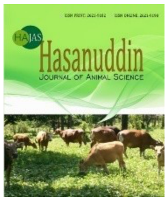

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Effect of Mixed Cropping Between Zea maize and *Arachis pintoi* on the Nutrient Content of Grain and Straw

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ABSTRACT

This study aimed to evaluate the effect of mixed cropping of maize (*Zea mays*) with pinto peanut (*Arachis pintoi*) on the nutrient content of maize grain and straw. A randomized group design (RGD) was employed with five treatments and three replications. The treatments consisted of P0 (100% maize), P1 (80% maize + 20% legume), P2 (50% maize + 50% legume), P3 (20% maize + 80% legume), and P4 (100% legume). The parameters observed included crude protein, neutral detergent fiber (NDF), and acid detergent fiber (ADF) content of maize grain and straw. Analysis of variance revealed that mixed cropping had no significant effect (P>0.05) on the nutritional composition of both maize grain and straw. In conclusion, intercropping maize with *Arachis pintoi* does not significantly influence the nutritional quality of maize under the conditions of this study.

Keywords: *Arachis pintoi,* maize feed, mixed cropping, production

INTRODUCTION

Maize is an important commodity for both humans and livestock. Maize is the most important food crop in the world, after wheat and rice, which are the main livestock feed crops. Almost all parts of corn can be used for various purposes. Corn kernels can be used for non-ruminant animal feed, while all parts of the corn plant, including young corn plants and straw, can be used for ruminant feed either directly or after processing. The most important factors in providing feed are that it must be available in sufficient quantities, contain the nutrients livestock need, and be available year-round.

Feed corn is a high-value grain crop. In addition to its grain, corn can also be a source of vegetable protein and carbohydrates. It can grow on various types of land and produce high yields. Therefore, it is very good to develop the corn plant as a forage source for animal feed, with additional advantages: it is relatively inexpensive, easy to plant, and can grow in various soil types.

Plants need fertilizer to promote optimal growth and yield. There are two main types of fertilizers: inorganic (chemical) and organic, both of which are used to boost forage corn production and nutritional value. However, inorganic fertilizers are generally more commonly applied by farmers to grazing land.

The use of inorganic fertilizers to increase forage productivity can degrade soil physical properties and increase production costs. Therefore, alternative strategies, such as mixed cropping systems, are worth exploring.

Mixed cropping is a system of planting two or more crops on the same plot of land during the same growing season. This system involves competition or mutual influence among plant components during growth, which can affect the yield of one or more plants. According to Abdullah [1], legumes contribute N to feed corn plants during their growth in mixed cropping. One advantage of a mixed cropping system is that it can increase land productivity per unit area and improve crop quality [2]. Mixed cropping of feed maize and pinto beans can increase feed maize production [3].

Pinto beans (*Arachis pintoi*) are a type of legume that can improve soil fertility. They are perennial legume plants that grow vines above the soil surface. The growth of pinto beans is influenced by environmental conditions and planting distance. They can grow well in both fertile and less fertile soils, though growth is slower in the latter [4]. Legume species such as *A. pintoi* have high nutritional value, with crude protein content reaching 21% and in vitro dry matter digestibility up to 74%, making them an excellent supplement to low-quality forages [5][6].

MATERIALS AND METHODS

This research was conducted in the Field Laboratory of Feed Crop Science and Pasture, Faculty of Animal Husbandry, Hasanuddin University, Makassar. The materials used consisted of feed corn seeds and legume seedlings, *Arachis pintoi*. The tools used were planting equipment, measuring instruments, analytical scales, and stationery. This study used a Randomized group design (RGD) consisting of 5 treatments and 3 groups as replicates for each treatment [7]. The data collected were subjected to analysis of variance followed by Duncan's test.

Research method

This study used a Randomized group design (RGD) consisting of 5 treatments and 3 groups as replicates for each treatment [7]. The treatments in this study were:

P0: 100% Maize
P1: Maize 80% + Legumes 20%
P2: 50% Maize + 50% Legume
P3: Corn 20% + Legumes 80%
P4: 100% Legumes

The total number of experimental units was 15. The treatment randomization plan is shown in Figure 1.

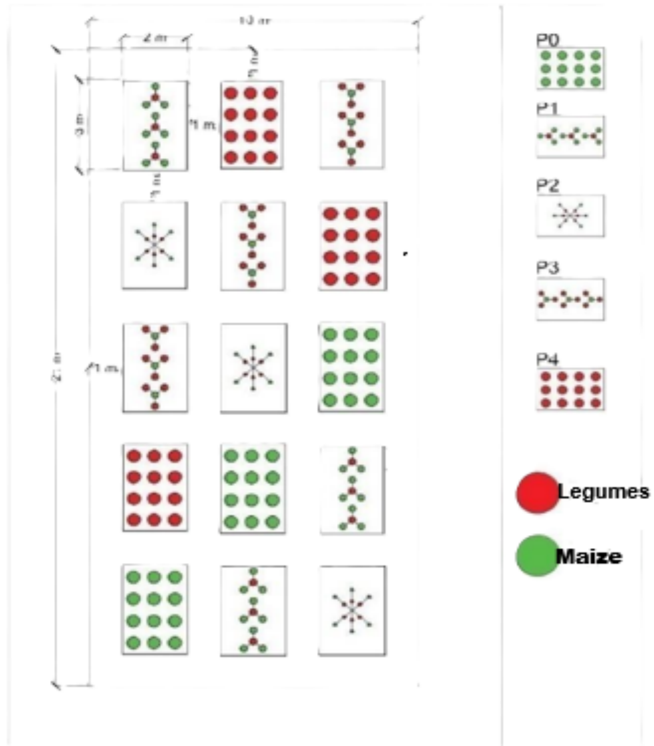

Figure 3. Research plan. Description: P0: 100% Maize (12 plants) P1: Maize 80% (9 plants) + Legumes 20% (3 plants) P2: Maize 50% (6 plants) + Legumes 50% (6 plants) P3: Corn 20% (3 plants) + Legumes 80% (9 plants) P4: 100% Legumes (12 plants)

Cultivation Method

Before planting, tillage is carried out to produce quality feed crop productivity. The first step is to clear the area of bushes, trees, and other grasses that interfere with plant growth. The next stage is to hoe and loosen the soil to break the layers into chunks, making them easier to break up. Then, the measurement of the research plot that will be carried out, the land with a size of 210 m2 is divided into 15 plots, each measuring (3 x 2 m), and the distance between each plot is 1m. The cleared land was planted with pinto bean legumes, which were first sown and grown in polybag media for 15 days before planting. Each polybag contained one pinto bean plant, so the total number of plants provided in the study was 250. Then plant Baskoro-type fodder corn seeds to a depth of 3-5 cm in each hole, with 2 seeds per hole. After that, watering was done twice a day. The research was conducted during the transition from the rainy to the dry season, so no watering was done during the rainy season. Each plant was planted in each plot according to the treatment composition. Data collection was done after harvest.

Observed Parameters

The parameters observed in this study were the nutrient content of corn straw and the production of corn kernels, whose chemical composition includes crude protein, ADF, and NDF.

RESULTS AND DISCUSSIONS

Nutrient Content of Maize Grain Production.

The nutrient content of maize grain, including crude protein (CP), neutral detergent fiber (NDF), and acid detergent fiber (ADF), is presented in Table 1.

a. Crude Protein

The results showed variation in crude protein content, but the differences were not statistically significant. The highest crude protein content was found in treatments P2 (14.28), P1 (13.00), P0 (12.26), and P3 (12.07)

Table 1. Nutrient content of maize grain under different mixed cropping treatments

Treatment	Parameters		
	Crude Protein	**NDF**	**ADF**
P0	12.26	22.34	9.77
P1	13.00	31.73	6.23
P2	14.28	31.49	6.53
P3	12.07	30.52	6.66

Description: Treatment P0 = 100% corn, P1 = 80% corn + 20% legume, P2 = 50% corn + 50% legume, P3 = 20% corn + 80% legume

Treatment P2: Corn 50% (6 Trees) + Legumes 50% (6 Trees) performed better than several other treatments, although the differences were not statistically significant. This is because the number of legumes in treatment P2 is balanced with the maize plants, allowing the maize to benefit from the nitrogen produced by the legumes. This aligns with the opinions of Silva et al. [8], Tang et al. [9], and Zak et al. [10], who report that the presence of legumes in an ecosystem generally increases soil N (nitrate and total) levels. The increase in soil nitrate levels is due to the supply of N from N2 fixed by leguminous plants. In addition, there is no competition for light between the two.

A meta-analysis by Liu et al. [11] confirmed that cereal/legume intercropping significantly increases crude protein yield per unit area (by 0.20 ± 0.05 Mg/ha) compared to sole cropping, although the percentage concentration of CP in the total biomass may not change significantly. This suggests that the primary benefit of intercropping is increased protein production per unit land area rather than improved protein concentration in the cereal component alone. Furthermore, a recent global meta-analysis by Zhang et al. [12] demonstrated that forage intercropping increases crude protein yield by 36.7% compared to monocultures, while also enhancing nutrient efficiency by 40.3% per unit of nitrogen fertilizer.

This aligns with Giller [13], who noted that the efficiency of nitrogen fixation in legumes is influenced by environmental and physiological factors, including plant age. He added that in young plants, more energy is allocated to vegetative growth and nodule formation, whereas in older plants, nitrogen fixation competes with seed formation. In their research on nitrogen use efficiency in legume crops, Ciampitti and Salvagiotti [14] examined how soybeans accumulate nitrogen and found that nitrogen fixation efficiency varies throughout the plant life cycle, with a significant decrease during the seed-filling phase.

The lower crude protein content in P3 (20% maize + 80% legume), despite the highest legume proportion, can be attributed to several interacting factors. First, intense competition for nutrients, water, and light likely occurred due to the dominance of legume plants, which may have limited maize growth and nutrient uptake. While intercropping offers multiple agronomic benefits, the design of crop mixtures must carefully account for competitive interactions that can negatively affect the productivity of the primary crop. Ripoche et al. [15] state that although intercropping has several benefits, the design of intercrops needs to account for competition that may affect the productivity of the most important plants in the crop mix.

Second, the efficiency of biological nitrogen fixation (BNF) in *Arachis pintoi* is not constant throughout the growing period but varies with plant age and physiological stage. Giller [13] explained that in young legume plants, more energy is allocated to vegetative growth and nodule development, whereas in mature plants, nitrogen fixation competes with seed formation for photosynthetic assimilates. This pattern is particularly relevant in mixed cropping systems, where the timing of nitrogen availability may not align with the companion maize crop's peak nitrogen demand. Studies on *A. pintoi* as a cover crop in Kenya showed that it can accumulate 51–74 kg N ha^{-1} over 12 months, with 52–63% derived from atmospheric N_2 fixation [16].

Furthermore, Ciampitti and Salvagiotti [14] demonstrated that nitrogen fixation efficiency in legumes declines significantly during the seed-filling phase. In this study, if the peak nitrogen fixation period of *Arachis pintoi* occurred before or after the critical period of maize grain development, the transfer of fixed nitrogen to maize would be suboptimal. This temporal mismatch may explain why higher legume proportions did not consistently increase crude protein content in maize grain.

These findings highlight that the benefits of intercropping legumes with cereals are not solely determined by legume planting density but are mediated by complex interactions among resource competition, nitrogen fixation dynamics, and phenological synchrony between component species. Therefore, optimizing intercropping systems requires a holistic approach that considers not only the proportions of each species but also their growth patterns and resource-use efficiency.

Protein is an essential nutrient for livestock growth and is the most important component of animal body tissues. Therefore, it is necessary to practice mixed cropping of grass and legumes so that the nitrogen deficiency in grass can be compensated for by legumes, allowing them to complement each other [17]. Protein in feed plays a key role in body weight gain in livestock. The functions of protein include building and maintaining tissues and organs, providing energy, serving as a source of body fat, and supplying amino acids. The most important function of protein is to produce enzymes that catalyze various chemical reactions in the animal's body. Proteins also produce important hormones that regulate respiration, nutrient delivery in the bloodstream, growth, and reproduction.

Animals that experience protein deficiency will disrupt the growth and development of their body tissues. If the food does not contain enough protein, the body cannot build and maintain tissues, resulting in impaired growth and reduced production.

Protein formation begins with anabolism and is then broken down in the plant through catabolism. In plants, the nitrogen content is visible. Nitrogen content is a key factor that predominantly affects the growth of these plants. So plants really need nitrogen for protein formation, and a nitrogen deficiency can be interpreted as a lack of protein. Protein is found in young leaves and in other body parts, such as fruit [17].

In addition to the cropping system, the crude protein content of maize grain is influenced by harvest age and planting arrangement. Wea et al. [18] reported that intercropped maize had lower crude protein when harvested at 80 days than at 60 days, indicating that delayed harvesting may reduce protein quality. Similarly, Fitriansa et al. [19] found that intercropping *Brachiaria decumbens* with *Canavalia gladiata* (koro pedang) increased crude protein to 12% and reduced crude fiber to 23.32%, further supporting the potential of legume integration to improve forage quality. These findings suggest that both harvest timing and the selection of companion legume species play critical roles in determining the nutritional outcome of intercropping systems. The decline in protein content with advancing harvest age is likely associated with an increased stem-to-leaf ratio and lignification, which dilute protein concentration in the harvested biomass [20]. Therefore, optimizing harvest timing is essential to maximize the nutritional value of intercropped forage maize.

b. NDF (Neutral Detergent Fiber) content.

Analysis of variance showed no significant differences (P>0.05) in NDF content among treatments, although numerical variation was observed. The highest NDF content was recorded in P1 (31.73%), followed by P2 (31.49%), P3 (30.52%), and P0 (22.34%). Notably, the monoculture treatment (P0) had the lowest NDF content, whereas the mixed-cropping treatments (P1, P2, P3) had higher NDF values. This pattern suggests that including *Arachis pintoi* in the cropping system may influence fiber accumulation in maize grain, possibly due to changes in resource allocation or competition.

NDF represents the cell wall fraction of feed, primarily composed of hemicellulose, cellulose, and lignin. NDF content is widely used as an indicator of feed quality because it is inversely related to digestibility [21]. Higher NDF values generally indicate lower digestibility because a larger proportion of the feed consists of less digestible cell wall components. Conversely, lower NDF content suggests that a greater proportion of the feed consists of readily digestible cell contents [22]. The relatively high NDF values observed in mixed-cropping treatments (P1, P2, P3) compared with the monoculture (P0) warrant further investigation. One possible explanation is that intercropping with legumes may alter the physiological status of maize plants, potentially leading to changes in cell wall composition. Additionally, the competitive environment in mixed-cropping systems may influence the allocation of photosynthates between grain filling and structural tissue formation.

A meta-analysis on forage quality in cereal/legume intercropping found that while intercropping increased NDF yield per unit area, it did not significantly change the percentage concentration of NDF in the harvested biomass [11]. This suggests that the increase in NDF production is primarily due to higher biomass yield rather than to changes in fiber concentration. However, Alaca and Parlak [23] reported that intercropping maize with soybean or cowpea reduced the NDF content of silage compared with maize monoculture, indicating that the effect on fiber content may depend on the specific legume species and environmental conditions.

It is important to note that NDF digestibility depends not only on its absolute content but also on the composition of the fiber fraction. Hemicellulose, a component of NDF, is more digestible than lignin. Higher hemicellulose content is associated with faster rumen degradation rates, which can improve feed intake and nutrient utilization. Therefore, although the NDF values in this study were elevated in intercropping treatments, the overall nutritional value of the feed may also depend on the relative proportions of hemicellulose and lignin within the NDF fraction.

c. ADF (Acid Detergent Fiber) content

Analysis of variance showed no significant differences (P>0.05) in ADF content among treatments, although numerical variations were observed. The highest ADF content was recorded in P0 (9.77%), followed by P3 (6.66%), P2 (6.53%), and P1 (6.23%). The monoculture treatment (P0) exhibited the highest ADF content, whereas the mixed-cropping treatments (P1, P2, P3) showed substantially lower ADF values.

ADF represents the fraction of feed that is insoluble in acid detergent solution, consisting primarily of cellulose, lignin, and silica. Unlike NDF, which includes hemicellulose, ADF provides a more specific estimate of the less digestible components of plant cell walls. The lower ADF content observed in mixed-cropping treatments suggests that intercropping maize with *Arachis pintoi* may improve the nutritional quality of maize grain by reducing the proportion of indigestible fiber.

Among the components of ADF, cellulose is partially digestible by rumen microorganisms, while lignin is highly indigestible due to its complex aromatic structure with double bonds that resist enzymatic breakdown. Consequently, feeds with high lignin content exhibit low digestibility coefficients. The reduction in ADF content in intercropping treatments may therefore indicate a favorable shift in cell wall composition, potentially enhancing feed digestibility for ruminants.

Liu et al. [11] reported that cereal/legume intercropping increased ADF yield per unit area while the ADF percentage remained unchanged compared to sole crops, consistent with the pattern observed for NDF. However, Alaca and Parlak [23] found that intercropping maize with soybean or cowpea significantly reduced ADF content in silage compared to maize monoculture, suggesting that the effect on ADF may vary with legume species and cropping system design.

Nurkhasanah et al. [24] noted that ADF analysis serves as a preparatory step for lignin determination and allows estimation of hemicellulose content by calculating the difference between NDF and ADF. In this study, the lower ADF values in mixed-cropping treatments (P1, P2, P3) compared with those in monoculture (P0) suggest that the inclusion of legumes may influence the deposition of structural carbohydrates in maize grain, although the exact mechanisms require further investigation.

The decrease in ADF content in intercropping treatments indicates improved forage quality, as lower ADF values are linked to higher digestibility and better nutritional value for livestock. These findings support the potential of mixed cropping systems to enhance the quality of maize grain as a feed resource.

Nutrient Content of Maize Straw

The nutrient content of maize straw, including crude protein (CP), neutral detergent fiber (NDF), and acid detergent fiber (ADF), is presented in Table 2

Table 2. Nutrient content and fresh weight of maize straw under different mixed cropping treatments

Treatment	Parameters			
	Crude Protein (%)	NDF (%)	ADF (%)	Fresh Weight (kg)
P0	7.30 ± 1.68	73.46 ± 1.71	48.55 ± 4.51	332.61 ± 49.60
P1	8.90 ± 1.82	76.34 ± 0.95	48.13 ± 4.82	319.81 ± 67.59
P2	7.79 ± 1.89	76.28 ± 2.47	48.38 ± 5.49	341.48 ± 91.75
P3	8.53 ± 2.23	74.33 ± 5.30	48.62 ± 6.38	337.22 ± 71.42

Description: Treatment P0 = 100% maize, P1 = 80% maize + 20% legume, P2 = 50% maize + 50% legume, P3 = 20% maize + 80% legume.

a. Crude Protein

Analysis of variance showed no significant effect of mixed cropping on the crude protein content of maize straw (P>0.05), although numerical differences were observed among treatments. The highest crude protein content was recorded in P1 (8.90%), followed by P3 (8.53%), P2 (7.79%), and P0 (7.30%). Notably, all mixed-cropping treatments (P1, P2, P3) had higher crude protein content than the monoculture control (P0).

In the monoculture treatment (P0), maize plants relied solely on nitrogen from the soil or added fertilizer. Without nitrogen-fixing legumes, the nitrogen supply to maize was limited, resulting in relatively low crude protein content. In contrast, the inclusion of *Arachis pintoi* in mixed cropping treatments increased nitrogen availability through biological nitrogen fixation (BNF) mediated by rhizobia bacteria in legume root nodules [13].

The higher crude protein content in P1 (80% maize + 20% legume) compared with treatments with higher legume proportions (P2 and P3) suggests an optimal balance between maize and legume components. Excessive legume density may lead to competition for resources such as light, water, and nutrients, potentially limiting the benefits of nitrogen transfer to maize plants. Fitriansah et al. [19] noted that legumes are effective for soil rehabilitation and can improve nitrogen availability in cropping systems, but the magnitude of this benefit depends on the proportion and arrangement of component species.

Studies on *A. pintoi* as a forage legume have shown its potential to improve soil nitrogen status and subsequent crop yields. Mate [25] reported that while intercropping maize with forage legumes did not significantly increase maize grain protein content, the addition of legume straw to maize stover enhanced the crude protein content of the total dry matter by 3-4 times. This highlights the importance of considering the combined nutritional value of the whole biomass rather than focusing solely on the cereal component.

It is important to note that the crude protein content of maize straw observed in this study (ranging from 7.30% to 8.90%) is relatively low compared with the nutritional requirements of ruminants. Suhartanto et al. [26] stated that using maize as ruminant feed requires supplementation with additional protein and energy sources due to its inherently low quality.

This finding underscores the importance of integrating legumes into cropping systems to enhance the nutritional value of crop residues, although the effects in this study were not statistically significant.

Protein requirements in livestock vary depending on growth stage, physiological status, pregnancy, lactation, and body condition [27]. Protein deficiency can slow rumen emptying and reduce feed intake, ultimately impairing animal performance. Therefore, efforts to improve the protein content of forage crops, including through intercropping strategies, remain important for sustainable livestock production.

In ruminants, dietary protein is hydrolyzed by rumen microbes into amino acids, which are then deaminated to produce ammonia. This ammonia serves as a nitrogen source for microbial protein synthesis. The microbial protein that reaches the small intestine accounts for approximately 65% of the protein available to the animal [28]. Thus, increasing the crude protein content of forage can enhance microbial protein synthesis and overall ruminant nutrition.

b. NDF (Neutral Detergent Fiber) content

Analysis of variance showed no significant effect of mixed cropping on the NDF content of maize straw (P>0.05), although numerical differences were observed among treatments. Based on the data in Table 2, the NDF content ranged from 73.46% to 76.34%, with the highest value recorded in P1 (76.34%), followed by P2 (76.28%), P3 (74.33%), and P0 (73.46%).

Interestingly, the monoculture treatment (P0) had the lowest NDF content, whereas mixed-cropping treatments had slightly higher values. This pattern suggests that including *Arachis pintoi* may influence fiber accumulation in maize straw, potentially due to changes in plant growth dynamics and resource allocation under intercropping conditions. However, the relatively small numerical differences among treatments and the lack of statistical significance indicate that the effect of mixed cropping on NDF content was limited under the conditions of this study.

NDF represents the total cell wall fraction of feed, consisting of lignin, cellulose, hemicellulose, and fiber-bound protein. NDF values are widely used to estimate feedstuff digestibility, as lower NDF content generally indicates higher digestibility and better feed quality. Conversely, higher NDF values indicate a greater proportion of structural carbohydrates that are less accessible to rumen microorganisms.

The NDF values observed in this study (73.46% to 76.34%) are relatively high, indicating that maize straw contains a substantial proportion of cell wall components. This aligns with the characteristics of crop residues, which typically have higher fiber content than fresh forage. The high NDF content suggests that maize straw alone may not provide sufficient energy for high-producing ruminants without additional supplementation. Harkin [29] noted that NDF degradation in the rumen is generally higher than ADF degradation because NDF includes hemicellulose, which is more soluble and digestible than lignin. Hemicellulose has a more amorphous structure than cellulose and lignin, making it more accessible to rumen microbial enzymes. Therefore, feeds with higher hemicellulose content relative to lignin tend to have faster rumen passage rates and higher digestibility.

The ability of legumes to fix nitrogen varies among species, which can influence the growth and nutritional composition of companion crops [30]. However, in this study, the effect of *Arachis pintoi* on the NDF content of maize straw was not statistically significant, suggesting that the choice of legume species, their proportion in the mixture, and environmental conditions all play important roles in determining the outcomes of intercropping systems.

c. ADF (Acid Detergent Fiber) content

Analysis of variance showed no significant effect of mixed cropping on the ADF content of maize straw (P>0.05). Based on the data in Table 2, ADF content ranged from 48.13% to 48.62%, with the highest value recorded in P3 (48.62%), followed by P0 (48.55%), P2 (48.38%), and P1 (48.13%). The numerical differences among treatments were minimal, and the lack of statistical significance indicates that the inclusion of *Arachis pintoi* in the cropping system did not substantially affect the ADF content of maize straw under the conditions of this study.

ADF represents the fraction of feed that is insoluble in acid detergent solution, primarily cellulose and lignin, with lignin being the major indigestible component [21]. ADF content is inversely related to digestibility because higher lignin levels limit the accessibility of cellulose to rumen microorganisms. The relatively high ADF values observed in this study (ranging from 48.13% to 48.62%) are typical of crop residues such as maize straw, which are characterized by high fiber content and moderate digestibility.

Unlike the previous discussion on ADF in maize grain, where treatment differences were more pronounced, the ADF content of maize straw showed minimal variation across treatments. This suggests that the effect of intercropping on fiber composition may be more evident in the grain than in the straw. Because straw is predominantly structural tissue, it may be less responsive to changes in nitrogen availability than the grain, which is metabolically more active during the reproductive phase.

It is important to note that fiber concentration in forages generally increases with advancing plant maturity due to the proportionally greater accumulation of cell wall components relative to cell contents [20]. However, in this study, all plants were harvested at the same age, so the observed numerical differences in ADF content among treatments cannot be attributed to variations in harvest timing. Instead, these minor differences may reflect subtle variations in plant growth dynamics influenced by the mixed cropping treatments.

The nutritional quality of crop residues, including NDF and ADF content, can be influenced by multiple factors, such as seed variety, soil moisture, climatic conditions, and agronomic practices [31]. In intercropping, interactions among component species can affect resource allocation and plant development, potentially altering fiber composition. However, the absence of significant differences in this study suggests that the mixed cropping system with *Arachis pintoi* did not substantially alter the fiber characteristics of maize straw under the specific conditions of this experiment.

CONCLUSION

Based on the results of this study, intercropping maize with *Arachis pintoi* does not significantly affect the nutritional quality of maize grain and straw.

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AUTHORS' CONTRIBUTIONS

Andi Nur Insani: Conceptualization, data collection, drafting the manuscript, and final revision; M. Mariam: Conceptualization, data collection and tabulation, drafting the manuscript, and final revision; M. Yusuf and S. Sudarsono: Conceptualization, drafting the manuscript, data collection, tabulation, and final revision.

COMPETING INTERESTS

All the authors declared that there is no conflict of interest

ETHICAL CLEARANCE

This research does not use animals as subjects of research, so there is no need for ethical clearance

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