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Full Paper

Growth response of broilers given varying levels of bamboo-derived wood vinegar via drinking water

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Abstract

Wood vinegar has been used as a feed supplement and antibiotic alternative in livestock. This study assessed the growth response and profitability of wood vinegar in broilers given varying levels of wood vinegar via drinking water. A total of 100 broilers were randomly assigned to four treatments: T_0: 0% wood vinegar (control), T_1: 2% wood vinegar, T_2: 3% wood vinegar, and T_3: 4% wood vinegar, replicated five times with five birds per replication laid out in a Completely Randomized Design. The results revealed that the weekly feed intake (WFI) in Days 9-15 was significantly different across the four treatments, and the lowest WFI was observed in T_0 and T_3. No significant difference was noted on cumulative weight gain (CWG), average daily weight gain (ADWG), and feed conversion ratio (FCR). Cost analysis revealed that T_3 resulted in return above feed and wood vinegar and animal cost (RAFWVAC), net income (NI), and return on investment (ROI) of PhP36.10 (USD 0.75), PhP12.52 (USD 0.26) and 9.56%, per bird. Further studies can investigate treatments with higher or lower wood vinegar concentration, and analyze the organic components, anti-microbial property, bioactive compounds, and toxicity of wood vinegar to provide a clearer explanation of the findings.

Keywords - broilers, drinking water, growth response, profitability, wood vinegar

Introduction

Poultry has been a significant contributor to the agriculture sector in the Philippines (Philippine Council for Agriculture, Forestry and Natural Resources Research and Development [PCARRD], 2015). It is one of the progressive farm animal enterprises and a major contributor to meat production. In modern systems of broiler production, birds are exposed to continuous and long-term use of antibiotics to control diseases and to improve growth performance (Baurhoo et al. 2009; Samli et al. 2007). The problem with continual use of antibiotics is that animal tissues can contain drug residues which can be consumed by humans (Andi et al. 2011). In the Philippines, all 38 out of the sampled 39 broiler farms spread across various regions reported the use of at least one antimicrobial active ingredient, most notably enrofloxacin (Barroga et al., 2020), which is a fluoroquinolone whose approval had already been withdrawn by the United States Food and Drug Authority (2017). As a result, government regulations and consumer perception are driving the need to develop antibiotic alternatives such as probiotics or other substances for the promotion of microbial growth (Han et al., 2007).

Some potential alternatives to antibiotics are probiotics or live microbial feed supplements (Fuller, 1989) and short-chain fatty acids or organic acids like wood vinegar (Bagal et al. 2016; Dahiya et al. 2016; Van Immerseel et al., 2005). This study investigated wood vinegar (WV) as an antibiotic alternative for poultry production. wood vinegar is the more common term for pyroligneous acid, and

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is a byproduct of charcoal production. The liquid is generated from the gas and combustion of fresh wood burning in airless condition. Wood vinegar can be sourced from various plant materials such as bamboo (Mu et al., 2004; Yan et al., 2012), mangosteen (Rodjan et al., 2018), eucalyptus (Diógenes et al., 2019), broad-leaf trees (Samanya & Yamauchi, 2001) and coconut shells (Wititsiri, 2011). It contains 280 different organic acids, 12 minerals, and 13 microelements that can activate physiological functions in animals (Kim, 1996). Its principal components include acetic acid, methanol, phenol, ester, acetals, ketone, formic acid, and many others (Santos et al. 2013; Yoshimoto, 1994). Wood vinegar is also known as a natural organic acid (Sasaki et al. 1999) that can modify intestinal microflora by maintaining a low pH of gastric contents (Burnell et al., 1988; Kirchgessner & Roth, 1982; Thomlison & Lawrence, 1981). The recommendation is to blend wood vinegar with water in a ratio of 1:50, or up to 1:800 (Food and Fertilizer Technology Center for the Asia Pacific Region, 2005), to be used as drinking water or as a feed fermenter to facilitate fermentation.

In swine, wood vinegar has been shown to provide beneficial effects. Pigs fed 0.1, 0.2 and 0.3% wood vinegar diets exhibited significantly higher average daily weight gain (ADWG) and average daily feed intake (ADFI) than those without wood vinegar supplementation (Choi et al., 2009). Further, higher concentrations of wood vinegar resulted in higher ADWG and ADFI. In another study (Yan et al., 2012), bamboo vinegar diets resulted to a significantly higher ADWG and gain:feed (G:F) ratio in pigs, as compared to a control group from 0 to 3 weeks and 0 to 6 weeks. Moreover, in their study, the fecal *Escherichia coli* (*E. coli*) numbers were reduced by increasing bamboo vinegar supplementation. The mechanisms related to the positive effects of wood vinegar may be influenced by the general characteristics of the organic compounds, leading to improvement of the gastrointestinal tract, enhancement of nutrient digestibility, and the competitive elimination of pathogenic bacteria (Khan & Iqbal, 2016).

Although the benefits of wood vinegar for swine have been observed, the results on the effects of wood vinegar or other organic acids on feed efficiency, growth, and gut microbiota of poultry are inconsistent. On one hand, there are documented advantageous effects of organic acids and vinegars on the general health, growth and feed efficiency of broilers (Bagal et al. 2016; Samanya & Yamauchi, 2001), laying hens (Dahiya et al. 2016), and quails (Diógenes et al. 2019). For example, Diógenes et al. (2019) found that the effects of wood vinegar varied when quails were housed in fresh or recycled bedding. The use of 2.5% wood vinegar resulted to decreased feed consumption and feed conversion ratio (FCR) and increased weight gain in quails housed in recycled bedding. However, there was no significant difference in final weight, feed consumption, and weight gain in quails housed in fresh bedding. Similarly, Samanya and Yamauchi (2001) observed that including wood vinegar derived from a broad-leaf tree in drinking water resulted to significantly higher body weight gain in Comb White Leghorn chickens. Finally, Allahdo et al. (2018) concluded that the addition of probiotic and apple vinegar in drinking water led to a significant decrease in ADFI and FCR of chicks 1-10 days of age as compared to those without any supplementation.

On the other hand, there are studies that showed no significant effect of wood vinegar on various growth parameters. Hanchai et al. (2021) found that supplementation of wood vinegar in drinking water did not influence body weight gain (BWG), feed intake (FI), or FCR during the starter (1-21 days old), grower (22-35 days old), and whole (1-35 days old) growth periods. Moreover, Ruangwittayanusorn et al. (2018) concluded that the supplementation of wood vinegar in diets showed no adverse effects on the growth performance of broilers. Similarly, Allahdo et al. (2018) reported that during the starter periods (1-10 days of age), supplementation with wood vinegar in drinking water improved the feed efficiency of broiler chickens but there was no difference on BWG, FI, and FCR for the whole growth periods (1-42 days of age). Hernández et al. (2007) and Lertpatarakomol et al. (2012) also showed that supplementing drinking water with organic acids did not affect BWG and FCR of broiler chickens.

Wood vinegar also did not show any effect on gut microbiota of poultry. Hanchai (2021) found that wood vinegar supplementation in drinking water had no effect on cecal microbial (lactic acid bacteria and *E. coli*) between treatments. Likewise, the same study showed that the number of salmonella, coliform, and lactic acid bacteria in feces and intestine were not affected by raw and distilled wood vinegar supplementation in the diet.

The inconsistencies in the effects of wood vinegar on poultry can be due to several factors such as the buffering capacity of dietary ingredients, the amount of antimicrobial compounds, the composition of gut microbiota, and the sanitary condition of the growth environment (Dibner & Buttin, 2002). Thus, additional studies on the effects of wood vinegar on the growth performance of broilers are warranted. Further, the Philippine Department of Agriculture Region 8 is promoting the use of wood vinegar as a feed supplement and antibiotic alternative for livestock through the establishment of wood vinegar plants (Department of Agriculture Region 8, 2013). The effects of the wood vinegar produced by these plants had not yet been investigated. There has also been no previous study of the profitability derived from the use of wood vinegar when added via the drinking water. The present study aimed to evaluate the efficacy of varying levels of wood vinegar sourced from bamboo as a drinking water supplement on growth performance of broilers, and to assess the profitability of using wood vinegar in raising broilers.

Methodology

Bird Management and Experimental Design

All management procedures for this research followed the protocol of animal handling ethics, and the stand procedure for health management as prescribed by the Philippine National Standard (Department of Agriculture Bureau of Agriculture and Fisheries Standards, 2016) was followed for the entire duration of the experiment. A total of 100 one-day-old broiler chicks (Cobb 500 strain) were obtained from a commercial hatchery and were selected based on the criteria for assessing chick quality as described by Lambio (2010). The birds were then brooded for eight days with a maintained temperature of 32ºC. On day nine of age, the birds were housed in experimental cages that were properly prepared and randomly assigned to four treatments, replicated five times, with five birds per replication laid out in a Completely Randomized Design (CRD). The temperature was gradually decreased by 2.5 ºC weekly to a constant temperature of 20-24ºC at 24 days of age. The birds had continued access to feeds and drinking water. The drinking water contained an amount of wood vinegar according to the treatments. No mortality occurred in the entire duration of the experiment.

The wood vinegar used in this study was sourced from bamboo and acquired in 1-liter bottles from the production area of Abuyog Experiment Station, Abuyog, Leyte, Philippines. The experimental drinking water was prepared in four treatments with different concentrations of wood vinegar in plain water (PW), specified as follows.

- T_0: 0% wood vinegar (control) (1000mL PW)
- T_1: 2% wood vinegar (20 mL wood vinegar and 980 mL PW)
- T_2: 3% wood vinegar (30 mL wood vinegar and 970 mL PW)
- T_3: 4% wood vinegar(40 mL wood vinegar and 960 mL PW)

No antibiotic was added to the feeds or the drinking water. For Treatments T_1, T_2, and T_3, wood vinegar was used as a food supplement and directly added twice daily (8:00 AM and 3:00 PM) to the drinking water. Feeding was given to birds ad libitum based on the recommended daily commercial feed requirement of broilers with three commercial diet formulas for starter (1-10 days), grower (11-21 days), and finisher (22-37 days). The main ingredients of feed formulation included the following: 19.0% Crude Protein Min., 3.0% Crude Fat Min., 2900 Metabolizable Energy Kcal/Kg, 6.0% Crude Fiber Max., 0.90-1.10% Calcium, 0.55% Phosphorus Min., and 12.0% Moisture Max. The daily feed consumption of the chicks in each replicate was recorded. The initial body weight was recorded at the time of the initial application of treatments (Day 9). Body weight and feed intake were also recorded at weekly intervals for four weeks starting at Day 9.

Data Gathered

The following parameters were gathered during the experiment.

1. Weekly feed intake (WFI) - the total amount of feed consumed per broiler every week, calculated as

$$\text{WFI (g/bird)} = \frac{\text{Feed offered} - \text{Feed refused}}{\text{Number of birds}}$$

2. Cumulative weight gain (CWG) - the amount of weight gained

$$\text{CWG (g)} = \text{Final weight} - \text{Initial weight}$$

3. Average daily weight gain (ADWG) - the average gain in body weight per day, calculated as

$$\text{ADWG (g)} = \frac{\text{Final weight} - \text{Initial weight}}{\text{Number of feeding days}}$$

4. Feed conversion ratio (FCR) - the amount of feed required to produce one kilogram live weight, calculated as

$$\text{FCR} = \frac{\text{Feed consumed}}{\text{Cumulative weight gain}}$$

5. Return above feed, wood vinegar and animal cost (RAFWVAC), calculated as

RAFWVAC = Final weight (FW) (kg) × Price/kg of FW – Feed intake (kg) x Price/kg of feeds – Cost of WV – Cost of day-old chick

6. Revenue = Final weight x Price/kg

7. Net Income (NI) = Revenue – Total cost

8. Return of Investment (ROI)

$$= \frac{\text{Net income}}{\text{Total cost}} \text{ X } 100\%$$

Statistical Analysis

The data reported in this paper are based on the means of the five replicates. A one-way Analysis of Variance (ANOVA) was used to test for significant differences in WFI, CWG, ADWG, and FCR across all treatments at 5% level of significance. Post-hoc analysis was performed using the Least Significant Difference (LSD) test. The Statistical Package for Social Sciences (SPSS) software version 20.0 was used for all statistical analyses.

Results and Discussion

Weekly Feed Intake

Table 1 shows the WFI of the broilers across all treatments. The varying concentrations of wood vinegar resulted in significant differences in the WFI of the broilers at Days 9-15 (p = 0.013) and 16-22 (p = 0.005), but no significant difference was noted at Days 23-29 (p = 0.593) and 30-36 (p = 0.663). Post-hoc analysis shows that in Days 9-15, the only clear significant difference was between T_2 and T_3, where the feed intake in the 4% wood vinegar concentration was significantly lower than that in the 3% wood vinegar concentration. In Days 16-22, the WFI in T_0, T_1, and T_3 were significantly lower than the WFI in T_2, with the lowest WFI observed in T_3. These findings are in agreement with those of Allahdo et al. (2018), who stated that the reason for lower feed intake in high wood vinegar concentrations might be that the organic acids produced a strong taste that reduced the bird's appetite. However, in the present study, WFI was reduced only at the early stages of growth, suggesting that the birds may have adapted to the taste. Further, as with previous studies (Diógenes et al., 2019; Hanchai et al., 2021), there was no consistent trend in WFI with respect to wood vinegar concentrations. A significant decrease in food intake was observed when vinegar was paired with a probiotic in the drinking water (Allahdo et al., 2018), which was not the case in this study.

Cumulative Weight Gain, Average Weight Gain, and Feed Conversion Ratio

Tables 2, 3, and 4 present the CWG, ADWG, and FCR, respectively. The CWG, ADWG, and FCR of broilers were not significantly affected (p > 0.05) by varying levels of wood vinegar via drinking

Table 1. Weekly feed intake (g/bird) of broilers given varying levels of wood vinegar via drinking water.

Treatment	Day			
	9-15	16-22	23-29	30-36
$T_{0:}$ 0% WV	310.54^{ab}	808.14^{a}	1554.77	2405.71
$T_{1:}$ 2% WV	307.57^{ab}	814.29^{ab}	1550.10	2387.20
$T_{2:}$ 3% WV	314.54^{b}	823.76^{b}	1556.26	2388.88
$T_{3:}$ 4% WV	296.63^{a}	804.22^{a}	1526.01	2361.95
p-value	0.013*	0.005**	0.593	0.663

** Column means with no common superscripts are significantly different (p < 0.01) from each other.
* Column means with no common superscripts are significantly different (p < 0.05) from each other.

Table 2. Initial, final, and cumulative weight gain (CWG) (g) of broilers given varying levels of wood vinegar via drinking water.

Treatment	Initial weight (Day 9)	Final weight (Day 36)	CWG	% increase
$T_{0:}$ 0% WV	116.92	1416.36	1299.44	1111%
$T_{1:}$ 2% WV	116.07	1411.10	1295.03	1116%
$T_{2:}$ 3% WV	117.51	1403.86	1286.35	1095%
$T_{3:}$ 4% WV	115.40	1434.94	1319.55	1143%
p-value	0.975	0.971	0.965	

Table 3. Average daily weight gain (ADWG) (g/day) of broilers given varying levels of wood vinegar via drinking water.

Treatment	Day			
	9-15	16-22	23-29	30-36
$T_{0:}$ 0% WV	42.23	43.22	45.05	46.41
$T_{1:}$ 2% WV	39.91	41.75	44.65	46.25
$T_{2:}$ 3% WV	41.88	42.36	50.37	45.94
$T_{3:}$ 4% WV	40.26	43.41	48.75	47.13
p-value	0.441	0.537	0.449	0.965

Table 4. Feed conversion ratios of broilers given varying levels of wood vinegar via drinking water.

Treatment	Day			
	9-15	16-22	23-29	30-36
$T_{0:}$ 0% WV	1.05	1.33	1.65	1.86
$T_{1:}$ 2% WV	1.11	1.40	1.67	1.86
$T_{2:}$ 3% WV	1.07	1.40	1.65	1.86
$T_{3:}$ 4% WV	1.05	1.32	1.61	1.80
p-value	0.508	0.205	0.894	0.804

water. Despite the insignificant results, the 4% wood vinegar supplementation produced numerically higher CWG and ADWG and lower FCR value among treatments. The result is consistent with non-significant results on ADWG and carcass yield when apple vinegar was used (Allahdo et al., 2018). Apparently, the positive effects of organic acids such as wood vinegar on growth performance are more consistent in swine than in poultry (Choi et al., 2009; Dibner & Buttin, 2002; Yan et al., 2012). For poultry, the effects of wood vinegar on growth parameters are greater in less sanitary environments (Diógenes et al. ,2019), which was not the case in this study. In cleaner environments, results do not show a clear positive effect of wood vinegar in growth performance (Hernández et al., 2006).

Return Above Feed, Wood Vinegar and Animal Cost (RAFWVAC)

Table 5 presents the RAFWVAC for all treatments. The differences in feed cost among treatments were computed based on the actual

Table 5. RAFWVAC, net income and ROI per broiler given varying levels of wood vinegar via drinking water at Day 36.

	Treatment			
	$T_{0:}$ 0% WV	$T_{1:}$ 2% WV	$T_{2:}$ 3% WV	$T_{3:}$ 4% WV
Variable cost (PhP)				
Total feed cost	70.34	68.91	68.41	64.39
Cost of WV (PhP 100/L or PhP 0.1/ml)	0.00	2.00	3.00	4.00
Chick cost,	39.00	39.00	39.00	39.00
Electric bill	1.50	1.50	1.50	1.50
Multivitamins pre-mix	1.43	1.43	1.43	1.43
Housing disinfectant	0.25	0.25	0.25	0.25
Total variable cost (PhP)	**112.52**	**113.09**	**113.59**	**110.57**
Fixed cost (PhP)				
Housing/ cages and labor	18	18	18	18
Weighing scale	2.4	2.4	2.4	2.4
Total fixed cost (PhP)	**20.4**	**20.4**	**20.4**	**20.4**
Total cost	**132.92**	**133.49**	**133.99**	**130.97**
Final weight (g)	1416.36	1411.10	1403.86	1434.94
Selling price	100/kg	100/kg	100/kg	100/kg
RAFWVAC	**32.30**	**31.20**	**29.98**	**36.10**
Gross income (PhP)	141.64	141.11	140.39	143.49
Net income (PhP)	**8.72**	**7.62**	**6.40**	**12.52**
ROI (%)	**6.56**	**5.71**	**4.78**	**9.56**

* 1USD = PhP 48.13

feed intake of the bird (Table 1). The feed cost computation is in agreement with Reece and Lott's (1983) procedure for calculating the daily net return from broiler production. The highest RAFWVAC was recorded at PhP36.10 (USD 0.75) in birds given 4% wood vinegar (T3). This resulted to a net income of about PhP12.52 (USD 0.26) per bird, which is higher than the net income of PhP8.72 (USD 0.18) per bird in the control condition. These correspond to ROI of 9.56% and 6.56%, respectively, and can translate into a significant amount in commercial level broiler farms. It should be noted that profitability in broiler enterprise depends on the bulk of production.

Total Cost, Revenue, Net Income and Return on Investment (ROI)

The cost of production per broiler is lowest for T_3, with 4% wood vinegar (Table 5). This is because the feed intake of broiler in this group was lower among the treatments (Table 1). It should be noted that feed accounts for up to 70% of the total cost (Hagan et al., 2016) because the feeds satisfy the protein requirements necessary for growth. Table 5 also shows the revenue of each treatment. Among the treatments, 4% wood vinegar yielded the highest revenue. Similarly, among treatments, broilers provided with 4% wood vinegar (T_3) resulted in a higher net income of PhP12.52 per broiler. Further, the highest ROI of 9.56% was noted in the broilers given 4% wood vinegar in this study.

Conclusion

The current study revealed that there was a significant difference in WFI in broilers during the early stages of growth. However, no significant difference was noted on CWG, ADWG, and FCR. Another important finding of this study was that the addition of 4% wood vinegar resulted in a net income of P12.52 (USD 0.26) per bird which was PhP3.80 (USD 0.08) higher than the net income derived from birds without supplementation of wood vinegar. This positive advantage per broiler can be translated to a significant amount at a commercial level of broiler production, although this result has to be treated with caution given that there was no significant difference in the weekly feed intake between birds in T_0 and T_3.

This study was limited to the effects of wood vinegar on growth parameters and profitability. Effects on gut microbiota can be investigated in future studies. Further, there was no measurement of the nutrient and antimicrobial contents of the wood vinegar. Thus, it cannot be stated with certainty why WFI, but not CWG, ADWG, and FCR was significantly affected by wood vinegar concentrations. It is recommended to analyze the organic and bioactive components of wood vinegar, anti-microbial property, and toxicity effects to elucidate the mechanisms by which wood vinegar can facilitate nutrient absorption, protein digestibility, and body weight gain. It is also recommended to conduct histopathological studies of liver tissues, kidneys, and other parts to explore possible effects of wood vinegar supplementation. It may also be beneficial to include vitamin-mineral supplementation as a basis for comparison. Finally, further studies can investigate wood vinegar treatments sourced from other plant materials, or explore higher or lower wood vinegar concentrations.

Disclosure Statement

No potential conflict of interest was declared by the authors.

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