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Impact of *Tithonia diversifolia* and *Pennisetum purpureum*-based Ration on Nutrient Intake, Nutrient Digestibility and Milk Yield of Etawa Crossbreed Dairy Goat

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ABSTRACT

The research aimed to discover the effect of *Tithonia diversifolia* (TD) and *Pennisetum purpureum* (PP)-based ration on nutrient intake, nutrient digestibility and milk yield of Etawa crossbreed dairy goat. Sixteen Etawa crossbreed dairy goats in the second month of lactation with live weight 60-70kg were the object in this study. Completely Randomized Design (CRD) was used with 4 treatments and 4 replications for each treatment. The treatments were as follows: A=20% fermented palm frond (FPF) + 16% *Tithonia diversifolia* (TD) + 64% *Pennisetum purpureum* (PP), B=20% FPF + 32% TD + 48% PP, C=20% FPF + 48% TD + 32% PP and D=20% FPF + 64% TD + 16% PP. The data were analyzed using analysis of variance, and the Duncan's s Multiple Range Test. The parameters examined were nutrient intake including dry matter and organic matter; protein intake; nutrient digestibility which cover dry matter, organic matter, crude protein, Neutral Detergent Fiber (NDF), Acid Detergent Fiber (ADF), cellulose; hemicellulose digestibility; and milk yield. The results of the experiment showed that the combination of 64% *T. diversifolia* and 16% *P. purpureum* increased nutrient intake (P<0.05) while dry matter intake increased 2.57-3.01kg/head/day, organic matter 2.32-2.67kg/head/day and protein intake 0.32-0.48kg/head/day. Nutrient digestibility and milk yield were non-significantly different (P>0.05), although the rise of *T. diversifolia* did not decline nutrient digestibility and milk production. This study concluded that the combination of 64% *T. diversifolia* and 16% *P. purpureum* resulted in the best nutrient intake, nutrient digestibility, and milk yield of Etawa Crossbreed Dairy Goat.

Key words: Etawa crossbreed dairy goat, milk yield, intake, digestibility, *Tithonia diversifolia*, *Pennisetum purpureum*.

INTRODUCTION

Indonesia was in state of milk emergency until 2018. Indonesia's fresh milk production throughout 2017 only grew 0.81% to 920.000 tons from 912.000 tons the previous year. National milk demand reaches 4.500.000 tons per year, while domestic demand for milk was only around 18% (Badan Pusat Statistik 2018). The data shows that Indonesia's milk imports in 2018 were very high reaching 82%. The condition requires all stakeholders to work hard to achieve milk self-sufficiency. Development of new milk production centers outside of Java and development or diversification of alternative milk-producing livestock outside dairy cows, for instance the Etawa crossbred dairy goat (ECDG), can help to meet milk self-sufficiency program target (Azilia 2016). Asia had the greatest increase in goat milk yield (22%) during the last decade, followed by Africa (13%), Oceania (9%), the Americas (5%) and Europe (4%) (Miller and Lu 2019).

Etawa crossbreed dairy goats (ECDG) have been reared for a long time. Therefore, they are considered as local goats of higher genetic quality than other goats in Indonesia. ECDG is a dual-purpose goat that can produce both milk like Etawa goat and meat like Kacang goat. Another argument for choosing Etawa crossbreed goats is their high growth rate, which results in litter sizes of up to two heads. Raising a goat is also simple and does not necessitate a vast space (Rosartio et al. 2015). The livestock has a very wide distribution due to its good ability to adapt to various types of climates and environments. Milk yield of ECDG can reach 2.1 liters per day (Syawal and Solehudin 2019). Fat and protein content of ECDG's milk

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is high reaching 6.08 and 4.48% (Arief et al. 2018). Goat's milk is superior to cow's milk in term of digestibility due to its smaller fat grain size and homogeneous form (Yangilar 2013). Both conventional and new markets are eager for dairy goat products. Goat milk and products are becoming more popular as a result of their health and nutritional benefits, which enhance digestion and lipid metabolism, as well as flavor (Miller and Lu 2019).

The utilization of feed in dairy farming has a significant impact on milk production. Smallholder farmers in developing countries generally have limited access to adequate feed (Sidawi et al. 2021). Limited sources of feed with low nutritional content from the surrounding environment have a detrimental impact on the productivity of livestocks. Feed sources used are typically difficult to digest and low in protein. Therefore, it is essential to improve feed quality and investigate novel feed sources.

One of the alternative feed items is *Tithonia diversifolia*, which belongs to the tree legume family. *T. diversifolia* has spread throughout Indonesia, notably in West Sumatra, where it is widely found as shrubs, waste bushes and useless plants, with some used as compost and natural pesticides on roadside and in rice fields. Meanwhile, *T. diversifolia* has not been widely utilized as animal feed, especially ruminants. In 1.5 hectare, *T. diversifolia* plants cultivated in West Sumatra can produce up to 30 tons of fresh material or 6 tons of dry stuff each year (Jamarun et al. 2017a).

T. diversifolia grows fast with a high nutritional value. *T. diversifolia*'s whole plant (leaves + stems) has a nutritional composition of 22.98% crude protein and 18.17% crude fiber (Jamarun et al. 2017a). Fasuyi et al (2010) claimed that the amino acids in *T. diversifolia* leaves are highly complicated. *T. diversifolia*'s plant contains essential amino acids for rumen microbial development, such as methionine, leucine, isoleucine, and valine (Oluwasola and Dairo 2016). Also, *T. diversifolia* can be used as a ruminant feed supplement, particularly during the dry season when fodder is limited (Osuga et al. 2006). García et al. (2017) claimed that *T. diversifolia* has essential micro mineral namely phosphorus, calcium, and magnesium. This research was aimed to discover the best *Tithonia diversifolia* and *Pennisetum purpureum*-based ration formula to optimize milk yield of Etawa crossbreed dairy goat.

MATERIALS AND METHODS

Animal Ethics

Animal experiments were conducted in accordance with Republic of Indonesia Law No. 18 of 2009 (section 66), which addressed animal keeping, raising, killing, and proper treatment and care.

Animal Maintenance

Sixteen Etawa crossbreed dairy goats in the second month of lactating with live weight 60-70 kg were raised in individual metabolic cages, which were stage cages measuring 1.5x2m each and equipped with a place to eat and drink. The cage's floor is about one metre above the ground. Rations were prepared by mixing concentrate and forage where concentrate consisted of palm kernel cake, maize, rice bran, tofu waste, and mineral. While forage included *T. diversifolia*, *P. purpureum*, and fermented palm frond with 60:40 forage and concentrate ratio. Forage consisted of 20% fermented palm frond and 80% mixed of *T. diversifolia* and *P purpureum*.

The study of Etawa crossbreed dairy goat (ECDG) was conducted into three phases: adaptation, introduction, and collection. ECDG was given 15 days adaptation period to help them adjust to the experimental ration. The introductory period was 25 days long, with the purpose of removing the influence of the previous ration. The data collection period was five days long to collect feces sample and calculate ration consumption. After three phases has passed, milk yield variables was proceed.

Variables Analysis

Nutrient Intake

By subtracting the number of rations delivered from the remaining rations, the ration intake was calculated. These formulas were used to determine nutrient intake of ECDG (Pazla et al. 2021a).

Dry matter intake = dry matter of ration – dry matter residual of ration

Organic matter intake = dry matter intake x organic matter of ration

Crude protein intake = dry matter intake x crude protein of ration

Nutrient Digestibility

Nutrient digestibility (dry matter, organic matter, crude protein, crude fiber, crude fat, NDF, ADF, hemicellulose, cellulose) was determined by subtracting the nutrient intake and nutrient in the feces and divided with nutrient in feces.

$$\text{Nutrient digestibility} = \frac{\text{nutrient intake} - \text{nutrient in feces}}{\text{nutrient in feces}} \, x\, 100\%$$

Milk Yield

Milk yield/head/day in kg is obtained by adding milk yield from morning and evening milking. A two-kilogram scale was used to quantify milk yield and standardized to four months of lactation. Milk yield during lactation was determined using the conversion method (4% FCM/day) according to Mavrogenis and Papachristoforou (1988).

Milk yield 4% FCM = M (0.411 + 0,147 f)

Where:

M = Average of daily milk yield (kg/head/day)

f = percentage of fat (%)

Feeding Formulation

Palm kernel cake, maize, rice bran, tofu waste, minerals are blended with fermented palm fronds. According to the treatment, *P. purpureum* and *T. diversifolia* were combined. Feeding was done twice a day, at 08.00 and 17.00, and the feed was 4% of body weight in the form of dry matter, according to National Research Concil (1981). Drinking water is available all times. Table 1 and 2 show the ingredient and chemical composition for the treatment rations used in this experiment.

Table 1: Feed Chemical Composition

Chemical composition (% DM)	Feeds						
	FPF	TD	PP	Palm kernel cake	Maize	Rice bran	Tofu waste
DM	72.01	25.57	21.23	91.83	85.80	87.80	28.40
OM	91.34	84.01	89.46	91.41	99,10	90.80	97.67
CP	08.89	22.98	10.88	12.36	07.70	10.72	20.11
CF	38.59	18.17	32.77	26.68	02.44	11.60	19.00
EE	01.27	04.71	02.48	08.23	03.50	08.73	01.25
NDF	66.52	61.12	66.57	66.70	49.96	55.13	59.28
ADF	57.85	40.15	41.71	46.10	36.76	29.35	26.65
Cellulose	37.50	34.59	34.18	43.25	29.52	15.52	22.93
Hemicellulose	08.67	20.97	24.86	20.60	13.20	25.78	32.63
Lignin	18.35	04.57	06.29	17.29	07.50	06.90	02.20
TDN	61.90	62.60	63.48	65.40	81.90	66.63	74.61

Fermented Palm Frond (FPF); *Pennisetum purpureum* (PP); *Tithonia diversifolia* (TD), dry matter (DM), organic matter (OM), crude protein (CP), crude fiber (CF), ether extract (EE), Neutral Detergent Fiber (NDF), Acid Detergent Fiber (ADF), Total Digestible Nutrient (TDN)

Table 2: Ingredients and chemical composition of treatments

Component	Treatments			
	A	B	C	D
Ingredient composition (%)				
FPF	12	12	12	12
Tithonia diversifolia	9.6	19.2	28.8	38.4
Pennisetum purpureum	38.4	28.8	19.2	9.2
Palm kernel cake	9	9	9	9
Maize	8	8	8	8
Rice bran	12	12	12	12
Tofu waste	10	10	10	10
Mineral	1	1	1	1
Total	100	100	100	100
Chemical composition (%DM)				
DM	47.75	48.17	48.58	49.00
OM	90.20	89.67	89.14	88.62
CP	12.48	13.64	14.79	15.96
CF	24.84	23.44	22.04	20.68
EE	03.75	03.96	04.17	04.39
NDF	61.95	61.43	60.90	60.38
ADF	40.08	39.94	39.79	39.64
Cellulose	31.35	31.39	31.43	31.47
Hemicellulose	21.86	21.49	21.11	20.74
Lignin	08.18	08.02	07.85	07.69
TDN	65.71	65.62	65.53	65.45
Ca	00.71	00.72	00.85	00.94
P	01.87	01.90	02.07	02.44

Fermented Palm Frond (FPF), Dry matter (DM), organic matter (OM), crude protein (CP), crude fiber (CF), ether extract (EE), Neutral Detergent Fiber (NDF), Acid Detergent Fiber (ADF), Total Digestible Nutrient (TDN)

Table 3: Nutrient digestibility of Treatments

Digestibility (%)	Treatments			
	A	B	C	D
DM	71.93	73.01	74.71	75.40
OM	74.09	74.60	76.79	78.24
CP	74.67	75.24	79.15	80.52
NDF	65.62	66.15	68.64	69.83
ADF	54.63	56.55	58.37	61.83
Cellulose	68.23	69.78	70.71	73.17
Hemicellulose	82.41	85.90	87.26	87.30

Dry matter (DM), organic matter (OM), crude protein (CP), Neutral Detergent Fiber (NDF), Acid Detergent Fiber (ADF)

Experimental Design

The *in vivo* approach was used with a Completely Randomized Design (CRD) in this research, four treatments with four replications for each treatment. The following were the treatments:

A = 20% FPF + 16% TD + 64% PP
B = 20% FPF + 32% TD + 48% PP
C = 20% FPF + 48% TD + 32% PP
D = 20% FPF + 64% TD + 16% PP
Where:
FPF : Fermented Palm Frond
TD : *Tithonia diversifolia*
PP : *Pennisetum purpureum*

The variables examined were nutrient intake, nutrient digestibility, and daily milk production.

Statistical Analysis

According to Steel and Torrie (1995), analysis of variance (ANOVA) was used to analyze the data, and the Duncan's multiple distance test was performed to evaluate the difference in the treatment mean at a confidence range of 5 and 1%.

RESULTS

Nutrient Intake

Fig. 1 shows the nutrient intake of Etawa crossbreed dairy goats (ECDG) given fermented palm fronds (FPF) with varying levels of *T. diversifolia* and *P. purpureum*. The analysis of variance revealed that the treatments had a valuable influence on nutritional consumption (P<0.05). Dry matter and organic matter in treatment A were not substantially different from treatment B after the DMR test, but considerably different (P<0.05) from treatment C and significantly different (P<0.01) from treatment D. Treatment B did not differ meaningfully from treatment D. Treatment C did not differ remarkably from treatment D. Meanwhile, with increasing levels of *T. diversifolia* and *P. purpureum*, crude protein intake increased crucially (P<0.05). Supplying 64% *T. diversifolia* and 16% *P. purpureum* increased nutritional intake according to the findings.

Nutrient Digestibility

The ECDG nutrient digestibility fed with FPF with various level of *T. diversifolia* and *P. purpureum* is presented in Table 3. The treatments had no effect on nutrient digestibility according to the analysis of variance (P>0.05), although ECDG that received higher *T. diversifolia* level in each treatment had higher nutrient digestibility than ECDG that received the least *T. diversifolia*. Therefore, it suggests that giving 64% *T. diversifolia* and 16% *P. purpureum* improved nutrient digestibility.

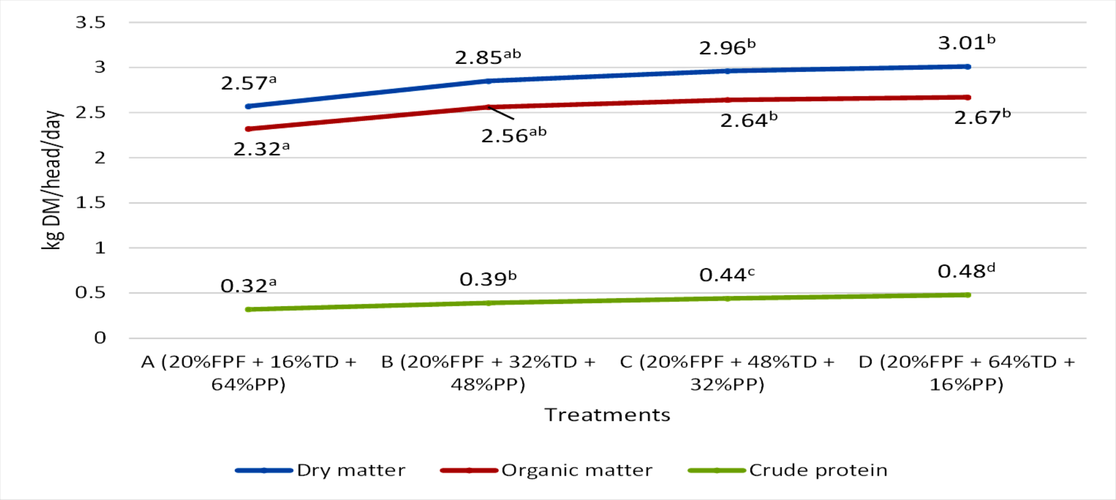

Fig. 1: Effect of varying levels *Tithonia diversifolia* and *Pennisetum purpureum* on dry matter, organic matter, and protein intake of Etawa crossbreed dairy goat: Superscript means significantly different in a row (P<0.05).

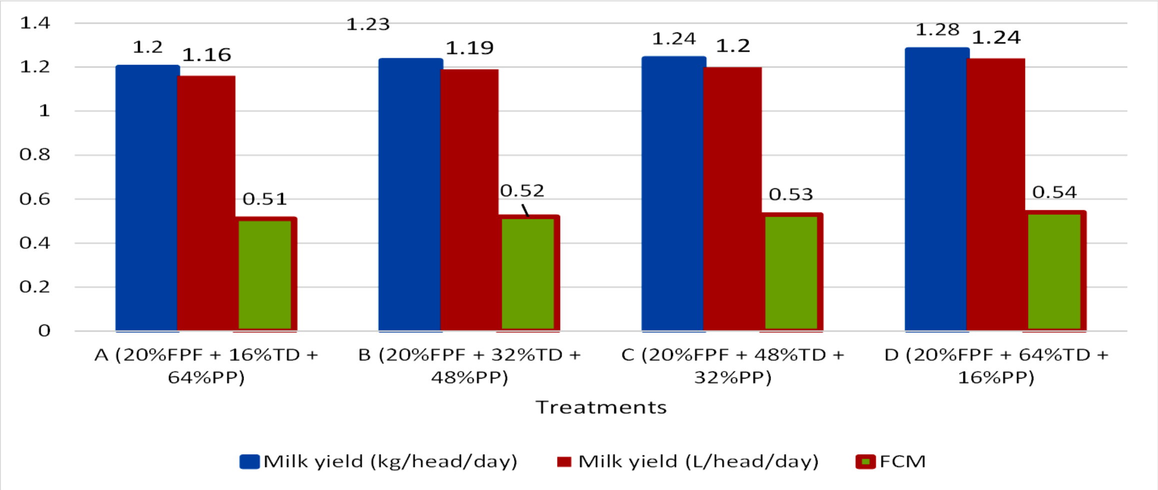

Fig. 2: Effect of different level of dietary *Tithonia diversifolia* and *Pennisetum purpureum* on milk yield of Etawa crossbreed dairy goat.

Milk Yield

The ECDG milk yield after being fed with FPF with various level of *T. diversifolia* and *P. purpureum* is presented in Fig. 2. Treatments had no effect on milk yield according to the analysis of variance (P>0.05). Although the addition of *T. diversifolia* to the ration resulted in an increase in milk production. Thus, it suggests that giving 64% *T. diversifolia* and 16% *P. purpureum* resulted in improving milk yield.

DISCUSSION

Nutrient Intake

The raising of *T. diversifolia* in the ration increase ECDG's nutrient intake, as shown in Fig. 1. It indicates that combining FPF and *T. diversifolia* in the diet of ECDG can reduce the use of *P. purpureum*. As the palm fronds had been fermented, finely ground, and blended with concentrate to prevent cattle rejection, dry matter intake (DMI) revealed that the ration provided was palatable to ECDG. These results are higher than Ramírez-Rivera et al. (2010) who found that lambs fed Taiwan grass hay supplemented with varied quantities of *T. diversifolia* had dry matter intake of 1.05-1.55kg/head/day. During the growing period, García et al. (2017) discovered 0.36kg/head/day DMI on Alpine, Nubian, and Saanen dairy goats fed with one litre goat milk and a mixture of *T. diversifolia* meal, maize meal, soybean meal, urea, premix, and salt.

The level of palatability is determined by nutrient intake. A greater value of nutrient intake indicates that the ration is well-palatable. It is critical to determine the animal's amount of consumption in order to calculate the nutrients available for maintenance and production (Barreto et al. 2012). High level of consumption affects livestock production performance (Pazla et al. 2021a; Saldanha et al. 2021). Furthermore, according to Baumont (1996), palatability of the feed is defined as all the physical (plant bearing, spines, etc.) and chemical (odour, taste, etc.) qualities of the feed that act on appetite, whereas eating rate is a measure of the animal's appetite. Furthermore, the lignin content of palm fronds has been successfully reduced through fermentation with *Phanerochaete chrysosporium* supplemented with minerals Ca, P, and Mn, which acts as a barrier to cellulose hydrolysis. Similarly, Febrina et al. (2017) and Jamarun et al. (2017b) claimed that the lignin content of palm frond was reduced after fermentation with *P. chrysosporium* that increased consumption in goats. The *lignin peroxidase* (LiP), *manganese peroxidase* (MnP), and *laccase* enzymes produced by *P. chrysosporium* may break down bonds and degrade lignin with the help of lignin-degrading enzymes (Yanti et al. 2021).

With an average of 3.01kg/head/day, treatment D had the highest DMI. Performance parameters (body weight, age, and environmental condition of goats), feed digestibility, feed quality, and palatability are all factors that determine the level of variance in consumption. Giving up to 64% *T. diversifolia* to ECDG is appetizing and increasing intake. It is owing to the goat's tendency to "browsing" for food and preference for leaves (selective). The greatest crude protein content level in treatment D (15.96%) was also a factor responsible for the rise in DMI. Likewise, Cannas and Pulina (2008) stated that feed digestibility, palatability, retention time, crude protein content, organic matter content, and animal physiological parameters, all influence DMI.

The lowest DMI was found on treatment A (2.57kg/head/day) caused by high level of *P. purpureum* in the ration. *P. purpureum* has bulky characteristics which increase volume per unit weight, resulting in a slow pace of stomach emptying. Goats are reluctant to ingest extra feed due to the rumen's restricted capacity to accommodate it, resulting in decreased DMI. *P. purpureum* has a high crude fiber content, which decreases nutrient digestibility and nutrient intake because of "rumen fill" (Yansari et al. 2004; Rusdy 2016). Coleman and Moore (2003) stated that nutrient intake is the result of a complex interaction between feed ingredients, the rumen, and the livestocks. Also, crude fiber content on ration affected DMI. The highest crude fiber on treatment A also caused the lowest DMI. The ration's high crude fiber content reduces the digestion of the nutrients. Feed consumption will decrease if the rate of digestion reduces. On the other hand, if the rate of digestion increases, the amount of food consumed will raise. The fiber fraction considerably influences the digestibility of fiber, both in terms of amount and chemical composition (McDonald et al. 2010). The pattern of organic matter intake (OMI) is similar to DMI due to identical chemical content. The greater dry matter intake, the higher organic matter intake (Kamalidin et al. 2012; Febrina et al. 2017).

Treatment D had a higher protein content than the other treatments due to the rise of crude protein intake (CPI). According to Martawidjaja et al. (1999), the consumption of crude protein rations increased as the rise of protein content in the rations, so the protein to be used is greater. The increase of *T. diversifolia* in each treatment potentially escalate CPI. Treatment D had the highest CPI with an average of 0.48kg/head/day. Protein is one of the nutrients that function in growth and milk production. Therefore, CPI can be used to measure the validity of the ration studied in this study. Since crude protein is one of the organic ingredients in the diet, the amount of DMI and crude protein in the ration determine the amount of crude protein consumed. A high CPI comes from a ration with a high crude protein content and DMI. The results is higher than Krisnan et al. (2015) who reported that 0.24kg/head/day CPI of ECDG fed with *Pennisetum purpupoides, Leucaena leucocephala,* and concentrate, and Marwah et al. (2010) who claimed that 0.34/kg/head/day CPI of ECDG fed with *Calliandra calothyrsus* and concentrate.

The anti-nutritional effect of *T. diversifolia* plants has not reduce nutrient intake. DMI, OMI, and CPI steadily advance with mount up of *T. diversifolia.* It shows that *T. diversifolia* level of up to 64% in rations are safe for livestock. Studies found that adding *T. diversifolia* to the ration mix had no negative impact on ruminant productivity or digestibility as long as the dosage was not too high in livestock rations (Odedire and Oloidi 2014; Arief et al. 2018).

Nutrient Digestibility

The treatments had no effect on digestibility, however ECDG that received higher level of *T. diversifolia* in each treatment had higher digestibility than those with the least *T. diversifolia*. It suggests that *T. diversifolia* potentially improved digestion from the results of this study showed, dry matter digestibility was ranged 71.93–75.40% in which treatment D had the highest dry matter digestibility (75.40%). Dry matter digestibility (DMD) is one criterion for determining the ration's quality. High dry matter digestibility indicates high utilization of nutrient. The result is higher than Febrina et al. (2017) who found 42.19-64.58% DMI on Etawa crossbreed fed with combination of fermented palm frond and *P. purpureum.* Odedire and Oloidi (2014) also found 70.98% dry matter digestibility on goat fed with *T. diversifolia* mixed with concentrate.

By knowing how much is digested and eliminated through feces, the digestibility of feed ingredients has a significant impact on the feed's quality (Coleman and Moore 2003). High DMI level suggests an increase in digested nutrients by rumen bacteria in ruminants (Ningrat et al. 2019; Ningrat et al. 2020; Putri et al. 2021). High percentage of ration indicate its quality. DMI is determined by the amount of ration consumed, the rate of digestion, and the type of nutrient content (Saldanha et al. 2021). Besides that, crude fiber content on ration impacts nutrient digestibility. High crude fiber indicates high lignin in the ration, which declined the nutrient digestibility. Higher organic matter digestibility (OMD) was observed in treatment D (78.24%). As organic matter is a component of dry matter, it increased DMD. Similarly, Tillman et al. (1998) and Sutardi (1980) stated that DMI consists mostly of OMD (protein, fat, and carbohydrates).

Crude protein digestibility (CPD) ranged from 74.67-80.52%. Treatment D had the highest value (80.52%), whereas treatment A had the lowest (74.67%). Although no significant effect on CPD, the addition of *T. diversifolia* to the ration resulted in increasing trend. The chemical of feed ingredients has a strong influence on digestibility (Jamarun and Zain 2013). Dietary protein digestibility is related to the quality of feed ingredients, particularly the CP content. CPI increases along with the amount consumed. The rate of reproduction and the rumen microbial population will both be benefitted from the rise of crude protein content which improve the ability to digest. The feed composition, nutritional content, and the digestion process in the rumen and post-rumen tract will all influence the feed's digestibility (Beever and Mould 2000).

The findings showed that adding the amount of 64% *T. diversifolia* in the treatment had no effect on crude protein digestibility. Protein digestibility is influenced by the condition of the rumen bacterial population, particularly those that are proteolytic, i.e. bacteria that produce extracellular protease enzymes. According to the findings, the number of proteolytic bacteria in each treatment was most likely similar. Likewise, Supriyati and Haryanto (2011) discovered that the combination of *P. purpureum* and palm kernel cake had a crude protein digestibility of 73.02-75.99%.

The level of cell wall component degradation in feed ingredients is the most important factor impacting nutritional value (National Research Council 2001). NDF digestibility is an important criterion for predicting feed ingredient quality (Spanghero et al. 2003). Van Soest (1965) stated that the fibrous component of the cell wall is NDF, which contains lignin, cellulose, hemicellulose, and a number of proteins joined together by fibers. Although the fiber fraction's digestibility had no influence, the fiber fraction's digestibility value increased in line with the *T. diversifolia* level in the ration. With 64% *T. diversifolia*, the digestibility of fiber fraction is higher than other treatments. It was most likely caused by the treatment rations' NDF, ADF, and lignin content decreased from treatment A to D. Treatment D had the maximum digestibility of NDF, ADF, cellulose, and hemicellulose. Treatment D had a lower lignin content than the other treatments. The low lignin content benefits rumen bacteria in breaking down cellulose and hemicellulose in feed. The lignin-cellulose and lignin-hemicellulose bond in the cell wall acts as a barrier to the enzymes produced by microbes in the rumen.

The combination of lignin with cellulose and hemicellulose components in the cell wall prevents rumen bacteria to utilize cellulose and hemicelluloses. Microbial activity is inhibited by lignified cell walls, which allow microorganisms to only attack the cell wall's surface. Lignin is a difficult-to-digest component of plant cell walls (Van Soest 1965).

T. diversifolia also contains anti-nutritional compounds or secondary metabolites such as phytic acid, tannin, oxalate, saponins, alkaloids, and flavonoids, which might block digestion (Fasuyi et al. 2010). Rumen activity is to be reduced by the presence of secondary metabolite plants (Makmur et al. 2020). Depending on the dose, these antinutrients have both favorable and detrimental effects on livestock. The most abundant anti-nutritional chemicals in the *T. diversifolia* plant are phytic acid molecules. The concentration reaches 79.2mg/100g (Oluwasola and Dairo 2016). Ruminants, unlike monogastric animals, have phytase enzyme produced by microbes in the rumen, such as *Actinobacillus sp*. and *Bacillus pumilus* rumen bacteria (Lamid et al. 2014). The enzyme detaches phosphor from phytate, allowing phosphor to be released and used as a phosphorus source (Jamarun et al. 2019; Pazla et al. 2021b). Also, phytate can create complex bonds with Zn in the rumen, forming Zn-phytate complexes, which degraded by microbial rumen and released Zn, to be used for rumen microbial development and livestock growth (Hernaman et al. 2007).

T. diversifolia level 64% had the highest digestibility because the rumen microbial phytase enzymes degraded phytic acid antinutrients, resulting in mineral phosphor or rumen microbe growth and development. Phosphor is required for microbial growth, particularly in the maintenance of cell membrane and cell wall integrity. (Rodehutscord et al. 2000; Bravo et al. 2003; Zain et al. 2010; Suyitman et al. 2021). The sufficient phosphor improves microbial protein synthesis since some feed ingredients are deficient in the mineral phosphor. Phosphor is added to the feed to promote rumen bacterial growth and development that enhance digestibility (Zain et al. 2010; Febrina et al. 2017; Jamarun et al. 2017c; Pazla et al. 2020). In treatment D, ideal rumen microbial growth enabled optimal rumen bacteria to degrade feed which resulting in the maximum digestibility of dietary components and fiber fraction.

Protein is protected from rumen degradation by antinutrient tannins in *T. diversifolia*, which forms protein-tannin complex bonds ensuring protein not to degrade in the rumen. Therefore, it can reach the small intestine to be used for basic needs and production. Henson et al. (1997) claimed that the undegradable protein escalates the amount of protein and amino acids to be digested and absorbed by the small intestine that improved protein synthesis. Also, Widyobroto et al. (1995) added that in the abomasum and intestine, protected proteins can be digested by enzymes. Treatment D's high *T. diversifolia* level and consumption made animals more tannin tolerant, allowing them to get the most out of the nutrients in *T. diversifolia*. Similarly, (McSweeney et al. 1999) claimed that proteolytic bacteria are typically found in rumen microbes that can thrive in the presence of tannins, in which their ability to grow is determined by adaptive factors. Besides that, *T. diversifolia* contains anti-nutritional saponins as a defaunation agent in certain quantities, enhancing the bacterial population and, as a result, enhancing the digestibility of feed elements in the rumen (Suharti et al. 2009).

Milk Yield

The major purpose of growing dairy cattle is to maximize milk output, while good milk quality, particularly fat content, determine its selling value. The key component influences the quantity and quality of milk production is the ration. The availability of food ingredients, both in terms of quality and quantity impacts milk yield (Mačuhová et al. 2020). The results of the study had higher milk yield (1.2-1.28kg/head/day) compared to Arief et al. (2020) who reported suplementation of *T. diversifolia* in ECDG's ration affect milk yield (range 0.84-1.23kg/head/day) and greater than Arief (2013) who used palm concentrate on ECDG diet obtained 0.65kg/day/head milk production and an FCM 0.29. Aside from that, the non-significant variation in milk yield and milk fat between treatments A, B, C and D was due to each treatment's varying nutrient digestibility. ECDG consumed crude protein, which acted as a precursor in the rumen's synthesis of NH_3. NH_3 used as a source of nitrogen for rumen bacteria, resulting in optimal microbial activity in the rumen as well as optimal carbohydrate fermentation into volatile fatty acids (VFA) (Camero et al. 2001; Putri et al. 2021). Ideal VFA production optimized energy sources in livestock that resulted in higher productivity and greater milk production.

Protein is the most important component in ruminant productivity. Protein-rich diet enhances metabolism and increases the ability of microorganisms to breakdown feed (Zain et al. 2020). Methionine, leucine, isoleucine, and valine are all necessary amino acids for microbial development in *T. diversifolia* (Ramírez-Rivera et al. 2010;

Oluwasola and Dairo 2016; García et al. 2017; Durango et al. 2021). Milk yield from all treatments was the same due to the same TDN content of rations. Although statistically non-significant, the addition of *T. diversifolia* level to the ration enhanced milk production. It demonstrates that *T. diversifolia* can maximize milk yield. *T. diversifolia*'s supply of ration protein helps to retain cells in the mammary glands and create hormones and enzymes that aid milk production, resulting in greater milk production. Tannins in *T. diversifolia* also protect protein from rumen breakdown by forming a protein-tannin complex link in the small intestine, ensuring that protein does not degrade in the rumen and instead enters the small intestine, where it can be best utilized by the ruminant body for milk production. The amount of protein and amino acids digested directly by enzymes and absorbed in the small intestine can be increased by feeding protein that is not digested in the rumen, which can enhance milk and body protein synthesis (Widyobroto et al. 1995; Henson et al. 1997; Putri et al. 2019; Zain et al. 2019).

T. diversifolia contains anti-nutritional tannin and saponins as a defaunation agent in certain quantities, enhancing the bacterial population and as a result, increasing the digestibility of feed elements in the rumen and also milk yield. Saponins in excess of the dose can kill most or even all populations of rumen protozoa, resulting in decreased rumen digestibility. Saponins reduce protozoa population, which inhibits fiber-breakdown enzyme activity, lowering the digestibility value of dry matter, including fiber digestibility in the rumen. Similarly, Wina et al. (2005) and Krisnawan et al. (2015) found that in an *in vitro* experiment utilizing *Sapindus rarak* extract, the digestibility of feed in the rumen was reduced in the presence of saponins. In addition, Hess et al. (2004) studied the effects of sheep fed tropical grass hay-concentrate diets with Sapindus saponaria fruits, which contain saponin, in an *in vivo* experiment concluded that excessive consumption of saponins by animals can decline nutrient digestibility. Although *T. diversifolia* contains tannin and saponin, supplementation of 64% *T. diversifolia* (treatment D) gave positive effect to ECDG as evidenced by the fact that milk yield is not declining. In addition, treatment D's high *T. diversifolia* consumption made microbial rumen more tannin tolerant, allowing them to get the most out of the nutrients in *T. diversifolia*. Also, the findings of McSweeney et al. (1999) claimed that microbial rumen are able to thrive in the presence of tannins tended to be proteolytic, and that their increased growth was determined by adaption factors.

Conclusion

We suggest that the combination of 64% *Tithonia diversifolia* and 16% *Pennisetum purpureum* in the diet of lactating Etawa crossbreed dairy goats resulted in the best nutrient intake, nutrient digestibility, and milk yield of Etawa crossbred dairy goats.

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Author's Contribution

R. Pazla designed the experiment while primary manuscript was written by N. Jamarun, M. Zain. Arief supervised *in vivo* and laboratory experiment. G. Yanti conducted laboratory and data analysis. E.M. Putri edited and finalized the manuscript. R.H. Candra conducted *in vivo* experiment.

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