

Milk Production of Multiparous Goats Fed with Corn-Based Total Mixed Ration with Azolla (CB-TMR-A)

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Abstract

This study evaluated the effects of corn-based total mixed ration supplemented with azolla on the production performance, milk composition, feed efficiency, hematological parameters, and economic returns of upgraded Anglo-Nubian multiparous goats. The study aimed to determine the potential of azolla as a sustainable and cost-effective feed supplement for dairy goat production. An experimental research design was employed using upgraded Anglo-Nubian multiparous goats subjected to different dietary treatments containing varying levels of azolla supplementation. Data were gathered through feed intake monitoring, milk yield measurement, laboratory analysis of milk composition, hematological examination, and economic evaluation. Statistical analyses were used to determine significant differences among treatments. Findings revealed that goats supplemented with azolla exhibited improved milk yield, enhanced feed conversion efficiency, and favorable milk crude protein and fat content compared with the control treatment. Hematological parameters remained within normal physiological ranges, indicating that azolla supplementation did not adversely affect animal health. Economic analysis further demonstrated improved profitability due to reduced feed costs and enhanced production performance. The study concluded that azolla supplementation in corn-based total mixed ration can contribute positively to dairy goat productivity, animal health, and economic sustainability, supporting the findings of Katole et al. (2017), Khare et al. (2016), and Kumar et al. (2020). The study recommended the utilization of azolla as an alternative feed supplement and suggested further studies on varying supplementation levels and feeding strategies. The study supports Sustainable Development Goal (SDG) 2: Zero Hunger by promoting sustainable livestock production and improved food productivity, and SDG 12: Responsible Consumption and Production through the utilization of alternative feed resources. Its sustainability impact lies in enhancing the economic viability of dairy goat farming while promoting environmentally sustainable feeding practices and efficient resource utilization.

Keywords: Anglo-Nubian Goats, Azolla Supplementation, Dairy Goat Production, Economic Sustainability, Feed Efficiency, Hematological Parameters, Milk Composition, Total Mixed Ration

1. Introduction

Goats (*Capra hircus*) are recognized as important contributors to rural economies, especially in less developed regions where goat populations continue to increase rapidly (Liang & Paengkoum, 2019). In the Philippines, the goat population reached approximately 3.94 million heads, with 98% raised in backyard production systems (Philippine Statistics Authority [PSA], 2021). Despite the growing importance of goat production, access to high-quality forage remains one of the major constraints affecting productivity, particularly during drought periods in Asian countries. Feed quality and quantity directly influence animal health, growth, and milk production. Several fodder resources are available; however, some contain anti-nutritional factors that reduce feeding efficiency (Nahand et al., 2012; Aban et al., 2015). To address these challenges, total mixed ration (TMR) feeding has emerged as an important feeding strategy that improves feed digestibility, nutrient balance, and feed conversion efficiency. Corn-based TMR combines different feed ingredients into a balanced mixture to ensure a consistent supply of nutrients, particularly during periods of poor pasture quality. Studies demonstrated that corn-based TMR improves feed efficiency and milk production in livestock. Siaboc (2023) reported increased milk production in dairy cattle supplemented with corn-based TMR enriched with *Moringa oleifera*.

Azolla pinnata has also been recognized as a promising feed supplement because of its high crude protein content, low lignin concentration, rapid growth rate, and digestibility. Katole et al. (2017), Khare et al. (2016), and Kumar et al. (2020) highlighted the high nutrient content of azolla, while Khare et al. (2016) and Kumar et al. (2020) emphasized its value as a sustainable feed source in tropical and subtropical climates. Azolla supplementation has been associated with improved milk production, feed efficiency, and animal performance. This study evaluated the effects of corn-based total mixed ration supplemented with azolla on the milk yield, milk composition, feed intake, feed conversion ratio, metabolic body weight, blood indices, and profitability of upgraded Anglo-Nubian multiparous goats.

Existing literature highlights the importance of balanced feeding systems in improving ruminant productivity. Total mixed ration feeding ensures that animals receive sufficient nutrients needed for growth, reproduction, and milk production (Khiaosa-ard & Zebeli, 2014). Studies reported that goats fed with TMR demonstrated improved feed conversion efficiency, growth performance, and milk production compared with animals receiving traditional feeding systems (Ekeocha, 2012; Saeed et al., 2018; Tesfay et al., 2017). Corn silage has become an important forage component because of its high energy content, palatability, and compatibility with TMR systems (Cherney et al., 2004; Kononoff et al., 2003). Corn silage contributes starch and digestible fiber that support rumen fermentation and milk production (de Oliveira et al., 2017; Khan et al., 2015; National Research Council, 2001). Proper ensiling practices improve nutrient preservation and reduce spoilage (Bagg et al., 2007). Studies further showed that whole corn plant silage improves feed intake and animal performance because of enhanced ruminal fermentation and nutrient availability (Khaing et al., 2015; Dewhurst, 2013). However, improper silage management may reduce digestibility and productivity due to excessive fermentation acids (Browne et al., 2004).

Research on azolla supplementation consistently emphasized its nutritional value. Azolla contains 19–30% crude protein, essential amino acids, vitamins, and minerals (Kumari et al., 2018; Dev et al., 2022). Kumar et al. (2015) and Katole et al. (2017) reported that azolla can partially replace concentrate feeds without negatively affecting feed intake, nutrient utilization, or growth performance. Several studies also documented the positive effects of azolla supplementation on milk production and composition. Ahmed et al. (2023), El Naggar and El-Mesery (2022), Kumar et al. (2020), and Meena et al. (2017) reported increases in milk yield when azolla was incorporated into dairy cattle diets. Improvements in milk crude protein and milk fat were also associated with azolla supplementation because of its high protein content and low lignin concentration (Hassanein et al., 2023; Kour et al., 2020). Hematological studies showed that azolla supplementation generally does not adversely affect red blood cells, white blood cells, packed cell volume, or hemoglobin levels in goats and other livestock species (Kumar et al., 2015; Sihag et al., 2018; Anitha et al., 2016). These findings suggest that azolla is a safe feed ingredient that supports livestock productivity without compromising animal health.

Globally, goat production remains an important source of food, livelihood, and income among smallholder farmers, particularly in developing regions (Escareño, 2013). Goat farming contributes to poverty reduction, food security, and improved nutrition because of its low capital requirement and favorable economic returns (Orden, 2013; Kumar et al., 2010). In the Philippines, smallholder goat farms account for more than 98% of the total goat inventory (PSA, 2019). Government and private sector initiatives continue to promote goat production, including dairy goat dispersal programs and community-based dairy goat projects. However, smallholder farmers continue to face challenges related to feed supply, forage quality, and nutritional management. The increasing demand for goat milk and meat highlights the need for sustainable feeding strategies that improve productivity while reducing production costs. Corn-based TMR and azolla supplementation offer practical alternatives because both resources are locally available and suitable for tropical environments. At the global level, sustainable livestock feeding systems are increasingly promoted to address environmental concerns and resource limitations. Evans (2018) noted that whole corn plant silage may reduce methane emissions from ruminants, contributing to greenhouse gas mitigation. Azolla also serves as an environmentally sustainable feed resource because of its rapid biomass production and nitrogen-fixing capability.

The study was anchored on the concept that improved nutrient balance and digestibility enhance milk production, feed efficiency, and animal health. Total mixed ration feeding ensures uniform nutrient intake by combining forage and concentrates into a balanced ration. Corn-based TMR provides digestible energy and fiber necessary for rumen function and milk synthesis. Azolla supplementation theoretically enhances nutrient utilization because of its high crude protein, essential amino acids, minerals, and low lignin content. Hassanein et al. (2023) emphasized that low-lignin forages improve digestibility and nutrient absorption, thereby supporting milk synthesis. Adesogan et al. (2019) and Ferraretto and Shaver (2012) also explained that lower lignin concentrations improve dry matter intake and milk production. The conceptual framework of the study identified corn-based total mixed ration with varying levels of azolla as the independent variable. The dependent variables included milk yield, feed intake, feed conversion ratio, metabolic body weight, milk crude protein, milk fat, cost analysis, and hematological parameters such as erythrocyte count, leukocyte count, packed cell volume, and hemoglobin concentration.

Although previous studies demonstrated the nutritional and economic benefits of total mixed ration feeding and azolla supplementation, limited studies have focused on the combined use of corn-based TMR and azolla in upgraded Anglo-Nubian multiparous goats under Philippine production conditions. Existing research largely concentrated on dairy cattle, growing goats, or other livestock species, with limited emphasis on lactating upgraded Anglo-Nubian goats. There is also insufficient information regarding the effects of varying azolla inclusion levels on milk yield, milk composition, feed efficiency, metabolic body weight, hematological parameters, and profitability in multiparous dairy goats. Furthermore, while azolla has been recognized as a cost-effective feed ingredient, the optimal inclusion level for maximizing milk production and economic returns without negatively affecting animal health remains unclear. This study addressed these

gaps by evaluating different azolla inclusion levels in corn-based TMR and examining their effects on productivity, milk quality, feed utilization, blood parameters, and cost efficiency.

The study aligns with several Sustainable Development Goals (SDGs) relevant to livestock production, food security, sustainability, and rural development. SDG 2 – Zero Hunger is supported through the improvement of goat milk production and feed efficiency, which can enhance food availability and nutritional security in rural communities. SDG 8 – Decent Work and Economic Growth is reflected in the study's emphasis on increasing the profitability of goat farming through cost-effective feeding strategies and improved income over feed cost. SDG 12 – Responsible Consumption and Production is addressed through the utilization of locally available feed resources such as corn silage and azolla, which reduce dependence on expensive commercial feeds and promote sustainable resource utilization. SDG 13 – Climate Action is supported through the promotion of sustainable feeding systems that may reduce methane emissions and improve feed efficiency, as discussed by Evans (2018). SDG 15 – Life on Land is connected to the sustainable use of plant-based feed resources and environmentally friendly forage production practices. 1.7 Importance of the Study to Multidisciplinary Sustainability

The study contributes to multidisciplinary sustainability by integrating livestock nutrition, agricultural productivity, environmental sustainability, rural livelihood development, and economic efficiency. From a socio-economic sustainability perspective, the findings provide practical feeding alternatives that may increase milk production while lowering feeding costs, thereby improving the profitability and resilience of smallholder goat farming systems. In terms of agricultural and technological sustainability, the study promotes the adoption of innovative feeding technologies such as corn-based TMR and azolla supplementation to improve feed utilization and livestock productivity. The research also contributes to environmental sustainability by encouraging the use of renewable and locally available feed resources. Azolla cultivation supports sustainable feed production because of its rapid growth and nitrogen-fixing properties, while corn silage utilization contributes to efficient forage preservation. From a public health and nutritional sustainability standpoint, increased milk production and improved milk composition may contribute to improved access to nutrient-rich dairy products in rural communities. Finally, the study supports institutional and community sustainability by generating scientific information that may guide extension programs, livestock development initiatives, and farmer education on sustainable goat production practices.

2. Material and methods

2.1 Research Design

The study utilized an experimental research design using a Completely Randomized Design (CRD). Different dietary treatments consisting of corn-based total mixed ration with varying levels of azolla supplementation were administered to determine their effects on milk yield, milk composition, feed intake, feed conversion ratio, metabolic body weight, hematological parameters, and economic performance of upgraded Anglo-Nubian multiparous goats. The treatments were assigned randomly to experimental animals to minimize bias and ensure reliable comparison among treatment groups. The experimental period included adaptation, feeding, and data collection phases to evaluate animal performance under controlled management conditions.

2.2 Locale of the Study

The study was conducted at the goat production facility where upgraded Anglo-Nubian multiparous goats were maintained under uniform housing and management conditions. The area provided suitable environmental and management conditions for conducting feeding trials involving dairy goats. The feeding trial was performed under controlled conditions to ensure consistency in feeding, handling, and observation of the animals throughout the experimental period.

2.3 Respondents of the Study

The experimental animals used in the study were upgraded Anglo-Nubian multiparous goats in the lactation stage. The goats were selected based on similarity in age, body condition, physiological status, and health condition to reduce variability among experimental units. All goats were maintained under similar management and health care practices throughout the duration of the experiment to ensure consistency in data collection and animal performance evaluation.

2.4 Sample and Sampling Procedure

The goats were randomly distributed among treatment groups following the Completely Randomized Design. Each treatment consisted of goats receiving corn-based total mixed ration with different levels of azolla supplementation. The animals underwent an adaptation period prior to the feeding trial to familiarize them with the experimental diets and feeding management. Feed and water were provided regularly, and the animals were monitored throughout the study period. Daily feed allocation and feed refusals were measured to determine feed intake. Milk yield was recorded regularly during the

lactation period. Body weight measurements were also obtained to calculate metabolic body weight and feed conversion ratio.

2.5 Research Instrument

The primary materials used in the study included corn-based total mixed ration, azolla, feeding equipment, weighing scales, and milk collection materials. Corn silage and other feed ingredients were prepared and mixed to formulate the experimental diets according to the treatment requirements. *Azolla pinnata* was utilized as a feed supplement because of its high crude protein content and nutritional value as reported by Katole et al. (2017), Khare et al. (2016), and Kumar et al. (2020). The corn-based total mixed ration was formulated to provide balanced nutrients necessary for milk production and animal maintenance. Milk samples were collected and analyzed for milk crude protein and milk fat content. Hematological analyses included erythrocyte count, leukocyte count, packed cell volume, and hemoglobin concentration to assess the health status of the goats during the feeding trial.

2.6 Data Gathering Procedure

The experimental animals were first subjected to an adaptation period before the actual feeding trial. During the feeding period, the goats received their assigned dietary treatments consisting of corn-based total mixed ration with varying levels of azolla supplementation. Feeds were offered daily, and feed refusals were collected and weighed to determine feed intake. Water was provided ad libitum throughout the experiment. Milk production was measured regularly during the lactation period, and milk samples were collected for laboratory analysis of milk composition. Body weights of the goats were monitored to determine metabolic body weight and feed conversion efficiency. Blood samples were collected for hematological analysis to evaluate the physiological responses of the animals to the dietary treatments. Economic data, including feed cost and income over feed cost, were also recorded to assess the profitability of the feeding strategies.

2.7 Data Analysis Techniques

The collected data were subjected to statistical analysis appropriate for the Completely Randomized Design to determine significant differences among treatment means. Parameters analyzed included milk yield, feed intake, feed conversion ratio, metabolic body weight, milk crude protein, milk fat, hematological parameters, and economic returns. Mean comparisons among treatments were conducted to evaluate the effects of varying levels of azolla supplementation in corn-based total mixed ration. The results were interpreted to determine the effectiveness of corn-based total mixed ration with azolla supplementation in improving milk production, feed utilization, animal health, and profitability of upgraded Anglo-Nubian multiparous goats.

3. Results and Discussion

3.1 Effects of Azolla Supplementation on Production Performance

3.1.1 Milk Yield

The results showed that goats fed corn-based total mixed ration with azolla supplementation produced higher milk yield compared with goats receiving diets without azolla. Increased levels of azolla supplementation generally improved milk production performance throughout the feeding trial. The improvement in milk yield may be attributed to the high crude protein and nutrient content of azolla, which enhanced nutrient availability and feed efficiency. Azolla is recognized as a rich protein source capable of improving productivity in ruminants as reported by Katole et al. (2017), Khare et al. (2016), and Kumar et al. (2020). Improved nutrient utilization likely supported greater milk synthesis and lactation performance in the goats.

3.1.2 Feed Intake and Feed Conversion Ratio

The findings indicated variations in feed intake and feed conversion ratio among treatment groups. Goats receiving azolla-supplemented diets showed improved feed conversion efficiency compared with those fed the control ration. Feed intake remained acceptable across all treatments, indicating good palatability of the experimental diets. The improved feed conversion ratio suggests that azolla supplementation enhanced nutrient digestibility and utilization efficiency. The nutrient-rich composition of azolla, particularly its protein and mineral content, may have contributed to better rumen function and metabolic efficiency. These findings support previous reports that azolla can serve as an effective feed supplement for ruminants due to its nutritional quality (Khare et al., 2016).

3.1.3 Metabolic Body Weight

The results revealed no major adverse effects of azolla supplementation on the metabolic body weight of the goats. Animals maintained relatively stable body conditions throughout the experimental period despite differences in dietary treatments.

The stable metabolic body weight indicates that the experimental diets were able to meet the maintenance and production requirements of the goats. Adequate nutrient supply from the corn-based total mixed ration and azolla supplementation likely supported normal physiological functions and energy balance during lactation.

3.2 Effects on Milk Composition

3.2.1 Milk Crude Protein

Milk crude protein content increased in goats receiving azolla supplementation compared with the control group. Higher supplementation levels generally resulted in improved milk protein composition. The increase in milk crude protein may be associated with the high protein content of azolla, which enhanced amino acid availability for milk protein synthesis. Similar findings have been reported in studies where protein-rich feed supplements improved milk quality and nutrient composition in dairy animals (Kumar et al., 2020).

3.2.2 Milk Fat Content

The findings showed differences in milk fat content among treatment groups, with azolla supplementation contributing to favorable milk fat levels. Goats fed supplemented diets maintained acceptable milk fat composition throughout the study. The improvement in milk fat content may be related to enhanced rumen fermentation and nutrient metabolism resulting from the inclusion of azolla in the diet. Balanced dietary nutrients are important in maintaining milk fat synthesis and overall milk quality in lactating goats.

3.3 Hematological Parameters

3.3.1 Erythrocyte and Leukocyte Count

The hematological analysis showed that erythrocyte and leukocyte count of goats across treatments remained within normal physiological ranges. No significant adverse effects were observed in animals receiving azolla supplementation. The normal hematological values indicate that azolla supplementation did not negatively affect the health status of the goats. Adequate nutrient intake and balanced dietary formulation likely supported normal blood cell production and immune function during the feeding trial.

3.3.2 Packed Cell Volume and Hemoglobin Concentration

Packed cell volume and hemoglobin concentration remained relatively stable among treatment groups throughout the experiment. The goats maintained normal physiological conditions regardless of dietary treatment. The stable packed cell volume and hemoglobin concentration suggest that the experimental diets provided sufficient nutrients necessary for maintaining proper oxygen transport and blood health. These findings indicate that azolla can be incorporated into goat diets without causing negative hematological effects.

3.4 Economic Performance

3.4.1 Feed Cost and Profitability

The results showed that azolla supplementation influenced feed cost and income over feed cost among treatment groups. Diets containing azolla demonstrated improved economic returns due to enhanced milk production and feed utilization efficiency. The improved profitability may be attributed to the relatively low cost and high nutritional value of azolla as a feed resource. Increased milk yield combined with efficient feed utilization contributed to better economic performance of the goats. These findings support the potential of azolla as a sustainable and cost-effective feed supplement for dairy goat production.

3.5 Overall Implications of the Study

The overall findings demonstrated that corn-based total mixed ration supplemented with azolla positively affected milk production, milk composition, feed efficiency, hematological parameters, and economic returns in upgraded Anglo-Nubian multiparous goats. The study confirms the potential of azolla as an alternative protein-rich feed supplement for dairy goats. Its nutritional benefits and economic advantages support its use in improving productivity and sustainability in small ruminant production systems, consistent with findings reported by Katole et al. (2017), Khare et al. (2016), and Kumar et al. (2020).

4. Conclusion & Recommendations

The study demonstrated that corn-based total mixed ration supplemented with azolla positively influenced the production performance, milk composition, feed efficiency, hematological parameters, and economic returns of upgraded Anglo-Nubian multiparous goats. Goats receiving azolla supplementation showed improved milk yield, better feed conversion efficiency, favorable milk crude protein and fat content, and maintained normal hematological values throughout the experiment. The findings indicate that azolla can serve as a nutritious and cost-effective feed supplement that supports improved productivity and sustainability in dairy goat production systems, consistent with the findings of Katole et al. (2017), Khare et al. (2016), and Kumar et al. (2020).

Based on the findings of the study, the inclusion of azolla in corn-based total mixed ration is recommended for dairy goat

production due to its positive effects on milk production, feed utilization, animal health, and economic performance. Further application of azolla supplementation may help improve the sustainability and profitability of small ruminant production systems. Additional studies may also be conducted to evaluate different supplementation levels and feeding strategies under varying production conditions while maintaining the nutritional benefits observed in this study.

Compliance with ethical standards

The authors declare no conflict of interest. This study complied with recognized ethical standards for human-participant research by ensuring voluntary participation with informed consent, the right to withdraw without penalty, and strict confidentiality through anonymous, secure, and aggregated data handling. Given the focus on psychological well-being, procedures were non-invasive, and safeguards were observed to minimize discomfort, with guidance to appropriate support services when needed, and required institutional permissions were secured for instrument use and access to academic records.

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