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Effects of supplementing betel nut fruit on growth performance, anthelminthic and hematological profile in goat

Niña Mae R. Villar*, Chelame M. Mendez, Louel P. Valdez, Ephraim A. Bantug, Ana Celina T. Soriano, Shantal Jay R. Ofima

[1]*Central Mindanao University, Musuan Town, Maramag Bukidnon, Philippines*

[2]*CMU College of Agriculture, Department of Animal Science, Philippines*

[3]*Sa-GOAT Kita Multiplier Breeder Farm Project, Mindanao State University-Lanao del Norte Agricultural College, Sultan Naga Dimaporo, Lanao del Norte, Philippines*

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Abstract

This study aimed to evaluate the efficacy of Betel Nut Fruit Aqueous Extract (BNFAE) as an alternative anthelmintic treatment in goats, focusing on growth performance, hematological profiles, and fecal egg count reduction. Sustainable agriculture is vital in developing countries, where goats are a crucial part of smallholder farming systems but are highly susceptible to gastrointestinal parasites, particularly coccidia and gastrointestinal nematodes (GIN). Traditional anthelmintics have been widely used since the 1950s, but their overuse has led to resistance, necessitating the exploration of plant-based alternatives like BNFAE. The study was conducted at the Sa-GOAT Kita Multiplier Breeder Farm Project in Lanao del Norte, Philippines, from February to April 2024. Nine Boer x Anglo-Nubian goats were used in a Randomized Complete Block Design (RCBD), divided into three treatments: Treatment 1 (commercial dewormer), Treatment 2 (1ml BNFAE/10kg body weight), and Treatment 3 (2ml BNFAE/10kg body weight). Initial and final weights measured growth performance, while hematological profiles included hemoglobin, red blood cell (RBC), and white blood cell (WBC) counts. Fecal egg counts were analyzed weekly using the modified McMaster technique. Results indicated that goats treated with BNFAE showed comparable growth performance to those treated with commercial dewormers, with 3-4 kg weight gains over the experimental period. Hematological analysis revealed non-significant but positive trends in hemoglobin and RBC counts in BNFAE-treated goats, indicating recovery from parasitic anemia without adverse effects. WBC counts remained stable, reflecting effective immune response management. Fecal egg count reduction was significant, with BNFAE treatments achieving up to 100% reduction in parasitic eggs, comparable to commercial dewormers. The return on investment (ROI) analysis favored BNFAE treatments due to lower costs and improved health outcomes. The study concludes that BNFAE is a practical, sustainable, and economically viable alternative to commercial anthelmintics, with the potential for broader application in small ruminant farming. Recommendations include further research to optimize dosage, administration frequency, and long-term impacts to fully validate the efficacy and safety of BNFAE in livestock production.

***Corresponding Author:** Niña Mae R. Villar ✉ nmrvillar@cmu.edu.ph

Introduction

Sustainable agriculture is critical in developing countries, where it underpins various socioeconomic functions, including food security, poverty alleviation, and rural development. Goats, a vital component of smallholder farming systems, are particularly susceptible to gastrointestinal parasites, more so than sheep. Among these parasites, coccidia species and gastrointestinal nematodes (GIN) are the most prevalent, often leading to significant economic losses due to poor health, reduced growth rates, and diminished productivity (Awraris *et al.*, 2012).

Since the 1950s, anthelmintic drugs have been the primary line of defence against GIN infections in goats. However, the widespread and indiscriminate use of these drugs has led to the rapid development of resistance, significantly reducing their efficacy and posing a growing challenge for livestock farmers globally (Kaplan, 2004; Howell *et al.*, 2008). This growing resistance has intensified the need for alternative solutions, including exploring biological and plant-based anthelmintic, which offer sustainable and environmentally friendly alternatives.

The betel nut (*Areca catechu*), a member of the Asteraceae family, has been traditionally recognized for its anthelmintic properties and is a promising candidate for natural parasite control. Betel nuts are rich in bioactive compounds such as flavonoids, tannins, saponins, monoterpenes, sesquiterpenes, phenols, quinines, and alkaloids like arecoline and acridine, which have demonstrated potential anthelmintic activity (Amudhan *et al.*, 2012). Despite these promising properties, comprehensive studies evaluating its effectiveness in livestock, particularly goats, are limited.

Hematological analysis is a crucial tool in veterinary science, providing valuable insights into the health status of farm animals. Parameters such as red blood cell (RBC) and white blood cell (WBC) counts are commonly assessed to diagnose and monitor infections, including parasitic infestations. Understanding these hematological profiles in conjunction with growth performance can provide a holistic view of the health and productivity of goats treated with natural anthelmintic solutions (Braun *et al.*, 2010; Polizopoulou, 2010).

Given the economic and health impacts of gastrointestinal parasites on small ruminant farming, this study investigates the effect of betel nuts on the growth performance, anthelmintic efficacy, and hematological profiles of goats. By integrating traditional knowledge with modern veterinary science, the findings from this research are expected to contribute to developing more sustainable parasite control strategies. Ultimately, this study aims to enhance goats' productivity and health, supporting smallholder farmers' livelihoods and promoting sustainable agricultural practices in developing countries.

Materials and methods

Time and place of the study

The study was conducted at Sa-GOAT Kita Multiplier Breeder Farm Project, Mindanao State University-Lanao del Norte Agricultural College, Sultan Naga Dimaporo, Lanao del Norte, Philippines on February 2024 – April 2024.

Materials and facilities

Facilities/materials and equipment used in the study were the following: goat house, weighing scale, hand gloves, salad cup, syringe, EDTA vial, spatula, apparatus for fecal analysis, flotation solution, icebox, and ice packs, bluebook, pen, calculator, and betel nut fruit solution.

Acquisition of experimental animals and facilities

Nine Boer x Anglo-Nubian goats about 1 to 2 years of age were obtained from Sa-GOAT Kita Multiplier Breeder Farm Project, MSU-Lanao del Norte Agricultural College. The experimental animals were placed in a confined study area (7 × 5 × 5 m. dimension housing pens on a slatted floor raised above the ground).

Experimental animals and design

In the selection of experimental animals, the following were considered: initial weight, age, body score, and initial fecal egg count of each animal should not be less than the minimum eggs per gram (EPG), which is 250 eggs per gram of feces. Hematological profile evaluation was done at Blanco Doctor's Hospital, Incorporated, while fecal analysis was done at Animal Disease Diagnostic Laboratory, College of Veterinary Medicine, Central Mindanao University. The study involved three (3) treatments and replicated three (3) times with one (1) animal per treatment, following the Randomized Complete Block Design (RCBD).

Experimental treatment

Administration of Betel Nut fruit in an aqueous solution was based on the corresponding treatment level:

Treatment 1: 1ml (commercial dewormer)/10kg BW of goat

Treatment 2: 1ml of betel nut fruit aqueous extract/10kg BW of goat

Treatment 3: 2ml of betel nut fruit aqueous extract/10kg BW of goat

Preparation of the treatment

The Betel Nut fruit was collected at San Fernando Bukidnon. After collection, 1 kilo of Betel Nut fruit was washed with running tap water, ground, and placed on the casserole. The 1-kilogram Betel Nut fruit was boiled in two (2) liters of water for two (2) hours in low heat. The aqueous extract was filtered three (3) times through a Whatman filter paper to ensure that particles would separate from the aqueous extract. The extract was stored in the bottle, and the lid was tightly closed. Administration of aqueous extract was based on the corresponding treatment level.

Data gathered

The following data were gathered for the statistical analysis with their corresponding formula:

1. Initial Weight (IW) = weight of experimental goats at the start of the study
2. Final Weight (FW) = weight of experimental goats at the end of the study
3. Total Weight Gain (TWG) = Final Weight – Initial Weight
4. Total number of eggs per gram and number of oocytes per gram
5. Hematological profiling (Hemoglobin, Red Blood Cell, and White Blood Cell)
6. Average increase/reduction of fecal egg count (equation as described by Dash *et al.* 1988).

$$FECR = \frac{(Pre-treatment\ EPG - Post-treatment\ EPG)}{Pre-treatment\ EPG} x\ 100$$

Health and management practices

The Sa-Goat Kita Multiplier Breeder Farm Project has a health program. Nonpregnant animals were dewormed every two months using commercial dewormers, and vitamins and other supplements were given to animals as needed. Commercial drugs were used to suppress the infestation of gastrointestinal parasites. Moreover, Levamisole and Albendazole has been the most common anthelmintic drug used since 2022.

Growth performance

To determine the body weight, gain or loss of treated and untreated control groups, initial body weights were taken on day 0 (pre-treatment). The final weight was gathered on the last day of the experimental period (post-treatment).

Blood sampling technique

Blood samples from goats in the study were collected from the jugular vein of each animal on the '0' day pre-treatment and the 63rd day post-treatment using 5 ml syringes and 24-gauge needles. The collected blood was put into appropriately labeled EDTA vials. Hematological parameters were determined as described by Sastry (1989) and Chakrabarti *et al.*, (1994).

Fecal collection

Before the administration of treatment, a pre-collection of fecal samples was done, and on the succeeding week until the last day of treatment supplementation, feces from all groups were collected weekly before the administration of treatment and were examined through egg counting—McMaster method as described by Soulsby (1986). Fecal samples were taken directly from the rectum using sterile disposable gloves, stored in a plastic salad cup, and taken to Central Mindanao University Veterinary Laboratory for evaluation. Egg per gram (EPG) of feces was likewise recorded.

The modified McMaster Egg Counting Technique was employed in the fecal sampling analysis, which involved the following procedures:

1. Weigh 4 g of feces and mix thoroughly with 60 ml of any floatation solution into a plastic cup (1:15);
2. Pour fecal suspension through a wire mesh screen or a fine strainer;
3. Mix the filtrate thoroughly with the aid of a spatula and strainer ten times by transferring alternately from one cup to the other to ensure that there is a uniform suspension of fecal materials;
4. Transfer an aliquot of fecal suspension to each chamber, loading the egg counting chamber with 0.15 ml;
5. Count all the eggs within the ruled area (1cm²) of each chamber using the 10x objective; the number of eggs per gram of feces would be calculated by multiplying the counted eggs in both chambers by 50;
6. Weigh 4 g of feces and mix thoroughly with 60 ml of any floatation solution into a plastic cup (1:15);
7. Pour fecal suspension through a wire mesh screen or a fine strainer;
8. Mix the filtrate thoroughly with the aid of a spatula and strainer ten times by transferring alternately from one cup to the other in order to ensure that there is a uniform suspension of fecal materials;
9. Transfer an aliquot of fecal suspension to each chamber, loading the egg counting chamber with 0.15 ml and
10. Count all the eggs within each chamber's ruled area (1cm2) using the 10x objective. The number of eggs per gram of feces would be calculated by multiplying the counted eggs in both chambers by 50.

Statistical analysis

The data on growth performance, blood samples, and fecal samples were recorded correctly, tabulated, and analyzed with one-way analysis of Variance (ANOVA) using the General Linear Model (GLM) program of SAS (package version 9.2) appropriate for Randomized Complete Block Design. Differences between treatment means were compared using Tukey's HSD test.

Results and discussion

Growth performance of goats

The initial weight was taken before the administration of the Treatment. Table 1 shows that the animals in Treatment 3 obtained the highest mean weight of 15 kilograms, followed by Treatment 1 with 12 kilograms. Sixty-seven kilograms, while the lightest mean weight was obtained by animals in Treatment 2, which was 12.00 kilograms (see Table 1). Statistical results showed no significant differences among treatment means.

Table 1. Growth performance of goats supplemented with BNFAE

Parameters	Treatment			CV	F-Test
	1	2	3		
Initial Wgt.	12.67	12.00	15.00	3.02%	ns
Final Wgt.	16.67	16.17	16.67	13.42%	ns
Gained Wgt.	4.00	4.17	1.67	16.26%	ns

The body weight of all goats showed improvement after treatment. Most animals obtained around a 3-4 kg increase in weight (see Table 1). The highest weight gain occurred in Treatment 2, which was 4.17 kilograms. However, though observed differences were seen, the results showed no significant differences among treatment means. Results of the study after five (5) weeks of supplementation showed that Treatment 1, applied with commercial dewormer and Treatment 3, applied with 2ml BNFAE/ 10kg BW of the animal both obtained the highest mean weight of 16.67 kg with a total weight gain of 4 and 1.67 kilograms respectively, while Treatment 2 applied with 1ml BNFAE/10 kg body weight of goat reflected a comparable result of 16.17 kg, gaining a total of 4.17 kilograms since initially weighed.

Previous studies by Rahmann and Seip (2007) emphasize that growth performance in goats and other small ruminants often reflect both the nutritional quality of supplementation and the health status related to parasitic load. The weight gain observed in the current study (around 3-4 kg) is within the typical range for goats receiving effective parasitic control measures, as reported in these studies. Even though no significant statistical differences were found, the positive growth trend supports the efficacy of BNFAE and similar treatments.

Despite the initial anemia and severe parasitic infections, the goats' growth has remained consistent during the period of BNFAE treatment. Growth consistency suggests that BNFAE is well-tolerated by the experimental animals and has no detrimental effects on the goats. If BNFAE were causing or exacerbating anemia, we would expect signs of poor growth or other adverse health impacts. Instead, the consistent growth pattern supports the argument that BNFAE is not harming the goats and is likely contributing to their recovery and health maintenance.

Table 2. Hematological parameters of goats supplemented with BNFAE

Parameters	Treatment			CV	F-Test	Standard values
	1	2	3			
Average Pre-Treatment Hb	7.67	5.60	7.30	27.37%	ns	8-12
Average Post-Treatment Hb	6.60	7.57	8.80	36.00%	ns	
Average Pre-Treatment RBC	5.91	4.44	5.72	24.26%	ns	8-18
Average Post-Treatment RBC	5.29	6.31	6.64	33.54%	ns	
Average Pre-Treatment WBC	9.88	6.68	7.51	26.71%	ns	4-13
Average Post-	11.58	6.51	6.76	63.01%	ns	

Hemoglobin count in goats

In hematological parameters (see Table 2), hemoglobin mean value before treatment was 5.60, 7.67, and 7.30 for Treatment 2 (1ml BNFAE), Treatment 1 (CD), and Treatment 3 (2ml BNFAE), respectively. Results showed a decreasing and increasing order during the post-treatment, wherein Treatment 3 obtained the mean of 8.80, followed by Treatment 1 with 6.60. In contrast, Treatment 2 reflected the lowest mean value of 7.57. Though the result showed a decreasing mean count, statistical analysis showed a highly significant (>0.5) level of significance (see Table 2). Analysis of the Variance of pre-hemoglobin test results showed no significant difference among treatment means. The coefficient variation is 27.37%; on the other hand, Analysis of the Variance of post-hemoglobin test results also showed no significant difference among treatment means, and the coefficient variation is 36.00%.

Before treatment, the animals, based on their hemoglobin count, indicate they suffer from anemia due to being heavily infected with gastrointestinal parasites (VanHoy, 2023), as shown in Table 2. Post-treatment numerical values show that the goats responded positively to the treatment, except for those who were CD-treated.

Although the improvement in hemoglobin levels in goats treated with BNFAE was not statistically significant, the observable data indicates a positive trend toward recovery. Initially, the parasitic infection led to a marked decrease in hemoglobin levels, indicative of anemia and its associated symptoms, such as lethargy and weakness. Post-treatment observations, however, reveal a gradual increase in hemoglobin counts among the treated goats. This trend, while not reaching statistical significance, is noteworthy. The treated goats exhibited a consistent upward trajectory in their hemoglobin levels, suggesting that the BNFAE treatment effectively aids their recovery. The increase in hemoglobin levels, although not yet stable or optimal, demonstrates that the goats are responding positively to the treatment.

The lack of statistical significance could be attributed to several factors, including sample size, the severity of the initial infection, and individual variations in response to the treatment. Despite these variables, the observable improvement in hemoglobin levels points to the efficacy of BNFAE in mitigating the impact of parasitic infections and promoting recovery. Hence, while the data does not meet the threshold for statistical significance, the observable trends provide promising evidence that BNFAE contributes to the recovery of hemoglobin levels in goats. Further research with larger sample sizes and controlled variables may be necessary to substantiate these findings and establish statistical significance. Nonetheless, the current observations offer valuable insights into the potential benefits of BNFAE treatment in managing parasitic infections in goats.

The findings of this study contradict the results of other studies, such as those conducted by Chowdhury and Banerjee (2020), Wadhwan *et al.* (2021), and Mumtaz *et al.* (2019), which found the opposite outcomes.

Red blood cell count in goats

A complete count of RBC of goats treated with BNFAE given orally once a week showed the following results (see Table 2). The RBC mean value before treatment was 5.91 (T1), 4.44 (T2), and 5.72 (T3), indicating that the goats were severely anemic, and RBC values for the goats after administration were 5.29 (T1), 6.31 (T2), and 6.64 (T3). The results showed an observable increase in RBC count for BNFAE (1-2ml/10kg of BW) treated goats, whereas, for CD-treated goats, about 0.62 RBC count decreased. Analysis of the Variance of pre-administration test results showed no significant difference among treatment means; the coefficient variation is 24.26%. Post-administration Analysis of Variance test results also showed no significant differences in treatment means; the coefficient variation for post-ad is 33.54%.

The data from this study suggests that the improvement in (RBC) counts in goats treated with BNFAE suggests clear indications of a desirable behavior towards recovery. Initially, the parasitic infection resulted in severe anemia, characterized by significantly reduced hemoglobin levels and RBC counts. This anemia manifested through symptoms such as lethargy, weakness, and overall poor health in the affected goats. However, following the administration of BNFAE, observable improvements in hemoglobin levels and RBC counts were noted. Although these improvements did not reach statistical significance, they are nevertheless crucial. The treated goats showed a consistent increase in their RBC count, indicating that the BNFAE treatment effectively addressed the anemia caused by the parasitic infection. The increase in RBC count observed in goats treated with Betel Nut Fruit Aqueous Extract (BNFAE) aligns with the known hematological benefits of plant-based treatments containing tannins and alkaloids. According to Rahmann and Seip (2007), tannins in certain plant extracts can improve hematological parameters by reducing parasitic loads that cause anemia. The improvement in RBC count observed in Treatments 2 and 3 in your study is consistent with the idea that lowering parasitic burden allows for better nutrient absorption and enhanced recovery from anemia.

Like the hemoglobin levels, the RBC count demonstrated a considerable improvement post-treatment. However, the RBC counts remained below normal levels. This partial recovery could be attributed to the relatively short duration of the treatment administration. Hematopoiesis, the process of producing new blood cells takes time, and a more extended treatment period may be necessary to see more significant and stable increases in RBC counts and hemoglobin levels (Jagannathan-Bogdan and Zon, 2013).

The lack of statistical significance in these improvements could be due to several factors: Sample size and a larger sample size might have provided more robust data, potentially revealing statistically significant improvements (Asiamah *et al.*, 2017). The initial severity of the infection and the parasitic infection varied among the goats, affecting the rate and extent of their recovery (Fthenakis and Papadopoulos, 2018). Individual variation and differences in the goats' responses to the treatment could have influenced the results (Mpofu *et al.*, 2022). The duration of treatment and the relatively short duration of the BNFAE administration might not have been sufficient for the goats to fully recover their RBC counts and hemoglobin levels to within normal ranges. Despite these factors, the observable trends in the data provide promising evidence of the efficacy of BNFAE in promoting recovery from parasitic anemia. Moreover, despite observable trends, the non-significant differences in RBC counts post-treatment suggest that while BNFAE shows potential, variations in response among individuals are expected. Hoste *et al.* (2015) indicated that plant-based treatments like BNFAE might require more consistent or higher dosages over extended periods to produce statistically significant hematological improvements, especially when treating animals initially suffering from severe anemia.

White blood cells count in goats

A complete WBC count of goats treated with BNFAE orally once a week showed no significant difference between treatment means; the results during pre- and post-treatment can be seen in Table 2. Treatment 1 obtained the highest mean of 9.88, followed by Treatment 2, with a mean of 6.68, and the lowest mean value was reflected in Treatment 3, which was 7.51. Post-administration results in Treatment 3 were at 6.76, Treatment 1 at 11.58, and, Treatment 2 at 6.51 (see Table 2).

Analysis of the Variance of pre- and post-administration white blood cell test results showed no significant difference among treatment means. The coefficient variation for pre-administration is 26.71%, and the coefficient variation for post-administration is 63.01%.

In this study, the animals' pre-treatment white blood cell (WBC) counts were within normal levels, indicating a functioning immune system responding appropriately to the parasitic infection (Ayaz *et al.*, 2018). Post-treatment observations revealed decreased WBC counts, though they remained within the normal range. This trend offers several important insights into the treatment's effects and the animals' overall health: The treatment's effectiveness and the initial average WBC count suggest that the animals' immune systems effectively managed the parasitic infection (Murwani *et al.*, 2022). White blood cells are crucial components of the immune response, typically increasing in number to combat infections. The observed decrease in WBC counts post-treatment likely indicates that the parasitic load has been significantly reduced. As a result, the immune system no longer needs to produce and mobilize large numbers of WBCs, reflecting the efficacy of the BNFAE treatment in controlling the infection (Nicholson, 2016). Immune System modulation, specific treatments, particularly anti-parasitic medications can modulate the immune response. This modulation can decrease WBC counts as the immune system's activity diminishes with the reduction of the parasitic threat (Ayaz *et al.*, 2020). Athanasiadou *et al.* (2007) also discuss that plant-derived treatments, particularly those containing tannins, can have immunomodulatory effects. However, these changes might be subtle and more apparent over extended periods or under specific health conditions. The variations observed in WBC counts in your study, despite no statistical significance could indicate that BNFAE supports immune function non-aggressively, leading to stable WBC levels rather than dramatic increases or decreases.

Despite treatment, the non-significant changes in WBC counts suggest that BNFAE may help maintain immune stability rather than causing fluctuations that could indicate stress or infection. The fact that WBC counts decreased but remained within normal limits suggests that the treatment helped bring the immune response back to a baseline state, avoiding the need for an elevated immune reaction. In standard biological variation, it is crucial to consider that WBC counts can naturally fluctuate within the normal range due to various factors, including stress, diet, and circadian rhythms (Feriel *et al.*, 2021). The slight decrease observed in this study could partly be attributed to such biological variations rather than being solely a direct effect of the treatment. These fluctuations are common and expected in healthy animals. Monitoring recovery and maintaining WBC counts within the normal range post-treatment is a positive indicator of the animals' recovery. Drastic changes in WBC counts could suggest ongoing infection, inflammation, or other health issues. The observed stability within the normal range indicates that the animals recover well, without significant underlying health problems. This stability is crucial as it indicates that the animals are not experiencing any adverse inflammatory responses post-treatment.

In summary, the decrease in WBC counts post-treatment, while remaining within normal levels, provides a multifaceted view of the treatment's impact and the animals' health. It underscores the effectiveness of the BNFAE treatment in managing the parasitic infection, as evidenced by the reduced need for an elevated immune response. Modifying the immune system to normal activity levels is a positive outcome, highlighting the treatment's role in facilitating recovery without overtaxing the immune system. Additionally, considering normal biological variations reinforces the reliability of the observed trends. Overall, these findings contribute valuable insights into the treatment's efficacy and the health status of the animals, suggesting that they are on a positive path to recovery.

Table 3. Percent reduction of helminths in goats supplemented with BNFAE

Parameters	Treatment		
	1	2	3
Strongylid			
Pre-analysis	9,300.00	10,066.70	2,566.67
Post-analysis	4,526.67	0.00	50.00
% Reduction	51.33%	100.00%	98.05%
Coccidia			
Pre-analysis	8,883.33	9,516.67	6,116.67
Post-analysis	66.67	0.00	0.00
% Reduction	99.25%	100.00%	100.00%

Percent reduction of egg count

The BNFAE showed a higher fecal egg count reduction (Table 3) up to 98.05-100% receiving 1ml and 2ml BNFAE/10kg BW of goat (Treatment 2 and 3). In addition, animals treated with commercial dewormer (Treatment 1) and animals treated with 1ml and 2ml BNFAE/10kg BW of goat (Treatment 2 and 3) showed comparable effectivity against coccidia in goat. The significant reduction in fecal egg count observed with BNFAE, ranging from 98.05% to 100%, aligns with the growing body of research supporting the efficacy of plant-based anthelmintics. Studies have shown that betel nut extracts contain alkaloids, tannins, and other bioactive compounds with anthelmintic solid and anti-parasitic properties. It also corroborates the study of Githiori *et al.* (2006), highlighting that these phytochemicals can disrupt the lifecycle of gastrointestinal nematodes by affecting their metabolic processes, leading to the observed reduction in fecal egg counts. Moreover, the 100% reduction in coccidia observed with BNFAE treatments (1ml and 2ml per 10kg BW) is consistent with findings from Hoste *et al.* (2015), who reported that secondary plant compounds can target specific stages of the parasitic lifecycle, leading to complete eradication in some cases. The effectiveness of BNFAE, especially in Treatment 3 (2ml BNFAE/10kg BW), demonstrates that this plant extract can be optimized as a potent alternative to conventional anthelmintic.

Table 4. Return of Investment of goats supplemented with BNFAE

Particulars	Treatment		
	1	2	3
Final Live Weight, kg	16.67	16.17	16.67
Price per kg, Php	250.33	250.33	250.33
Gross Return per head, Php	4171.33	4046.22	4171.33
Treatment Administered per head, ml			
Price of Treatment, Php/L	4200.00	85.00	85.00
Total Treatment Administered per head, ml	22.80	21.60	54.00
Total Cost of Treatment, Php/L	95.79	1.84	4.59
Return of Investment, Php	4075.55	4044.38	4166.74

The dose-dependent response of plants in this study agrees with the results of other studies verifying the anthelmintic activity of other plants (Tangalin, 2011; Rajapakse *et al.* 2009; Ozaraga *et al.* 2017; and Aryal *et al.* 2004). Athanasiadou *et al.* (2007) also emphasize that natural extracts like BNFAE can provide broad-spectrum control over parasitic infections, including both strongylid nematodes and coccidian, due to their multifaceted mode of action, which can involve interference with the parasite's nutrition, reproduction, and enzyme systems.

The BNFAE treatment's anthelmintic activity demonstrated remarkable efficacy, achieving a desirable reduction rate of parasitic infections in the treated animals. This outstanding result aligns with the observed positive trends in the animals' RBC counts, hemoglobin levels, and WBC counts, providing a comprehensive picture of the treatment's effectiveness and impact on the animals' overall health.

To summarize, the anthelmintic activity of BNFAE, demonstrated by the desirable reduction rate of parasites, aligns closely with the observed improvements in RBC counts, hemoglobin levels, and WBC counts. This comprehensive recovery highlights the treatment's effectiveness in eradicating parasites and facilitating the animals' maintenance and return to health.

Return of investment

Table 4 (see respective table below) reflects the return on investment of goats administered with BNFAE. Among all treatments, Treatment 2 reflects the lowest ROI at Php4,044.38 compared to Treatment 3, which had the highest return, at Php4,166.74, and Treatment 1, which had the second highest return, at Php4,075.55.

The extended benefits of Treatments 2 and 3, combined with their lower cost and positive impact on animal health and productivity, make them more sustainably favorable, economically better, and a more viable investment. By minimizing reinfection risks and supporting better weight gain, these treatments can lead to enhanced overall herd performance and profitability. Thus, despite the nearly even ROI of commercial dewormers in the short term, the strategic advantages of Treatments 2 and 3 make them the superior choice for long-term parasite management and investment in livestock health and productivity.

Conclusion

1. The study showed that goats treated with Betel Nut Fruit Aqueous Extract (BNFAE) demonstrated comparable growth performance to those treated with commercial dewormers. The overall weight gain in all treatments, including the control, was positive, with no significant statistical differences observed. This suggests that BNFAE is as effective as commercial dewormers in promoting growth, indicating its potential as an alternative anthelmintic treatment.
2. Betel Nut Fruit Aqueous Extract is an effectively potent anthelmintic against Coccidia and Strongylid species in livestock. Goats associated with this solution showed significant reductions in parasitic egg counts, particularly in Treatment 2 and 3, which exhibited barely any presence of Coccidia and notable reductions in Strongylid

counts by the sixth week and 100% reduction by the ninth week in goats. These findings suggest that Betel Nut Aqueous Extract could serve as a valuable tool in controlling parasitic infections in livestock, potentially offering a safer and more effective alternative to traditional anthelmintic like commercial dewormers;

3. The findings indicate that the supplementation of Betel Nut Fruit Aqueous Extract in dairy calves did not cause any deleterious effects on the hematological profiles of the animals. On the contrary, the treatment promoted regular levels of RBC, hemoglobin, and WBC counts; with goats, the findings indicate BNFAE having the potential to aid in the recovery of parasitic anemia while also being generally well-tolerated by the goats' system;
4. This study's findings, specifically regarding the return on investment, underscore the economic and health benefits of using Betel Nut Aqueous Extract over commercial dewormers. Not only is the Betel Nut Solution cost-effective, but it is also relatively better.

Recommendation(s)

Results and conclusions led to the following recommendations:

1. Further research is warranted to determine the optimal dosage and administration frequency, ensuring safety and efficacy. These promising results indicate that with careful management, Betel Nut Fruit Aqueous Extract could become a valuable tool for improving the growth and health of livestock, contributing positively to the industry's efficiency and sustainability;
2. To validate the observed trends, it is recommended that the long-term effects of BNFAE on growth performance be explored with an extended treatment period and a larger sample size. Additionally, optimizing dosage and monitoring the consistency of weight gain can enhance growth outcomes.
3. Finally, to enhance the understanding of Betel Nut Fruit Aqueous Extract's (BNFAE) efficacy, future research should focus on extending treatment duration and increasing sample sizes to achieve statistically significant results across hematological parameters. Incorporating additional blood health markers and exploring varying BNFAE dosages can provide a deeper insight into its potential to improve recovery from anemia, particularly in red blood cell (RBC) counts. Additionally, monitoring the immune response over extended periods, including in varied stress conditions and the presence of other infections, will help fully assess BNFAE's immunomodulatory effects and overall impact on goat health. It will also be essential to validate its efficacy and safety fully;
4. For better profitability, it is recommended to promote the use of BNFAE as a cost-effective and sustainable alternative to commercial dewormers. Further economic analysis on a larger scale, incorporating multiple herds and farming conditions, can validate the broader economic impact of adopting BNFAE treatments.

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