International Journal of Agriculture and Biosciences 2025 14(3): 483-489.
https://doi.org/10.47278/journal.ijab/2025.028

RESEARCH ARTICLE
eISSN: 2306-3599; pISSN: 2305-6622

# Effects of Lipid Source Supplementation on Rumen Microbial Population Dynamics and *In Vivo* Digestibility of Napier Grass in Goats

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## ABSTRACT

This study evaluated the effects of lipid source supplementation on rumen microbial population dynamics and in vivo digestibility of Napier grass in goats. 12 male goats aged six months were assigned to a Randomized Complete Block Design (RCBD) with four treatments: T0 (control, no fat), T1 (corn oil), T2 (coconut oil), and T3 (lard fat), with three replicates per treatment. Lipid sources were administered via stomach tubing at 3% of the goats' dry matter intake (DMI) for 14 consecutive days. Changes in bacterial and protozoal populations were assessed on day 0 and 14, and in vivo digestibility was measured at the end of the trial. Data were analyzed using analysis of variance (ANOVA) and compared with Tukey's Honestly Significant Difference (HSD) test using SPSS software (IBM version 20). The results indicated that corn oil supplementation led to the highest reduction in bacterial and protozoal populations, followed by coconut oil. Oils rich in polyunsaturated and medium-chain saturated fatty acids showed a stronger inhibitory effect on rumen microorganisms compared to lard fat, which contains more long-chain monounsaturated fatty acids, especially in reducing protozoal counts. However, there were no significant differences among treatments in rumen pH, intake, digestibility of dry matter (DM), organic matter (OM), crude fiber (CF), and crude protein (CP), although corn oil showed a slight advantage. Overall, supplementing with corn oil and coconut oil at 3% DMI/day may effectively promote defaunation without adversely affecting rumen pH, nutrient intake and digestibility.

**Keywords:** Microbial diversity, Lipid supplementation, Digestibility, Defaunation, Goats.

**Article History**
Article # 24-982
Received: 19-Nov-24
Revised: 20-Dec-24
Accepted: 28-Jan-25
Online First: 16-Feb-25

## INTRODUCTION

Animal-derived foods are indispensable to global nutrition, supplying approximately 35% of the world's dietary protein (Wood et al., 2024). With the global demand for animal products steadily increasing, meat production is projected to grow by 12% between 2022 and 2032 (OECD-FAO, 2023). Addressing this growing demand necessitates improving animal productivity, which is largely contingent on optimizing feed utilization. Strategies such as enhancing microbial protein synthesis and improving fiber digestion through rumen manipulation have been identified as critical approaches to boost livestock performance while simultaneously reducing production costs and enhancing the sustainability of livestock systems (Krause et al., 2003; Makkar and Beever, 2013).

Goats (*Capra hircus*), known for their ability to efficiently utilize a wide range of forages and grasses, contribute significantly to the sustainability and resilience of livestock systems. This capability is supported by their rumen which harbors a complex microbial ecosystem essential for their feed digestion and nutrient acquisition. Among host-associated ecosystems, the rumen microbiome is recognized as one of the most complex and diverse microbial environments (De jonge et al., 2022). Ciliated protozoa are a significant component of this ecosystem, accounting for nearly half of the microbial biomass in the rumen (Andersen et al., 2023). These protozoa fall into two primary groups: entodiniomorphs and holotrichs (Firkins et al., 2020). Their roles include shaping the rumen microbial balance through predation and mutualistic interactions (Shang et al., 2022).

**Cite this Article as:** Reproto RO, 2025. Effects of lipid source supplementation on rumen microbial population dynamics and *in vivo* digestibility of Napier grass in goats. International Journal of Agriculture and Biosciences 14(3): 483-489. https://doi.org/10.47278/journal.ijab/2025.028

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Protozoa act as predators within the rumen, significantly influencing the microbiome through both top-down mechanisms, by consuming prey organisms, and bottom-up processes, by altering the metabolism of their microbial hosts (Yan et al., 2023). Since rumen protozoa are not essential for the fundamental functions of the rumen (Newbold et al., 2015), managing their populations particularly those with limited contributions to fiber digestion can enhance dietary nitrogen utilization, leading to improved growth and productivity in livestock.

Defaunation, the removal of ciliate protozoa from the rumen, has demonstrated potential in improving ruminant productivity and feed efficiency. Studies have reported enhanced feed utilization, increased growth rates, and greater microbial protein flow to the intestines in defaunated animals, particularly when fed diets low in protein relative to energy (Santra and Karim 2000; Nguyen et al., 2020). Several approaches have been explored to achieve partial or complete defaunation, including the use of chemicals toxic to protozoa (e.g., copper sulfate, dioctyl sodium sulfosuccinate, alcohol ethoxylates, calcium peroxide), ionophores, lipids and saponins (Williams and Coleman, 1992; Jouany, 1996; Hook et al., 2010). Among these approaches, lipids have emerged as a preferred strategy, valued not only for their effectiveness in controlling protozoa but also for their role in mitigating methane emissions. However, lipid inclusion may impair fiber digestibility by coating feed particles, with the extent of this inhibition depending on the type and concentration of lipids used (Hristov et al., 2013). Research has further indicated that the anti-protozoal efficacy of lipids is influenced by their fatty acid composition, with medium-chain fatty acids demonstrating greater effectiveness compared to polyunsaturated fatty acids (Finlay et al., 1994; Machmüller et al., 2003; Machmüller 2006).

Despite extensive research on lipid-induced rumen manipulation, there is still limited understanding of the specific effects of various lipid sources on protozoal and bacterial populations, rumen pH and fiber digestibility, particularly in small ruminants such as goats. Identifying the optimal lipid source to balance microbial dynamics and enhance fiber digestion is essential for improving productivity without compromising rumen function. To address this gap, this study aims to evaluate the effects of different lipid sources on rumen microbial populations, rumen pH and the apparent digestibility of Napier grass in goats.

## MATERIALS & METHODS

### Ethics Statement

All experimental procedures involving animals were conducted following ethical guidelines. The welfare of the animals was a priority throughout the study, and every effort was made to minimize discomfort. The administration of lipid supplements and collection of rumen fluid samples were performed with care to avoid unnecessary stress or pain to the animals. Deworming, feeding, and housing conditions were maintained in accordance with established animal husbandry standards to ensure the health and well-being of all animals involved in the study.

### Experimental Design and Treatment

12 six-month-old male goats were selected from the small ruminant project at the Department of Animal Science, Visayas State University, Baybay City, Leyte, Philippines. Prior to the experiment, metabolism cages were disinfected with a multi-purpose disinfectant and repaired as necessary. To ensure the animals were free from internal parasites, they were dewormed with commercial dewormer (Ivermectin) one week before the study at a dosage of 0.5mL per 15kg body weight. The goats were housed in metabolism cages designed to separate urine and feces (Bestil & Espina, 1991). Lipid supplementation was provided at 3% of the average daily dry matter intake (DMI), with treatments as follows: T0 – no fat (control), T1 – corn oil, T2 – coconut oil and T3 – lard fat. The goats were randomly assigned to treatments in a Randomized Complete Block Design (RCBD), with three replicates per treatment.

### Preparation of Lipid Sources

Commercial corn oil and coconut oil were obtained from a local department store, while lard (hog fat) was sourced from pig belly trimmings purchased at the Baybay City wet market in Leyte, Philippines. The belly trimmings were chopped into small pieces (2-3 inches) and the fat was extracted by rendering over an open flame. The melted fat was strained through cheesecloth, cooled, and stored at room temperature until use. Since lard is solid at room temperature, it was heated to liquefy before administration to the experimental animals. The fatty acid composition of the lipid sources, as reported by Gunstone (1996), is presented in Table 1.

**Table 1:** Fatty acid composition of supplemental lipid sources

| Corn oil | 16% Saturated | 84% Unsaturated |
|---|---|---|
| | 13% Palmitic (16:0) | 52% Linoliec (18:2 n-6) |
| | 3% Stearic (18:0) | 31% Oleic (18:1 n-9) |
| | | 1% Linolenic (18:3 n-3) |
| Coconut Oil | 90% Saturated | 9% Unsaturated |
| | 48% Lauric (12:0) | 7% Oleic (18:1 n-9) |
| | 16% Myristic (14:0) | 2% Linoleic (18:2 n-6) |
| | 9% Palmitic (16:0) | Others 1% |
| | 8% Caprylic (18:0) | |
| | 7% Capric (10:0) | |
| | 2% Stearic (18:0) | |
| Lard (hog fat) | 40% Saturated | Unsaturated 59% |
| | 27% palmitic (16:0) | 44% Oleic (18:1 n-9) |
| | 11% Stearic (18:0) | 11% Linoleic (18:2 n-6) |
| | 2% Myristic (14:0) | 4% Palmitoleic (16:1 n-7) |
| | | Others 1% |

*Adopted from Gunstone (1996)

### Administration of Lipid Supplements, Animal Care and Sample Collection

Lipid supplements were administered directly into the rumen once daily at 3:00 p.m. for 14 consecutive days. Using a stomach tube (CH/R 18) attached to a 20mL plastic syringe, the liquid lipids were infused by inserting the tube approximately 45cm through the mouth and esophagus. The experimental animals were fed a basal diet of Napier grass (*Pennisetum purpureum*), offered twice daily at 8:00 a.m. and 3:00 p.m., with the grass chopped into approximately 5-inch pieces. A one-week adaptation period was observed, during which feed intake and

refusals were recorded to establish baseline voluntary intake. Water was provided ad libitum throughout the study. Rumen fluid was collected using a stomach tube following the technique of Ramos-Morales et al. (2014), avoiding the need for surgical cannulation. Samples were collected via a syringe attached to the stomach tube before (day 0) and after (day 14) lipid supplementation, with rumen pH measured using a Milwaukee SM101 digital pH meter with a glass electrode.

**Microbial Dynamics Assessment**

**Bacterial Counting**

Rumen bacterial population were quantified through standard plate count (SPC) by means of pour plate technique. It was done by taking 1mL subsample of rumen liquid and serially diluted into 1:1000, 1:10,000, 1:100,000 and 1:1,000,000 by subsequently pipetting 1mL sample of every dilution into sterile petri plates. Individual petri plates were poured with 25mL liquefied plate count agar (PCA) growth medium heated under temperature of 41°C.Thereafter, the rumen liquid was mixed carefully with the melted agar and incubated under anaerobic condition at 40°C using GasPak anaerobe container sachet for a period of 24 hours. Duplicate samples were analyzed in each treatment replicates. Any bacterial colonies formed after a period of 24 hours were counted using "Suntex"colony counter. Colony forming units (cfu) were computed based on this formula: cfu/mL = number of bacterial colonies x dilution rate.

**Protozoal Counting (Subsampling, Staining and Dilution)**

The number of protozoa was counted based on the procedure of Dehority (1984) with some modification as described by D'Agosto and Carneiro (1999). 1mL subsample of rumen liquid was poured using a 5mL pipette with a wide orifice (3 mm) into the test tube. Three drops of lugols solution were added into the test tube and allowed to stand for at least 15 minutes. Afterwards, 9mL of 30% glycerol solution was added into the test tube resulted in a 1:10 dilution of the original rumen contents. The 30% glycerol solution was used because of its high viscosity that prevents rapid settling of protozoa during the process of pipetting the subsamples for counting. This diluted sample was then pipetted into a Sedgewick rafter counting chamber by a wide-orifice pipette and examined under optical Olympus (CX11) microscope. The number of protozoa was counted at 10x magnification. All grids evenly spaced over the entire chamber surface were counted. Multiplying the total number of protozoa counted to the dilution factor which is 10 gives the number of protozoa per milliliter of diluted rumen liquid. Protozoal concentration was expressed on a logarithmic basis (log [no. cells/mL]). Example, if the total protozoa counted = 1,250 and the dilution rate is 1:10, the number of protozoa would be: 1,250 x 10 = 125,000 or 125 x $10^3$/mL rumen liquid.

**Digestibility Trial**

The digestibility trial was conducted based on the following procedure (Bestil, 2009).

**Day Activity**

**1-9: Adjustment Period**

This is the period to clear previously fed diets from the digestive tract and establish *ad libitum* intake level. The animals were weighed to get their initial body weight. *Ad libitum* intake of napier grass was established by giving a 20% allowance in feed given based on previous day's voluntary intake. Intra - ruminal infusion of fats was given daily at 3 o'clock in the afternoon.

**10 -14: Collection Period**

This is the period to quantify fecal excretion while recording the feed intake of the animal. The amount of napier grass fed was reduced to 90% of *ad libitum* feed intake of animals during the adjustment period to ensure that digestibility values represent the whole plant instead of the leafy portion only. A harness equipped with a bag was fitted to goats for fecal collection. Daily fecal output was collected and weighed for five consecutive days and a subsample of about 10% from the daily collection was pooled together and frozen for subsequent analysis. A separate fecal sample was set aside for DM determination of the fecal matter to calculate DM excretion.

**Parameter Measurement**

1. Voluntary Dry Matter Intake (Kg) of Napier grass

DMI = (Feed Given x %DM given) – (Feed Refused x DM of Feed refused)

2. *In vivo* digestibility of DM, CF, CP, and OM were calculated as nutrient intake (kg/DM/day) minus nutrient in fecal output (kg DM/day) divided by the nutrient intake (kgDM/day), value was express in percentage. The following equation was used:

$$\text{NAD (\%)} = \frac{\text{Nutrient Intake} - \text{Nutrient in feces}}{\text{Nutrient Intake}} \text{ X } 100$$

Where: NAD = Nutrient Apparent Digestibility

Nutrient intake = DM intake x % nutrient in feces

3. Rumen pH

The pH of rumen liquid was measured before (initial) and after (final) giving the different supplemental lipid sources for a series of fourteen days. Degree of acidity was determined using Milwaukee digital SM101 pH meter with glass electrode.

**Laboratory Analysis**

The composite sample from five days collection period was mixed thoroughly and dried in a forced draft oven set at 60°C for a period of 48 hours. Then, a representative sample of about 10% from each treatment was separated and ground through Willey-mill with 1mm sieve. This was then analyzed in duplicate for DM, Ash, CP and CF contents. DM content of Napier grass and fecal output was estimated by drying duplicate samples in an air-draft oven at 105°C for 16 hours. On the other hand, ash content was determined by burning the sample in a muffle furnace set at 650°C for four hours and organic matter was calculated by subtracting dry matter with ash content. Nitrogen content was measured by Kjeldahl

procedure and amount of CP was calculated using formula N x 6.25 while CF was determined using modified Henneberg-Stohmann method. Both Napier grass and fecal outputs were analyzed according to the standard procedures of AOAC (1990).

### Data Analysis

Results were analyzed using one-way analysis of variance (ANOVA). Treatment means for bacterial count, protozoal count, rumen pH, dietary nutrient intake, and digestibility were compared using the Honestly Significant Difference (HSD) test. Statistical analysis using Statistical Package for the Social Sciences (SPSS), IBM version 20.

## RESULTS & DISCUSSION

### Protozoal Population

The protozoal populations in goats on days 0 and 14, comparing the effectiveness of various lipid treatments in defaunating the rumen is given in Table 2. A significant reduction ($P<0.05$) in protozoal populations was observed, particularly in goats supplemented with corn and coconut oil. In agreement with Ningal (2020), dietary lipid supplementation effectively reduced protozoal populations. The efficacy of different fat sources in rumen defaunation can be attributed to their physical properties, particularly their melting points. Fats with higher melting points, such as lard, are less soluble in the rumen environment, making them more resistant to breakdown by protozoal enzymes. This resistance limits fatty acid release and consequently reduces their inhibitory effect on protozoal growth (Jenkins and Palmquist, 1984). In contrast, fats with lower melting points, such as corn oil and coconut oil, are more effective at promoting rumen defaunation. For instance, coconut oil, rich in medium-chain fatty acids such as lauric acid (C12:0) and myristic acid (C14:0), has been suggested to reduce rumen protozoal numbers (Panyakaew et al., 2013). Studies by Cusiayuni et al. (2022) and Yanza et al. (2021) further observed that coconut oil supplementation in feed tends to decrease protozoal populations in the rumen, which is linked to a reduction in methane ($CH_4$) production. Supporting this, Shi et al. (2020) mentioned that supplementing goat kids with 6 g/day of coconut oil significantly lowered protozoal populations. Similarly, Jordan et al. (2006) reported a 62% reduction in rumen protozoal population when feeding 250g of refined coconut oil to beef heifers. The effectiveness of coconut oil in defaunation is further supported by Lovett et al. (2003), who found that protozoal populations in beef heifers decreased by 63 and 80% after 45 and 75 days, respectively, when fed 300g/d of coconut oil. However, Toyber et al. (2024) noted that although dietary interventions can influence the size of protozoal populations, they do not lead to significant changes in the overall community composition. Likewise, it is important to note that while defaunation can modify ruminal digestion, complete elimination of protozoa may not be necessary or desirable. Rumen protozoa contribute significantly to microbial biomass and fermentation products in the rumen (Williams and Coleman, 1992; Newbold et al., 2015). Therefore, strategic use of fats for partial defaunation may be more beneficial for optimizing rumen function and animal performance.

**Table 2:** Rumen protozoal population in goats as influenced by supplemental lipid sources infused into the rumen at 3% of the daily dry matter intake (DMI) for fourteen consecutive days

| Treatments | Protozoal population (x$10^3$/mL of rumen liquid) | | %Change in protozoal population |
|---|---|---|---|
| | Initial (Day 0) | Final (Day 14) | |
| $T_0$ | 64.1b | 59.7b | -6.79a |
| $T_1$ | 44.9b | 2.73b | -94.19b |
| $T_2$ | 425a | 47.2b | -88.38b |
| $T_3$ | 341a | 298a | -11.75a |
| *P-value* | 0.001** | 0.001** | 0.001** |

** Highly Significant. Treatment means within a column having the same letter alphabets are not significantly different from each other. Treatments: $T_0$ - Without fat; $T_1$ - Corn oil; $T_2$ - Coconut oil; $T_3$ - Lard fat.

### Bacterial Population

Different types of supplemental dietary lipids at 3% DMI/d produce significantly varying effects on the percent change in rumen bacterial populations (Table 3). Compared to the control group without fat supplementation, goats supplemented with corn oil and coconut oil exhibited the highest reductions in rumen bacterial counts, indicating a higher degree of toxicity to bacterial populations. In contrast, the use of lard fat showed no significant ($P>0.05$) difference from the control, suggesting a limited inhibitory effect. Corn oil and lard fat are rich in long-chain polyunsaturated and monounsaturated fatty acids, while coconut oil contains a higher percentage of medium-chain saturated fatty acids. Burdick et al. (2022) observed that adding medium-chain fatty acids (MCFAs) at 0.063% of dietary dry matter (DM) in dairy cows led to a reduction in rumen bacterial diversity, although it did not have a significant impact on rumen fermentation processes. This is consistent with earlier studies by Machmüller (2003), who reported the toxic effects of certain fatty acids on rumen bacteria. Regardless of their saturation level, fatty acids released during lipolysis can incorporate into the cellular membranes of rumen bacteria, disrupting membrane integrity and reducing bacterial viability (Or-Rashid et al., 2007). The limited impact of lard fat on bacterial populations may be attributed to its inert physicochemical properties, including a high melting point and low solubility within the rumen environment (Firkins & Eastridge, 1994). This characteristic likely contributes to the lower impact of lard fat on rumen bacterial populations when compared to corn and coconut oil, which exhibit more pronounced bacterial inhibition.

**Table 3:** Rumen bacterial population in goats as influenced by supplemental lipid sources infused into the rumen at 3% of the daily dry matter intake (DMI) for fourteen consecutive days

| Treatments | Bacterial Population (x$10^6$ cfu/mL) | | % Change in bacterial population |
|---|---|---|---|
| | Initial (Day 0) | Final (Day 14) | |
| $T_0$ | 84.53 | 43.93 | -52.10a |
| $T_1$ | 46.33 | 5.56 | -88.03b |
| $T_2$ | 47.03 | 5.83 | -82.00b |
| $T_3$ | 15.66 | 3.80 | -75.48ab |
| P- value | 0.16 | 0.06 | .018* |

*Significant. Treatment means within a column having the same letter and with no alphabets are not significantly different from each other. Treatments: $T_0$ - Without fat; $T_1$ - Corn oil; $T_2$ - Coconut oil; $T_3$ - Lard fat.

**Rumen pH**

The changes in rumen pH of goats after a 14-day infusion of supplemental lipid sources are summarized in Table 4. Results indicate that rumen pH was not significantly (P>0.05) impacted by the type of lipid supplementation. However, a general increase in pH (decrease in acidity) was observed across all treatments. Among the lipid sources, coconut oil led to the highest pH increase, while lard fat showed the lowest. Although these findings differ from those of Machmüller et al. (2003), who reported that defaunation typically decreases rumen pH, the pH levels in this study remained within the normal range for rumen health (5.5–7.0), which provides an optimal environment for rumen microorganism. Rumen pH is influenced by various factors, such as saliva production, short-chain fatty acid (SCFA) generation and absorption, feed intake type and quantity, and bicarbonate-phosphate exchange across the ruminal epithelium (Aschenbach et al., 2011). In this study, the presence of unsaturated fatty acids from the lipid supplements may have contributed to the pH increase. Jenkins (1993) and Palmquist (2007) suggest that these unsaturated fatty acids enhance the utilization of free hydrogen ($H^+$) during biohydrogenation, where unsaturated fats are converted to saturated fats. This process consumes metabolic hydrogen ions (about 1–2%) as reported by Czerkawski (1984), thus raising the pH. An increase in rumen pH, as seen in this study, could benefit the host animal. By supporting a more favorable pH range, lipid supplementation might therefore improve fiber breakdown and overall rumen function.

**Table 4:** Rumen pH in goats as influenced by supplemental lipid sources infused into the rumen at 3% of the daily dry matter intake (DMI) for fourteen consecutive days

| Treatments | Rumen pH | | % Change in |
|---|---|---|---|
| | Initial (Day 0) | Final (Day 14) | rumen pH |
| $T_0$ | 6.71 | 6.85 | 2.13 |
| $T_1$ | 6.72 | 6.90 | 2.84 |
| $T_2$ | 6.57 | 7.04 | 1.07 |
| $T_3$ | 6.82 | 6.94 | 1.87 |
| *P- value* | $0.783^{ns}$ | $0.491^{ns}$ | $0.571^{ns}$ |

$^{ns}$ not significant. Treatments: $T_0$ - Without fat; $T_1$ - Corn oil; $T_2$ - Coconut oil; $T_3$ - Lard fat.

**Table 5:** Voluntary dry matter intake of goats as influenced by supplemental lipid sources infused into the rumen at 3% of the daily dry matter intake (DMI) for fourteen consecutive days

| Treatments | Voluntary dry matter intake | |
|---|---|---|
| | DMI (g) | DMI (% BW) |
| $T_0$ | 283.33 | 1.62 |
| $T_1$ | 322.75 | 1.29 |
| $T_2$ | 220.52 | 2.48 |
| $T_3$ | 206.72 | 2.61 |
| P- value | $.389^{ns}$ | $.372^{ns}$ |

$^{ns}$ not significant. Treatments: $T_0$ - Without fat; $T_1$ - Corn oil; $T_2$ - Coconut oil; $T_3$ - Lard fat.

**Voluntary Dry Matter Intake**

Table 5 presents the voluntary dry matter intake (DMI) of goats supplemented with different lipid sources. The results indicated that lipid supplementation did not significantly affect voluntary DMI (P>0.05), which is consistent with the findings of Gomes et al. (2021), who also observed no significant impact of lipid supplementation on DMI. When adjusted as a percentage of body weight (BW) to account for size variation, no significant differences were found between treatments. However, while all treatments showed intake levels below 3% BW on a DM basis, goats supplemented with lard fat exhibited the highest DMI, whereas those given corn oil had the lowest. This trend is in agreement with Harvatine and Allen (2006), who reported that unsaturated fats, such as those in corn oil, can suppress DMI. The decrease in DMI following lipid supplementation may be related to the impact of fat on diet digestibility, potentially mediated by the release of gut peptides in response to the added fat (Martínez Marín et al., 2013). Additionally, reduced dry matter intake (DMI) may be linked to an increase in ruminating time, as dietary fats can influence rumen digestion by slowing digesta passage rates due to the metabolic effects of long-chain fatty acids. This delayed passage rate may lead to extended rumen retention time, which subsequently reduces voluntary intake. Schauff et al. (1992) observed a 14% decrease in DMI with increased fat unsaturation, suggesting a direct relationship between dietary fat composition and feed intake. The impact of dietary fats on rumen function is particularly significant when fat content exceeds 8% of the diet's dry matter, potentially resulting in decreased fiber digestion, further reductions in DMI and overall declines in cow performance (Schauff and Clark, 1992; Pantoja et al., 1994). In contrast, Joy et al. (2021) demonstrated that moderate increases in dietary fat inclusion did not compromise nutrient digestibility or DMI. Their findings suggest that carefully balancing dietary fat levels is essential to avoid adverse effects on feed intake or digestion while still harnessing the benefits of dietary fats as a concentrated energy source. Overall, while lipid type did not significantly alter DMI, the observed trend of reduced intake in goats supplemented with unsaturated fats, particularly corn oil, suggests that these fats may affect feeding behavior and digestion kinetics.

**Diet Nutrient Intake and Digestibility**

The intake and digestibility of nutrients in a Napier grass diet supplemented with various lipid sources at 3% DMI/d is given in Table 6. The results showed that lipid supplementation did not significantly (P>0.05) impact the intake and digestibility of DM, CF, CP, or OM. Among the treatments, corn oil consistently yielded the highest nutrient intake (g) and digestibility percentages, suggesting that unsaturated fats have minimal effects on ruminal fermentation and may enhance digestibility. The increased DM digestibility observed with corn oil supplementation may be attributed to an extended retention time or a slower passage rate of digesta in the rumen (Van Soest, 1994; Mahmood et al. 2022' Syamsu et al. 2024). Although Doreau and Chilliard (1997) observed that unsaturated fats can reduce feed digestibility, the extent of this effect may vary depending on the type of roughage included in the diet (Huang et al., 2008; Arief et al. 2024). Conversely, fiber digestibility may be compromised by lipid supplementation due to its inhibitory effects on cellulolytic bacteria and protozoa, which contribute approximately 19–28% of total cellulase

**Table 6:** Intake and digestibility of nutrients in napier grass diet of goats as influenced by supplemental lipid sources infused into the rumen at 3% (DMI/d) of the daily dry matter intake (DMI) for fourteen consecutive days

| Treatments | Nutrient Intake and Digestibility | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | DMI (g) | DMD (%) | CFI (g) | CFD (%) | CPI (g) | CPD (%) | OMI (g) | OMD (%) |
| $T_0$ | 283.33 | 59.06 | 95.20 | 87.07 | 34.25 | 79.03 | 253 | 85.58 |
| $T_1$ | 322.75 | 76.90 | 108.44 | 89.44 | 39.02 | 85.09 | 228.9 | 88.36 |
| $T_2$ | 220.52 | 59.52 | 74.10 | 79.14 | 26.66 | 64.16 | 197.6 | 65.71 |
| $T_3$ | 206.72 | 42.01 | 69.46 | 80.03 | 24.99 | 74.20 | 185.2 | 76.67 |
| P- value | $0.39^{ns}$ | $0.54^{ns}$ | $0.39^{ns}$ | $0.47^{ns}$ | $0.39^{ns}$ | $0.37^{ns}$ | $0.39^{ns}$ | $0.09^{ns}$ |

$^{ns}$ not significant. Treatments: T0 - Without fat; T1 - Corn oil; T2 - Coconut oil; T3 - Lard fat. DMI – Dry matter intake; DMD – Dry matter digestibility; CFI – Crude fiber intake; CFD – Crude fiber digestibility; CPI – Crude protein intake; CPD – Crude protein digestibility; OMI – Organic matter intake; OMD – Organic matter digestibility

activity in the rumen (Gijzen et al., 1988). While unsaturated fats are more readily digestible in the rumen, their inhibitory action on fiber-digesting microorganisms can reduce fiber breakdown.

Saturated fats, on the other hand, have a lesser effect on fiber digestion but may still result in lower overall digestibility depending on their degree of saturation (Firkins and Eastridge, 1994). In general, unsaturated fats appear to influence ruminal fermentation more strongly than saturated fats (Jenkins, 1993) and lipid additions to the diet can modify basal metabolism, microbial populations, digestibility, and nutrient utilization (Moallem et al., 2007; Palmquist 2007).

## Conclusion

Infusing lipid sources at 3% of DMI/d into the rumen impacts the microbial population, with corn oil (rich in long-chain polyunsaturated fatty acids) and coconut oil (rich in medium-chain saturated fatty acids) showing greater toxicity to rumen protozoa than lard fat (rich in long-chain monounsaturated fatty acids). These lipids can therefore be effectively used as supplements to provide additional energy and to promote partial defaunation of the rumen in ruminants. However, while corn oil and coconut oil also exhibit high toxicity to rumen bacteria, their effects on rumen pH, voluntary intake, and nutrient digestibility remain minimal. Given their tendency to reduce bacterial populations, it may be beneficial to supplement the diet with additives that support bacterial recovery post-defaunation. This approach could help maintain a balanced microbial ecosystem, optimizing digestion and nutrient utilization in the long term.

**Conflicts of Interest:** The author declare no conflict of interest.

**Acknowledgment:** The author is grateful to the Department of Science and Technology- Science Education Institute (DOST- SEI) under the Accelerated Science and Technology Human Resource Development Program (ASTHRDP) for funding this research.

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