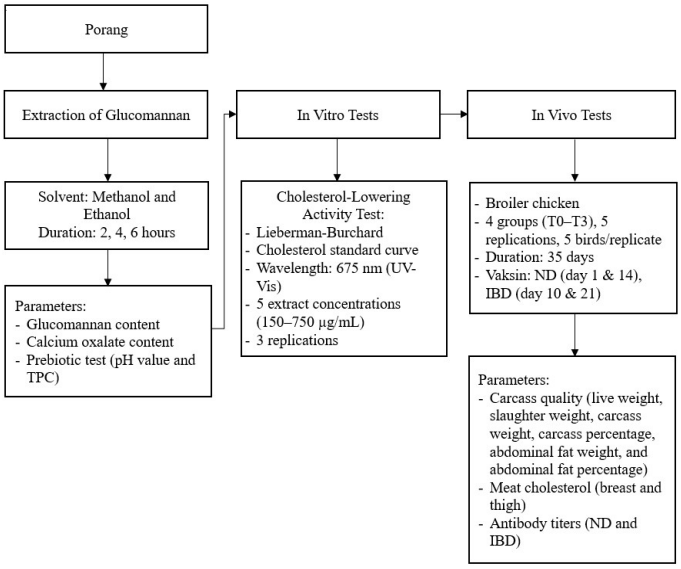

Figure 1: Graphical representation of the experimental workflow.

RESULTS AND DISCUSSION

Glucomannan

As shown in Table 3, the analysis results indicate that the type of solvent and extraction time have a significant effect ($P < 0.01$) on the glucomannan content produced from porang tubers. The highest glucomannan content (57.92%) was obtained through extraction with an ethanol solvent for six hours, while the lowest content (34.48%) was obtained through extraction with a methanol solvent for four hours. Generally, ethanol was more effective than methanol at dissolving polysaccharides, resulting in higher glucomannan yields. Interestingly, the glucomannan content from 4 hours methanol extraction was lower than that from 2 hours extraction. This decrease is likely due to the partial degradation of glucomannan caused by the tubers' prolonged exposure to the methanol solvent at room temperature. This exposure can lead to the breaking of glycosidic bonds and damage to the polysaccharide structure. Additionally, during the intermediate extraction duration (4 hours), the release of glucomannan from the plant cell walls may not have been optimal due to diffusion barriers or incomplete structural changes in the cell walls. However, glucomannan levels increased again at the 6 hours extraction time as the cell matrix opened, allowing for maximum release of active compounds. These findings are consistent with those of previous studies. For example, Saputro *et al.* (2014) reported glucomannan levels ranging from 36.69% to 64.22%, depending on the solvent and extraction time. Wardani *et al.* (2021) obtained 38.53% glucomannan using 60% ethanol for 30 minutes, and Fatmawati *et al.* (2016) reported results ranging from 53.17% to 59.36%, using an isopropanol solvent with ultrasonic assistance. Additionally, the pattern of changes in glucomannan yield corresponds with the reports of Chua *et al.* (2012) and Verawati *et al.* (2021). They stated that the polysaccharide extraction process generally involves a gradual release phase followed by a temporary decrease due to compound instability. Then, it increases again when release from the cell matrix reaches optimal conditions.

Calcium oxalate

The results of the analysis in Table 2 show that the type of solvent and extraction time have a very significant effect ($P < 0.01$) on the calcium oxalate content in glucomannan extract from porang tubers. average calcium oxalate

Table 2: Analysis results of glucomannan content (%) and calcium oxalate content (%).

Parameters	S1T1	S1T2	S1T3	S2T1	S2T2	S2T3
Glucomannan (%)	41.17±1.09	34.48±1.61	50.84±2.37	49.45±1.25	45.71±3.41	57.29±5.09
Calcium oxalate (%)	$7.53±0.27^{A}$	$7.91±0.03^{A}$	$7.98±0.05^{A}$	$6.60±0.30^{C}$	$7.08±0.16^{B}$	$4.98±0.09^{D}$

AB: Different superscripts on the same line indicate significant differences (P<0.01).

Table 3: Results of media pH values and colony growth of *Lactobacillus achidophilus* and *Lactobacillus casei* (CFU/mL).

Parameters	S1T1	S1T2	S1T3	S2T1	S2T2	S2T3
pH of *L. achidophilus* media	$4.75±0.03^{D}$	$4.82±0.03^{E}$	$4.45±0.01^{B}$	$4.40±0.02^{B}$	$4.60±0.03^{C}$	$4.30±0.01^{A}$
L. achidophilus colony count (CFU/mL)	$7.70×10^{8}±4.00^{B}$	$5.63×10^{8}±4.10^{A}$	$1.85×10^{9}±7.81^{E}$	$1.53×10^{9}±7.55^{D}$	$9.73×10^{8}±5.66^{C}$	$2.25×10^{9}±6.24^{F}$
pH of L. casei media	$4.78±0.02^{D}$	$4.89±0.01^{E}$	$4.55±0.02^{B}$	$4.50±0.02^{A}$	$4.70±0.02^{C}$	$4.48±0.01^{A}$
L. casei colony count (CFU/mL)	$7.17×10^{8}±5.56^{B}$	$4.87×10^{8}±3.90^{A}$	$9.53×10^{8}±3.56^{C}$	$9.77×10^{8}±5.70^{C}$	$8.53×10^{8}±4.68^{C}$	$1.31×10^{9}±6.00^{D}$

AB: Different superscripts on the same line indicate significant differences (P<0.01).

Table 4: Average live weight (g/head), slaughter weight (g/head), carcass weight (g/head), carcass percentage (%), abdominal fat weight (g/head) and abdominal fat weight percentage (%) in broiler chickens.

Parameters	T0	T1	T2	T3
Live weight (g/head)	1,388.53±77.86^{A}	1,542.40±75.23^{B}	1,516.53±36.79^{B}	1,489.20±37.77^{AB}
Slaughter weight (g/head)	1,336.13±81.02^{a}	1,471.60±73.68^{b}	1,456.67±38.82^{b}	1,419.73±33.05^{b}
Carcass weight (g/head)	946.15±56.65^{a}	1,038.18±57.67^{b}	1,024.99±36.69^{b}	1,004.68±28.94^{ab}
Carcass percentage (%)	70.82±0.60	70.54±0.74	70.35±0.92	70.76±0.78
Abdominal fat (g/head)	9.03±1.22	8.93±0.78	8.83±0.51	8.87±0.62
Abdominal fat percentage (%)	0.68±0.08	0.61±0.06	0.61±0.05	0.62±0.03

AB: Different superscripts on the same line indicate significant differences (P<0.01); ab: Different superscripts on the same line indicate significant differences (P<0.05)

Table 5: Cholesterol content of broiler meat (mg/100 g).

Parameters	T0	T1	T2	T3
Breast	76.33±1.00^{C}	70.93±0.24^{B}	68.77±0.92^{AB}	66.80±1.16^{A}
Thighs	93.36±1.14^{C}	87.77±0.67^{B}	85.54±1.23^{AB}	83.55±0.60^{A}

AB: Different superscripts on the same line indicate significant differences (P<0.01).

content in methanol solvent is 6.22%, while in ethanol it is lower, namely 4.98% at 6 hours extraction time, which is the lowest value of all treatments. The decrease in calcium oxalate levels compared to the initial content in porang flour was 22.72% (Widjanarko *et al*, 2024), reaching 65.6% in methanol and 72.6% in ethanol. This decrease is better than the wet fermentation method (62.28%) according to Ferdian and Perdana (2021). Extraction time affects calcium oxalate levels, especially in ethanol solvent, where the highest levels appeared at 4 hours and decreased again at 6 hours, possibly due to precipitation or complex formation with glucomannan. Meanwhile, calcium oxalate levels in methanol extraction were relatively stable at all extraction times, suggesting that this solvent has been effective in dissolving calcium oxalate since the first 2 hours, with no significant increase at 4 and 6 hours. This is supported by the nature of methanol which is more polar and efficient in dissolving polar compounds in a short time (Riyadi *et al*., 2023). In contrast, ethanol acts more selectively on glucomannan and affects the dissolution and precipitation of calcium oxalate gradually (Nurlela *et al*., 2021; Salgado *et al*., 2023).

Prebiotic test

Media pH value

As shown in Table 5, the type of solvent and the duration of glucomannan extraction significantly affect (P < 0.01) changes in the pH of the fermentation medium used for *Lactobacillus acidophilus* and *Lactobacillus casei*. These pH differences correlate with bacterial metabolic activity and glucomannan levels in the medium, both of which affect acid production during fermentation. In glucomannan extract using methanol, the pH of *Lactobacillus acidophilus* media ranged from 4.45-4.82, and *Lactobacillus casei* between 4.55-4.89, with the lowest pH occurring at 6 hours extraction. Extraction using ethanol resulted in a lower pH of 4.30-4.60 (*Lactobacillus acidophilus*) and 4.48-4.70 (*Lactobacillus casei*), indicating increased acid production as glucomannan levels and colony growth increased. Several studies support this, such as Daysita *et al*. (2024) who reported that porang flour is suitable for *Lactobacillus acidophilus* growth, and Azhari *et al*. (2021) which showed that *Lactobacillus casei* can grow on porang media even though the pH decreases more slowly than standard media. Other studies by Ngatirah and Syaflan (2016) and Satiti *et al*. (2024) emphasized the importance of pH and physicochemical properties of glucomannan (such as polymerization level and molecular weight) in supporting optimal fermentation by probiotic bacteria.

Total plate count (TPC)

According to Table 5, the results of this study suggest that glucomannan produced from porang tubers significantly affects (P < 0.01) the number of *Lactobacillus acidophilus* and *Lactobacillus casei* colonies. Extraction using ethanol for 6 hours produced the highest glucomannan content (57.29%) and consistently promoted the highest colony growth, namely 2.25 × 109CFU/mL (*Lactobacillus acidophilus*) and 1.31 × 109CFU/mL (*Lactobacillus casei*). Meanwhile, extractions with lower glucomannan content showed smaller colony counts. This positive correlation between high glucomannan content and colony growth confirms that glucomannan is a potential carbon source to support lactic acid bacteria fermentation. Several studies support this finding, such as Azhari *et al*. (2021) and Ngatirah and Syaflan (2016) who reported the effectiveness of porang media in increasing *Lactobacillus casei* growth. *Hydrolysed* glucomannan has also been shown to support *Lactobacillus acidophilus* growth, as it contains oligosaccharides that are easily fermented (Satiti *et al*.,

2024; Helmi and Karsiningsih, 2024; Daysita *et al*., 2024). Another important factor is the degree of polymerization (DP) and molecular weight (MW) of glucomannan, where the hydrolyzed form with lower DP and MW has higher solubility and lower viscosity, making it more easily utilized by probiotic bacteria (Ariestanti *et al*., 2019).

Cholesterol-lowering activity test

The data in Figure 2 shows that the absorbance value of cholesterol increases as the cholesterol concentration increases, with values from 0.134 (100 µg/mL) to 0.363 (500 µg/mL). The cholesterol standard curve at a wavelength of 675 nm shows a linear relationship with the regression equation y = 0.0006x + 0.0782 and a value of R^2 = 0.9997, which indicates the very high accuracy and reliability of the UV-Vis spectrophotometric method in cholesterol analysis. This curve was used to determine the residual cholesterol levels after treatment with glucomannan extract from porang tubers, thus allowing accurate calculation of percent cholesterol reduction. The principle of this analysis follows the Lambert-Beer law, where absorbance is directly proportional to the concentration of the substance (Nurjayadi *et al*., 2021; Gui *et al*., 2016). The absorbance value of standard cholesterol used as reference is 0.308.

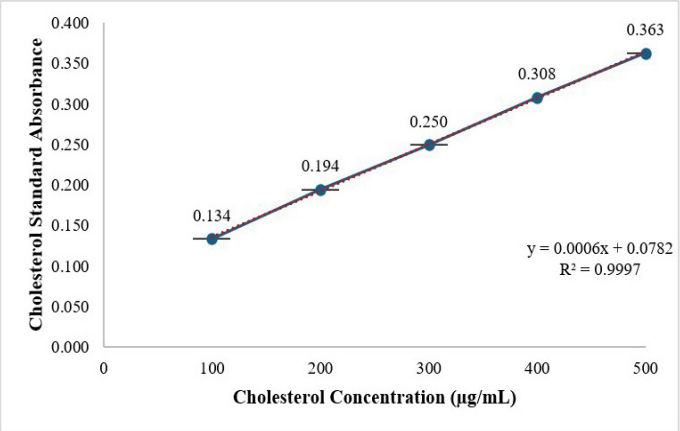

Figure 2: Cholesterol standard curve.

Glucomannan extract from porang tubers showed significant ability to reduce cholesterol levels in vitro as shown in Figure 3. The percentage of cholesterol reduction increased as the concentration of the extract increased, from 13.42% at 150 µg/mL to 45.56% at 750 µg/mL. This relationship followed the linear regression equation y = 0.0533x + 3.171 with R^2 = 0.9701, indicating that 97.01% of the variation in cholesterol reduction was explained by glucomannan concentration. The mechanism involves glucomannan's ability as a water-soluble fiber to form a viscous gel that inhibits bile acid reabsorption, increases bile acid excretion, and reduces cholesterol absorption through binding with lipids (Gallaher et al., 2000; Gunness and Gidley, 2010; Jin *et al*., 2025). These results are in line with previous research (Pasaribu *et al*., 2020) and support the potential of glucomannan as a raw material for cholesterol-lowering supplements or functional foods.

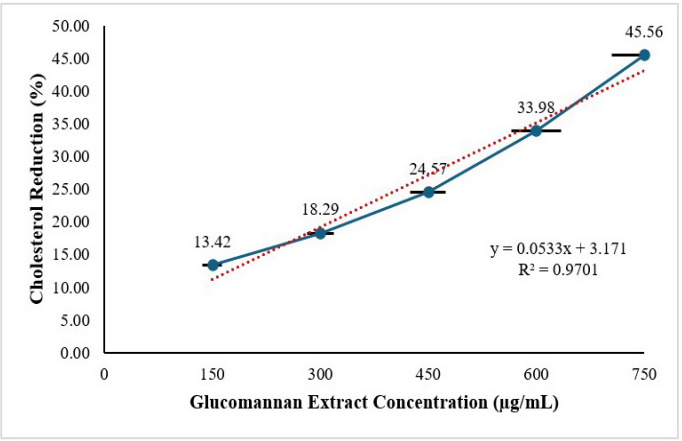

Figure 3: Relationship curve between the concentration of glucomannan extract from porang tubers with cholesterol.

Broiler carcass quality

Live weight

As shown in Table 4, the results of the analysis of variance indicate that administering glucomannan extract as a feed additive significantly affects (P<0.05) the live weight of broiler chickens. The highest average live weight (1,542.40 g/bird) was found in treatment T1 (0.2%), followed by treatments T2 and T3. The lowest weight (1,388.53 g/bird) was found in the control group, T0. This increase in live weight suggests that glucomannan extract enhances the efficiency of nutrient utilisation and body metabolism. This improvement may be related to a healthier gut environment and increased production of short-chain fatty acids (SCFAs). However, the highest dose (T3, 0.6%) resulted in a decrease in live weight compared to previous treatments. This suggests a dose-dependent effect: High fibre content in the diet can increase intestinal viscosity and disrupt optimal nutrient absorption. This phenomenon aligns with Joshua's (2017) findings, which describe a curvilinear relationship between feed additive levels and broiler chicken growth: optimal doses yield the best performance, while excessive doses produce counterproductive effects. These results are supported by those of Khanifah *et al*. (2018) and Perdinan and Larasati (2019), who reported improved digestibility and broiler performance at moderate glucomannan levels.

Slaughter weight

The results of the analysis of variance in Table 4 show that the provision of glucomannan extract from porang tubers as a feed additive showed a significant effect (P < 0.05) on broiler slaughter weight, with values ranging from 1,336.13 to 1,471.60 g/head. The highest slaughter weight was obtained in treatment T1, while T0 showed the lowest value. Although there was no significant difference between the T1-T3 groups, all three were significantly higher than the control. The increase in broiler slaughter weight is

in line with the increase in glucomannan level, thanks to its prebiotic role in improving nutrient absorption and metabolism (Leone and Ferrante, 2023). Factors such as age, sex and feed quality also affect slaughter weight (Nikolova and Pavlovski, 2009). Despite a slight decrease at the highest level, glucomannan still supports growth efficiency (Barekatain *et al*., 2024). In addition, glucomannan maintains the stability of post-slaughter meat moisture content, keeping.

Carcass weight

The results of the analysis of variance in Table 4 show that the provision of glucomannan extract from porang tubers as a feed additive into broiler rations significantly affects the carcass weight of broilers (P<0.05), with a range of 946.15 to 1,038.18 g/head. The T1 treatment produced the highest carcass weight, with a decreasing trend in T2 and T3. The results of this study were higher compared to Purba's Research (2023) which obtained carcass weights in the range of 782.87-914.53 g/head. Research by Haroen and Budiansyah (2019) also reported that the carcass weight obtained was in the range of 674.12-809.87 g/head. This study shows that cutting weight is directly proportional to carcass weight, in line with Mir *et al*. (2017) who stated that carcass production is influenced by live weight and factors such as age, genetics, feed, and health. The addition of glucomannan as a prebiotic improves digestive and metabolic efficiency through stimulation of gut microflora (Khanifah *et al*., 2018) and increases the size of intestinal villi that support nutrient absorption and carcass weight growth (Dev *et al*., 2022).

Carcass percentage

Based on the results of the analysis of variance in Table 4, it shows that the provision of glucomannan extract from porang tubers as a feed additive is not significant (P>0.05) to the percentage of broiler carcasses. with a range of 70.35%-70.82%. These results indicate that the increase in live weight and carcass weight is proportional, so it does not change the proportion of carcass to live weight. Subekti et al. (2012) states that the percentage of carcass tends to remain when the increase in live weight and carcass is balanced. These results are consistent with Bell and Weaver (2002) who reported that the percentage of broiler carcasses ranged from 65-75%. Reported by Daud *et al*. (2007) that the percentage of broilers varied from 65,35-68,04%. Research by Haroen and Budiansyah (2019) also reported that the percentage of carcasses obtained was in the range of 63.06-69.82%. A high carcass percentage indicates good growth and feed efficiency in broilers. An increase in slaughter weight correlates with a greater carcass percentage due to muscle growth (Sitanggang, 2020). Glucomannan increases production efficiency without changing carcass composition, in accordance with the findings of De Antonio *et al*. (2017) and Askri *et al*. (2020) on the role of management and feed quality.

Abdominal fat

According to Table 4, administering glucomannan extract did not have a significant impact on the abdominal fat weight of broiler chickens (P > 0.05). However, there was a numerical trend toward decreased fat weight with increasing doses, with the lowest value observed at the 0.4% dose (T2). While not statistically significant, this decrease is valuable in supporting the production of low-fat carcasses, which consumers prefer. This effect is likely related to glucomannan's mechanism of action as a soluble fibre that increases intestinal viscosity, slows nutrient absorption, and improves blood lipid profiles (Giuntini *et al*., 2022; Nie *et al*., 2024). Additionally, maintaining an appropriate balance of energy and protein in the diet helps prevent fat accumulation, as emphasised by Tumova and Teimouri (2010). The effectiveness of fibre is also influenced by the appropriate dose and duration of administration (Londok and Rompis, 2020). The fat content in this study remained within the physiological range, consistent with Gunawan *et al*.'s (2022) results of 6.94–8.20 g/head.

Abdominal fat percentage

Based on Table 4, the results of statistical analysis showed that glucomannan extract supplementation in feed did not have a significant effect (P>0.05) on the percentage of abdominal fat weight, with values ranging from 0.61% to 0.68%. The results of this study are not much different from the results of research reported by Mahata *et al*., (2008), the percentage of abdominal fat is 0.50-0.61%. Supported by research by Dewanti *et al*. (2013) using fermented water hyacinth, the percentage of abdominal fat ranged from 0.59-0.66%. Research by Pratiwi *et al*. (2017) also reported that the percentage of carcasses in Lohmann strain broilers with their own feed formulation was 0.57%. The effectiveness of glucomannan as a soluble fiber that can increase intestinal viscosity and bind lipids (Brockman *et al*., 2014) may not have been optimal at the dose used in this study. In addition, modern broilers have a genetic tendency to store fat to support rapid growth and feed efficiency (Boyle, 2022), and the proportion of body fat tends to remain stable if the energy-protein ratio in the diet is balanced (Tumova and Teimouri, 2010). This is in line with the findings of Kras *et al*. (2013) who emphasized that energy balance affects fat accumulation more than fiber addition alone.

Administering glucomannan extract from porang tubers has been shown to increase the number of *Lactobacillus acidophilus* and *Lactobacillus casei* colonies and significantly lower the pH of the fermentation medium. This indicates vigorous prebiotic activity. This activity is associated with the increased production of short-chain fatty acids (SCFAs), including acetate, propionate, and butyrate.

These SCFAs play a role in maintaining gut health and improving nutrient absorption (Perdinan and Larasati, 2019; Dev *et al*., 2022). SCFAs also support intestinal villi regeneration and increase the absorption surface area, impacting feed efficiency and muscle tissue growth. These effects account for the significant increase in live weight and carcass percentage observed in treatments T1 and T2.

Broiler meat cholesterol

According to Table 5, administering glucomannan extract from porang tubers had a highly significant effect ($p < 0.01$) on reducing cholesterol levels in broiler chicken meat, in both the breast and thigh. The control group (T0) without glucomannan had the highest cholesterol levels: 76.33 mg/100 g in the breast and 93.36 mg/100 g in the thigh. In contrast, treatments with graded doses of glucomannan (T1–T3) significantly reduced cholesterol levels, achieving the lowest values in T3: 66.80 mg/100 g in the breast and 83.55 mg/100 g in the thigh. These results are consistent with previous findings by Imran *et al*. (2021), who reported cholesterol levels in broiler chicken meat ranging from 78.96 to 90.51 mg/100 g, and by Oktarina *et al*. (2013), who found levels ranging from 60.14 to 86.50 mg/100 g in the breast. Suciani *et al*. (2011) also reported cholesterol levels ranging from 73.26 to 81.27 mg/100 g. The higher cholesterol levels in the thigh compared to the breast are likely due to the thigh having higher intramuscular fat content (Giampietro-Ganeco *et al*., 2021). This study's results indicate that the highest dose of glucomannan extract treatment can reduce chicken breast meat's cholesterol levels to 66.80 mg/100 g, which is substantially lower than the 85 mg/100 g reported by the USDA FoodData Central for skinless roasted broiler chicken breast meat (USDA, 2019). Thus, porang glucomannan shows great promise in producing healthier, low-cholesterol broiler chicken meat that aligns with consumer preferences. Glucomannan may lowers cholesterol by binding bile acids and forming a gel in the gastrointestinal tract (Gallaher et al., 2000; Sato, 2020) and supports lactic acid bacteria that assimilate cholesterol (Fakruddin *et al*., 2024). These results are supported by the findings of Khanifah *et al*. (2018), who reported that adding porang tubers to broiler feed improves nutrient digestibility and reduces cholesterol levels in the birds. Nugraheni *et al*. (2014) demonstrated that glucomannan effectively reduces blood cholesterol levels in rats fed a high-fat diet. Furthermore, Elrayeh and Yildiz (2012) demonstrated that beta-glucan, another type of soluble fibre, can lower cholesterol in broilers through a similar mechanism.

Blood antibody titer

Newcastle disease (ND)

Based on Table 6, the results showed that the provision of glucomannan extract in broiler diets had a significant effect ($P<0.05$) on ND antibody titer. The control treatment (T0) had an average titer of 6.00 $\log_2$, which decreased to 4.30 $\log_2$ at T2 and 4.10 $\log_2$ at T3. These decreases contradict the assumption that prebiotics act as immunostimulants and conflict with the findings of Mohaghegh *et al*. (2017), who reported an increase in ND titer with the administration of esterified glucomannan at low to moderate doses. This phenomenon is likely the result of a dose-dependent immunosuppressive effect. One primary mechanism is glucomannan's high viscosity, which forms a gel in the digestive tract. This gel binds and reduces the availability of essential nutrients for the immune system, such as vitamins A and E, zinc, and selenium. These nutrients are involved in antibody synthesis and lymphocyte proliferation (Tester and Al-Ghazzewi, 2016; Dai *et al*., 2021). Deficiencies in these micronutrients can lead to subclinical malnutrition, which suppresses the adaptive immune response. Additionally, high fibre levels can increase the digestive system's workload, trigger physiological stress, and divert metabolic energy from the immune system to the digestive tract (Kim, 2017). The combination of nutrient absorption disorders and metabolic stress may explain the decrease in ND antibody titers at high doses. Although technical artefacts cannot be entirely ruled out, the consistent pattern of decline suggests that biological effects are dominant. Therefore, caution is required when using high-dose glucomannan, particularly in the context of active vaccination.

Infection bursal disease (IBD)

Based on the results of the IBD antibody titer test presented in Table 6, it can be seen that the average antibody titer of broiler chickens after IBD vaccination on the 10th and 21st days, and examined at 35 days of age. Unlike ND, antibody titers against the infectious bursal disease (IBD) vaccine exhibit a biphasic dose-response pattern. With this pattern, the highest antibody titer (5195.60 units) occurs with low doses (T1: 0.2%), but the positive effect decreases dramatically with higher doses (T2 and T3), falling below the control level. A typical biological phenomenon can

Table 6: Results of ND ($\log_2$) and IBD antibody titer analysis.

Parameters	T0	T1	T2	T3
ND ($\log_2$)	6.00±0.61^{b}	5.30±0.84^{ab}	4.30±0.97^{a}	4.10±1.14^{a}
IBD	2,162.00±2,416.49	5,195.60±3,162.05	2,901.00±3,655.92	1,487.80±2,748.36

ab: Different superscripts on the same line indicate significant differences ($P<0.05$).

explain this inconsistency. At low doses, glucomannan acts as an immunostimulant, increasing the activity of phagocytic and antigen-presenting cells in the intestinal mucosa (Mohaghegh *et al*., 2017; Nidaullah *et al*., 2010). However, at high doses, two mechanisms may explain the opposite effect. First, excessive stimulation of the immune system may trigger a negative feedback loop that maintains homeostasis and prevents excessive inflammation. Second, the increased adsorption capacity of glucomannan at high doses may impair the absorption of immunocritical nutrients, leading to immunosuppressive effects (Tester and Al-Ghazzewi, 2016; Dai *et al*., 2021). These findings confirm that the immunological effects of glucomannan are highly dose-dependent. There is a narrow "therapeutic window" in which glucomannan provides optimal benefits; adverse effects emerge when doses exceed a certain threshold. A dose of 0.2% has been shown to most effectively support antibody responses to IBD, and high doses should be avoided to minimise the risk of immunosuppression.

However, this study has several limitations that need to be acknowledged to ensure a more balanced interpretation of the results. First, claims regarding improved gut health based on performance parameters, such as live weight, have not been supported by histopathological data that confirm changes in intestinal villi morphology. Second, no correlation analysis has been conducted to statistically link the ability of glucomannan to lower cholesterol *in vitro* with actual cholesterol reduction in chicken meat *in vivo*. This limitation opens the door for more comprehensive future research designs, which could include intestinal histological analysis and correlation studies to strengthen the validity of the proposed mechanism.

CONCLUSION AND RECOMMENDATIONS

The best glucomannan extract was obtained from ethanol for 6 hours with high glucomannan content and low calcium oxalate. This extract showed prebiotic activity, improved carcass quality, reduced abdominal fat and cholesterol levels of broiler meat. However, administration at the highest dose (0.6%) caused a significant decrease in ND and IBD antibody titers, indicating potential suppression of the immune response. These findings suggest a dose-dependent trade-off: A 0.4% dose is optimal for improving carcass parameters, while a 0.2% dose is more effective in supporting immune function. Therefore, selecting the appropriate dose is crucial when applying glucomannan as a feed additive. Further research is needed to explore the underlying mechanisms, evaluate long-term safety, and confirm these results on a larger scale.

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NOVELTY STATEMENT

The novelty of this study is an integrated approach that optimises the extraction of glucomannan from porang tubers by varying solvents and extraction times. Then it validates the results through in vitro (prebiotic activity and cholesterol reduction) and in vivo (carcass quality, meat cholesterol content, and immune response of broiler chickens) tests. This combination of extraction optimisation with both in vitro and in vivo validation has not been previously reported for porang glucomannan.

AUTHOR'S CONTRIBUTION

Desti Prestasi Zendrato: Carrying out experiments, conducting laboratory analysis, analyzing data, and drafting manuscripts. Nevy Diana Hanafi: Supervised the execution of the experiments and revised the manuscript. Elisa Julianti: Supervised the execution of the experiments. Ma'ruf Tafsin: Designed and supervised the experiment. All authors are responsible for reading and approval of the final manuscript.

Conflict of interest

The authors have declared no conflict of interest.

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