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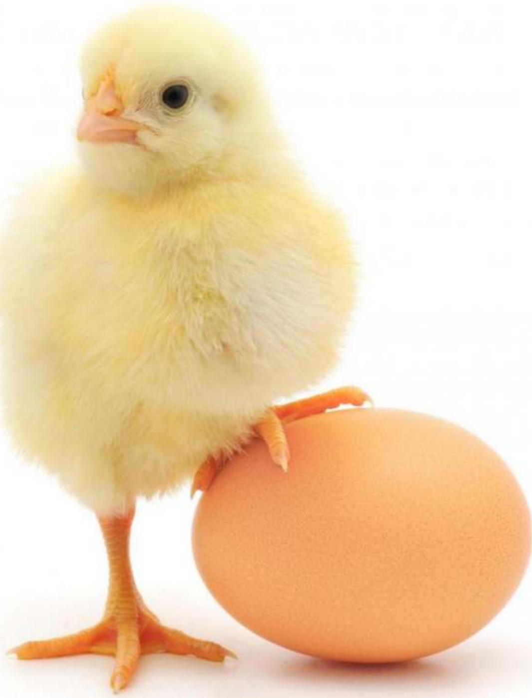

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Research Article
Effect of Palm Polysaccharides on Growth Performance, Feed Digestibility and Carcass Percentage of Broilers

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Abstract
Objective: A study was conducted to determine the effect of diets supplemented with several palm polysaccharides on chicken performance, fecal moisture, feed digestibility and carcass percentage. **Methodology:** A total of 168 unsexed broiler chicks were used in this trial. The broiler chicks were kept for 4 weeks. The broilers were then transferred into metabolism cages for 1 week for digestibility and fecal moisture studies. On day 35, the broilers were sacrificed by cervical dislocation for carcass measurements. The broiler chickens were fed with starter (23% protein and 13.39 MJ of metabolizable energy) and grower (21% protein and 13.39 MJ of metabolizable energy) diets. Feed and water were provided *ad libitum*. Six different types of diets: Control (C), control+2 ppm avilamycin (C+avi), control+0.05% copra polysaccharide (C+cop), control+0.05% salak polysaccharides (C+salak), control+0.05% sugar palm polysaccharides (C+sug palm) and control+0.05% sago polysaccharides (C+sag) were used. A completely randomized design was used with six treatments and four replicates of 7 birds each. **Results:** The study indicated that diets supplemented with avilamycin, copra polysaccharides and salak polysaccharides increased body weight gain ($p<0.05$) compared to the control birds. Feed conversion ratio was improved due to salak polysaccharide supplementation. A decreased fecal moisture was found in birds fed the diet supplemenetd with avilamycin and sago polysaccharides. The addition of avilamycin, copra and salak polysaccharides in the diets increased feed digestibility. **Conclusion:** Supplemented diet significantly increased the body weight gain, feed conversion ratio, feed digestibility and decreased the fecal moisture.

Key words: Palm polysaccharides, growth performance, feed digestibility, carcass percentage, sugar palm

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Indonesia produces a variety of palm trees such as coconut (*Cocos nucifera*), sugar palm (*Arenga pinnata*), sago (*Cycas revoluta*) and snake fruit or salak (*Salacca zalacca*) that provide large quantities of fruit. Attempts have been made to increase the feed value of palm fruits through physical[1] and enzymatic treatments[2], pelleting[3] and fermentation[4] with limited success. Instead of focusing on increasing fruit quality, extracting their carbohydrates, particularly mannose-based carbohydrates, as a feed additive might help to optimize the utilization of palm fruits for poultry feed. The use of palm carbohydrates to replace antibiotic growth promotants was initially reported by Sundu *et al.*[5]. Duesterhoft *et al.*[6] investigated the carbohydrate content of some feedstuffs, including coconut meal and palm kernel meal. The authors found that the main component of monosaccharides in these two palm nuts was mannose. Knudsen[7] and Balasubramaniam[8] reported that these two palm nuts mainly contain mannose-based polysaccharides, either in the forms of mannan or galactomannan.

Studies on mannose-based polysaccharides produced different conflicting results, depending upon the source of mannose-based polysaccharides[5]. Mannose-based polysaccharides from legumes (soybean meal) have been reported to have adverse effects on the growth of broiler chickens[9]. Galactomannan in legumes created viscous digesta and thus rendered nutrients unavailable for poultry[9]. Yeast mannans, on the other hand, behave differently. These substances have prebiotic properties due to their capacity to bind pathogenic bacteria, such as *E. coli and Salmonella*[10]. These findings triggered Sundu *et al.*[5] to intensively study the efficacy of palm polysaccharides in poultry diets. Studies on coconut polysaccharides[11] and palm kernel polysaccharides[12] as feed additives to replace antibiotic growth promotants for broiler chickens showed promising results. The body weight gain of birds fed with coconut and palm polysaccharides was better than those of birds fed the control diet.

Since 70% of palm kernel carbohydrates and 80% of coconut carbohydrates were mannose-based polysaccharides[6], these carbohydrates have the potential to be utilized as a feed additive because their properties may be similar to yeast mannan. It can be hypothesized that other palm polysaccharides, such as sugar palm nuts, sago nuts and snake fruit nuts, might have the same efficacy as found in the coconut and palm kernel meal. This study was, therefore, conducted to determine the effects of polysaccharides from several palm fruits (coconut, sugar palm, sago and snake fruit) on growth performance, feed digestibility and carcass percentage of broilers kept for 4 weeks.

MATERIALS AND METHODS

Production of palm polysaccharides: Palm nuts (coconut, sugar palm, sago and snake fruit) were sun-dried for 3 consecutive days and finely ground. The finely ground palm fruits had their oil contents extracted by using hexane. Each de-oiled fine-ground palm fruit had its polysaccharides extracted based on the methods described by Kusakabe and Takashi[13]. An alkaline solution (20% NaOH) was used in this extraction as a solvent with a ratio of 16 L NaOH to 2 kg palm fruit nuts as substrates. The mixture of substrate and solution was then regularly stirred for 24 h at room temperature. The mixture was then centrifuged to obtain the filtrate. An acid solution of 12 N H_2SO_4 was used to neutralize the filtrate until the pH solution reached approximately 5.5. The leftover residue was collected by centrifugation and dialyzed against distilled water to remove salts. The residue found in the extraction process was composed of polysaccharides.

Birds and managements: The study was conducted in the poultry station at the University of Tadulako, Palu, Indonesia. Experimental procedures used in this study were approved by an Animal Ethics Committee at the Faculty of Animal Husbandry and Fisheries, University of Tadulako, Indonesia. A total of 168 unsexed Cobb chicks were used. Birds were purchased from a commercial hatchery and weighed individually. The broiler chicks were randomly placed in six circular brooder cages (treatments) for 1 week and then transferred into 28 pens. The birds were vaccinated at day 3 against Newcastle disease. Broiler chickens were kept for 4 weeks. Each pen was equipped with a plastic feeder and a plastic drinker. The drinkers were cleaned whenever necessary. Basal diets (Table 1) were formulated by using a

Table 1: Basal diet and chemical composition

Feed ingredients	Starter diet (%)	Grower diet (%)
Full fat soybean meal	24.99	18.97
Corn	60.20	62.10
Fish meal	10.00	11.00
Rice bran	3.38	4.00
Dicalcium phosphate	1.03	0.92
Salt	0.07	0.66
Methionine	0.15	0.55
Lysine	0.05	0.11
Premix (© Topmix)	0.20	0.20
Calculated nutrients		
Crude protein	23.13	21.00
Crude fiber	3.50	3.60
Metabolizable energy (MJ kg^{-1})	13.39	13.39
Lysine	1.10	1.00
Methionine+cystiene	0.90	0.79
Selenium (ppm)	0.26	0.19
Calcium	1.11	1.02
Phosphorus	0.72	0.70

software of UFFF[14] created by the Department of Poultry Science and Agricultural Economics at the University of Georgia, Atlanta. Birds were offered experimental diets (Table 2) from day 1-21 and the birds were fed starter diets and grower diets from days 21-28. The experimental diets and water were offered for *ad libitum* consumption. The surroundings of all pens were cleaned regularly throughout the study. The broiler chickens were scheduled to have 20 h of light and 4 h of darkness throughout the study.

Measurements

Feed digestibility and carcass traits: The birds were placed in metabolism cages for 1 week for digestibility study from days 29-35 and the birds were fed grower diets. During the study, feces were collected on the plastic trays under the pen. The fecal collection was done for 3 days from days 33-35 and any foreign materials, such as feed particles and feathers, were discarded. The fecal discharges were weighed and then oven-dried to measure fecal moisture and feed digestibility.

One day after the digestibility study, three birds per replicate pen were randomly selected for carcass measurements on day 36. The birds were sacrificed by cervical dislocation. A mechanical plucker with revolving tuber fingers was used to remove the feathers. The eviscerated birds were dressed by removing the neck, shank and digestive tract and organs, based on the concept developed by Jensen[15]. The carcasses were individually weighed and expressed as a percentage of live body weight.

Statistical analysis: The study used a completely randomized design with six treatments and four replicates of 7 birds each cage. Data from each individual cage, as an experimental unit collected from the studies, were analyzed by one-way analysis of variance using a Minitab 14 Statistical Program[16]. Differences in analysis of variance were considered to be statistically significant at $p<0.05$ and differences among treatment means found in the analysis of variance were further tested by Tukey's test[17].

RESULTS AND DISCUSSION

Effects of diets on growth performance: The effects of diets on body weight gain, live body weight, feed intake and feed conversion ratio are shown in Table 3. Supplementation of the diets with either antibiotics or palm polysaccharides significantly increased ($p<0.05$) body weight gain and live body weight. There were increased in live body weight between 44 and 89 g due to feed additive supplementation. The birds fed the diets supplemented with antibiotic avilamycin, copra polysaccharides and salak polysaccharides had higher body weight gain and live body weight ($p<0.05$) than those of birds fed the control diets. Feed intake of birds fed the experimental diets varied from 1372-1511 g. However, the differences in feed intake were not statistically significant ($p>0.05$). The effect of diets on FCR was significant ($p<0.05$). Supplementation of diets with salak polysaccharides produced better FCR ($p<0.05$) than those of control diets. However, there was no significant difference ($p>0.05$) found among the diets supplemented with feed additives (antibiotic or palm polysaccharides).

The birds fed the diets supplemented with antibiotic avilamycin were 10% heavier than those birds fed the control diets. The efficacy of using antibiotic to promote growth has been reported by Leitner *et al.*[18]. The rationale of the improved body weight gain due to antibiotic supplementation in the diets is through the capacity of antibiotics to reduce the burden of pathogenic bacteria and thus maintain the health status of the digestive tract. A previous study indicated that the supplementation of the diets with antibiotic avilamycin

Table 2: Experimental diets

Treatments	Type of additives	Replicate cages
C	Control basal diet	4
C+avi	Control+2.0 ppm antibiotic avilamycin	4
C+cop	Control+0.05% copra polysaccharides	4
C+salak	Control+0.05% salak polysaccharides	4
C+sug palm	Control+0.05% sugar palm polysaccharides	4
C+sag	Control+0.05% sago polysaccharides	4

Table 3: Effect of type of diets on body weight gain, feed intake and FCR of broilers kept for 4 weeks

	Parameters			
Treatments	BWG (g)	Live weight (g)	Feed intake (g)	FCR
C	877 ± 8.1^{b}	917.0 ± 8.2^{b}	1415 ± 62.0^{a}	1.61 ± 0.06^{a}
C+avi	965 ± 9.0^{a}	1006.0 ± 9.1^{a}	1411 ± 46.2^{a}	1.46 ± 0.04^{ab}
C+cop	973 ± 50.8^{a}	1013.0 ± 50.8^{a}	1461 ± 75.8^{a}	1.50 ± 0.03^{ab}
C+salak	965 ± 24.2^{a}	1005.0 ± 23.7^{a}	1322 ± 46.7^{a}	1.37 ± 0.03^{b}
C+sug palm	923 ± 9.2^{ab}	963.0 ± 8.9^{ab}	1398 ± 57.1^{a}	1.52 ± 0.06^{ab}
C+sag	921 ± 18.2^{ab}	961.0 ± 17.8^{ab}	1388 ± 35.3^{a}	1.51 ± 0.03^{ab}

BWG: Body weight gain, FCR: Feed conversion ratio, Different superscript within a column was significantly different ($p<0.05$)

Table 4: Fecal moisture, feed digestibility and carcass percentage of broilers fed diets supplemented with antibiotic and palm polysaccharides

	Parameters (%)			
Treatments	Fecal moisture	Feed digestibility	Carcass	Breast muscle
Control	79.2±0.85[a]	75.2±0.90[b]	68.6±8.7[a]	23.3±0.42[a]
Control+avi	74.5±0.43[bc]	82.4±0.65[a]	67.8±9.3[a]	22.7±0.45[a]
Control+cop	76.5±0.71[abc]	82.9±1.00[a]	71.2±1.30[a]	24.2±0.22[a]
Control+salak	77.9±1.49[ab]	83.0±0.43[a]	71.2±0.40[a]	24.2±0.35[a]
Control+sug palm	76.9±1.21[abc]	78.1±1.40[b]	69.8±0.67[a]	24.5±0.25[a]
Control+sag	73.4±0.96[c]	76.6±0.94[b]	69.3±1.02[a]	23.2±0.62[a]

did not negatively affect body weight gain of birds challenged against *E. coli* with 1.5×10^8 CFU mL^{-1} on days 8, 10 and 12[16]. However, the birds fed the control diet (unsupplemented), challenged against *E. coli* in the drinking water had lower body weight gain than those of birds fed with antibiotic-supplemented diets[19].

The use of copra polysaccharides and salak polysaccharides increased body weight gain of birds kept for 4 weeks from 877-965 and 973 g. Sundu *et al.*[11] reported that the main monosaccharide present in NaOH-extracted coconut was mannose, while in salak palm polysaccharides were glucose and galacturonic acid. As the main component of coconut polysaccharide was mannose, it could be speculated that the way this polysaccharide behaves to promote growth was similar to yeast mannan. Mannose-based polysaccharides had the capacity to bind pathogenic bacteria in the digestive tract of birds[11]. Fitryani[20] challenged the broiler chickens against *E. coli* in their drinking water and offered diets supplemented with coconut polysaccharides that were mainly mannose-based. Fitryani[20] found that diarrhea incidence was decreased due to coconut polysaccharide supplementation and body weight gain was not adversely affected. The prebiotic properties found in coconut polysaccharides might play roles in positively influencing the growth of broiler chickens.

Since salak polysaccharides (rich in pectin as a polymer of galacturonic acid) are different from coconut polysaccharides (mainly mannose), the growth-enhancing mechanism of this carbohydrate present in salak palm might also differ from coconut polysaccharides. A study by Gomez *et al.*[21] indicated that pectic oligosaccharides, a galacturonic acid-based carbohydrate, could increase the population of beneficial bacteria *Bifidiobacteria* and *Lactobacilli* from 19 to 29-34% in human feces. The main goal for the inclusion of galacturonic acid-based polysaccharides, which are mainly present in salak palm, is to enhance populations of beneficial bacteria rather than flushing out the pathogenic ones. Other polysaccharides used in this study (palm sugar nut and sago nut polysaccharides) might have different properties and thus could not function as prebiotics in this particular diet formulation. Unfortunately, there was no study on these two palm nuts reported in the database, either as a feed ingredient or as a feed additive.

Feed intake of birds was not affected by the addition of feed additives in diets. Since feed intake was largely dependent upon nutrient content, particularly metabolizable energy[22], the very small quantity of antibiotic and polysaccharide additions in the diet did not increase metabolizable energy of the diets and thus did not affect feed consumption. The birds fed the diet supplemented with salak polysaccharides had better FCR than the control diet. This indicates that the increase in body weight gain of birds in the present study was due to the increased feed intake.

Effect of diets on fecal moisture: Table 4 shows fecal moisture, feed digestibility, carcass percentage and breast muscle of broilers. The effect of diets on fecal moisture was significant ($p<0.05$). The supplementation of diets supplemented with either antibiotic or palm polysaccharides decreased fecal moisture from 79% to between 73 and 78%. The broiler chickens fed the diets containing antibiotic avilamycin and sago polysaccharides had drier feces ($p<0.05$) than those control birds.

Fecal moisture of the birds fed diets containing antibiotic avilamycin and sago polysaccharides was drier than the birds fed the control diet. The mechanisms of the reduction of fecal moisture due to the addition of antibiotic and sago polysaccharides were unclear. Researchers speculate that birds fed antibiotics had healthier digestive tracts as a result of decreased pathogenic bacteria populations, which might be the reason for drier fecal discharges.

Sundu *et al.*[11] fed the *E. coli*-challenged birds with diets containing avilamycin and found an increased fecal dry matter of birds fed the antibiotic avilamycin-supplemented diets from 18.9% (control diets) to approximately 25%. Gaucher *et al.*[23] also reported that the birds kept in the drug-free flocks had higher fecal moisture, possibly due to an altered digestive function or the incidence of clinical and subclinical forms of necrotic enteritis. The same logic could be examined to elaborate upon the decreased fecal moisture of birds fed the diet supplemented with sago polysaccharides. However, further study is needed to prove this speculation by determining the chemical components of sago nut polysaccharides, particularly the monosaccharide profile.

Effects of diets on feed digestibility: Table 4 shows the feed digestibility was affected by the diets ($p<0.05$), in which antibiotic and palm polysaccharide supplementation increased feed digestibility from 75% to between 77 and 83%. The diets with avilamycin, copra polysaccharides and salak polysaccharides were more digestible ($p<0.05$) than the control diet and the diets supplemented with sugar palm polysaccharides and sago polysaccharides.

It is widely believed that antibiotic growth promoters could lower the population of bacteria in the digestive tracts of broilers. This condition could decrease the incidence of infection and thus reduce the use of nutrients by bacteria in the digestive tract. The decreased utilization of nutrients by bacteria could improve absorption of nutrients from the small intestine by thinning the intestinal mucosa[24] and thus increase feed digestibility. The increase in feed digestibility of the diets containing coconut and salak nut polysaccharides might follow the same mechanism as the antibiotic use. This rationale was supported by Lyons[10], who stated that yeast mannan (yeast polysaccharides) had the capacity to flush pathogenic bacteria, particularly *E. coli* and *Salmonella* sp., out of the digestive tracts of broiler chickens. These findings might encourage the use of palm nut polysaccharides (coconut and salak nut) to be used as growth-promoting feed additives. However, other palm polysaccharides (sago nut and sugar palm polysaccharides) could not increase feed digestibility significantly when the broiler chickens were kept for a month.

Effects of diets on carcass percentage: Table 4 shows the carcass and breast meat percentages. Although the body weight gain of birds was affected by the treatment diets, carcass and breast muscle percentages of the birds were not affected by the treatment diets ($p>0.05$).

Carcass percentages of birds fed the diets supplemented with palm polysaccharides increased from 68.6 to 69-71%, but carcass and breast meat percentages were not significantly affected by treatments. These current results support the previous findings of Toghyani *et al.*[25], who reported that supplementation of the diets with prebiotics, antibiotics, or probiotics failed to increase carcass percentages.

In overall, although there were increases in growth performance, feed digestibility and fecal dry matter, the economic effectiveness and environmental aspects of using palm polysaccharides in animal diets need to be considered. This is because the use of relatively high concentrations of sodium hydroxide (20% NaOH) could increase feed cost. The liquid waste discarded after extraction may deteriorate the environment if the palm polysaccharides are produced in large quantities. It is necessary to determine the minimum useful concentration of NaOH in order to minimize resulting economic and environmental problems.

CONCLUSION

Supplementation of the broiler chickens diets with either palm polysaccharides or antibiotic avilamycin increased the live weight and body weight gain of birds. The feed conversion ratio was improved by salak polysaccharide supplementation. Moreover, the uses of antibiotic avilamycin and salak polysaccharides decreased fecal moisture. Feed digestibility was increased as a result of antibiotics, copra and salak polysaccharide supplementation. Feed intake and broiler carcass percentages were not affected by the supplementation of the diets with antibiotic and palm polysaccharides.

SIGNIFICANCE STATEMENT

The current study discovers NaOH-extracted polysaccharides from palm nuts (coconut, salak nut, sugar palm nut and sago nut). The extracts had several benefits, such as improving body weight gain and FCR and improving environmental status by increasing feed diegstibility and decreasing fecal moisture.

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