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Chemical composition of Taiwan grass (*Pennisetum purpureum* Schum.) at different harvesting intervals

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ABSTRACT

Objective: To evaluate the effect of the harvesting interval on the quality of Taiwan grass (*Pennisetum purpureum* Schum.).

Design/Methodology/Approximation: Crude protein (CP), *in vitro* dry matter digestibility (IVDMD), crude fiber (CF), neutral detergent fiber (NDF), acid detergent fiber (ADF), lignin, ether extract, and ashes were determined. Samples were collected from the Papaloapan experimental site of the Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias, Isla, State of Veracruz (18° 01' 45" N, 95° 31' 35" W). Treatments consisted of five harvesting intervals (30, 60, 90, 120, and 150 days). Data were analyzed under the general linear model and means were separated using Tukey's test ($P<0.05$).

Results: The nutritional value decreased ($P<0.05$) as the harvesting interval increased from 30 to 150 days. The following elements decreased: CP (leaves, from 12.3 to 3.7%; stems, from 8.9 to 2.1%), IVDMD (leaves, from 66.5 to 43.5%; stems, from 62.7 to 32.5%), ether extract (leaves, from 2.4 to 1.4%; stems, from 1.4 to 0.6%), and ashes (leaves, from 10.3 to 6.1%; stems, from 10.9 to 2.9%). On the contrary, the following elements increased: CF (leaves, from 28.4 to 41.1%; stems, from 33.4 to 44.5%), NDF (leaves, from 60.4 to 72.5%; stems, from 63.8 to 74.3%), ADF (leaves, from 36.7 to 46.8%; stems, from 34.6 to 50.7%), and lignin (leaves, from 9.7 to 15.3%; stems, from 11.0 to 18.3%).

Study Limitations/Implications: Neither 30 days harvesting intervals nor yields (tons) per hectare were taken into account.

Findings/Conclusions: Taiwan grass should be harvested at 60 days, when its nutritional value has not decreased too much.

Keywords: Taiwan grass, nutritional value, harvesting interval, chemical composition.

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INTRODUCTION

The nutritional composition of grasses is very important in tropical regions (Araya and Boschini, 2005). High-quality and high-biomass annual production forages are a significant alternative for those regions (Singh *et al.*, 2013; Maldonado-Peralta *et al.*, 2019). On recent years, grasses (particularly, Taiwan grass) with high potential for cutting and grazing systems have been introduced to Mexico. Bohnert *et al.* (2011) and Norton *et al.* (2016) determined that *Pennisetum purpureum* Schum. is adapting to the tropical regions of Mexico (Madera *et al.*, 2013). Tropical forages are C_4 plants with a high photosynthetic rate, which provides them with a high capacity for biomass production (Bemhaja, 2000). These plants were selected as a result of their high biomass production (Na *et al.*, 2013). However, these plants have a lower digestibility (Bohnert *et al.*, 2011) and have a lower protein content (Barbehenn *et al.*, 2004; Sosa-Montes *et al.*, 2021) than C_3 plants. They develop in geographical regions where solar radiation and environmental temperature allow them to grow all year long (Singh *et al.*, 2013), as long as enough humidity is available.

An appropriate management of Taiwan grass could improve its nutritional value. Gómez-Gurrola *et al.* (2015) reported that the Taiwan grass' protein diminishes as the cutting interval increases. Santana *et al.* (2010) recorded over 14% of protein at 18 days of regrowth. Ramos-Juárez *et al.* (2018) proved that the protein content of grass increases with a 0.5-1% urea supplement.

Currently, there are few studies about the chemical composition and digestibility of Taiwan grass (*Pennisetum purpureum* Schum.). Therefore, the objective of this study was to evaluate the chemical composition and *in vitro* dry matter digestibility (IVDMD) of Taiwan grass, at different harvest intervals (30, 60, 90, 120, and 150 days).

MATERIALS AND METHODS

Forage samples were obtained from the Papaloapan experimental site of the Instituto Nacional de Investigaciones Forestales Agrícolas y Pecuarias, Isla, State of Veracruz (18° 01' 45" N and 95° 31' 35" W, at 65 m.a.s.l). The climate is subhumid warm, with summer rains, a 25.7 °C annual average temperature, and a 1,000 mm average precipitation (García, 2004).

Sampling collection

In order to obtain the samples, *Pennisetum purpureum* were cut from a 15 m long furrow, with 0.5 m of separation between furrows. The cutting was made up of three replications. The plants were initially fertilized with 75-33-10 kg ha^{-1} N-P-K. The same elements were used for the 150-66-20 kg ha^{-1} annual maintenance fertilization. Both applications were carried out during the rainy season. After the standardization cutting, plants were harvested at 30-, 60-, 90-, 120-, and 150-day intervals. The leaves and the stems were separated from each sample. The samples were then put in paper bags and dried in a forced-air stove at 55 °C, until they reached constant weight. Partial dry matter content was determined for each morphology component of the samples. Subsequently, the samples were crushed in a mill with a 1 mm crible.

Chemical analysis

Crude protein (N×6.25), neutral detergent fiber, acid detergent fiber, lignin, ether extract, and ashes percentages were determined using the AOAC method (1980). The analysis was carried out in the Sección de Nutrición Animal lab, Departamento de Zootecnia, Universidad Autónoma de Chapingo.

In vitro dry matter digestibility

A 0.3 g sample was subjected to a digestion (39 °C, 48 h) with ruminal fluid, using McDougal's artificial saliva as buffer solution. The residue was digested with neutral detergent; the digestibility percentage was calculated subtracting the non-digested cell wall percentage from 100% (Van Soest, 1994). The ruminal fluid of a Holstein bull with a fistula was used in all the samples. The bull was fed maize and alfalfa silage.

Statistical analysis

The experimental unit consisted of the plants from a 15-m long furrow. Three furrows, whose plants were harvested at 30, 60, 90, 120, and 150 days after the standardization cutting, were established. During the experimental period, leaves and stems were subject to fifteen observations. Each individual morphology component was statistically analyzed and the harvest ages were considered as treatments. The SAS 9.3 statistical package was used to analyze the data. The PROC GLM (lineal general model) was used to carry out the analysis of variance. Tukey's test was used to compare the means between treatments. The significance level was 5%.

RESULTS AND DISCUSSION

Crude protein

Figure 1 shows the crude protein content and the harvest interval for stem and leaf. Significative differences ($P<0.05$) were found between some of the intervals. The protein percentage diminished as the age of the plant increased ($P<0.05$). The stem recorded

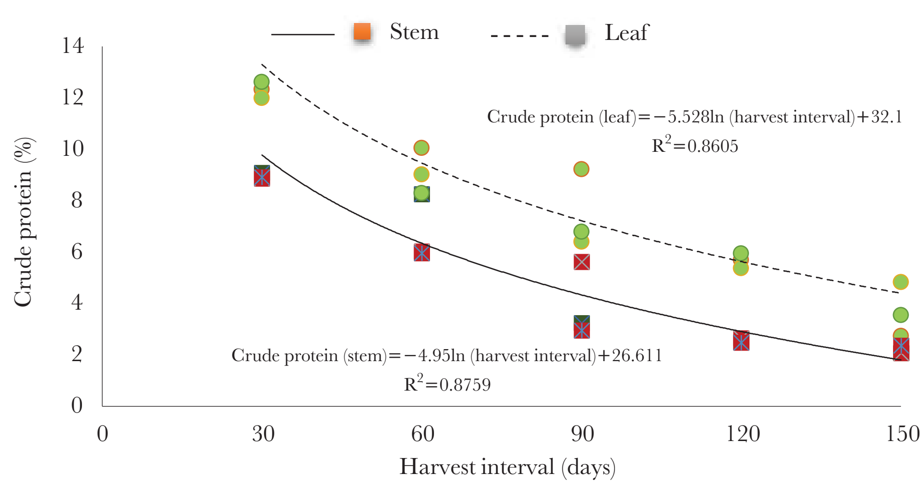

Figure 1. Leaf and stem crude protein content of Taiwan grass (*Pennisetum purpureum* Schum.), at different harvesting intervals.

the following values: 8.9, 6.7, 3.9, 2.5, and 2.1% for the 30-, 60-, 90-, 120-, and 150-day intervals, respectively. Without taking into account the 120 and 150 intervals —which were similar—, all other intervals had a different stem protein concentration. Leaf recorded the following values: 12.3, 8.1, 7.4, 5.6, and 3.7% at 30, 60, 90, 120, and 150 days, respectively. All the values are statistically different among themselves ($P<0.05$). Both stem and leaf recorded their maximum protein value at 30 days: 8.9 and 12.3%, respectively.

Araya and Boschini (2005) recorded 10.8, 7.1, 5.2, and 5.8% (stem) and 14.5, 14.3, 12.1, and 11.6% (leaf) values, at 70, 98, 126, and 140 days, respectively. These findings are higher than those found in this work. Bemhaja (2000) reported a 15.5% (13.9-17.1%) average protein in different *Pennisetum purpureum* Schum. cultivars, whose height reached 1.20 m. These results are higher than those obtained in this research at 30 days. The crude protein content and quality of the Taiwan grass tend to change and depend on different factors such as: harvesting interval, grazing frequency, soil fertility (Bemhaja, 2000), and leaf:stem ratio (Na *et al.*, 2015).

In vitro dry matter digestibility

Figure 2 shows the *in vitro* dry matter digestibility (IVDMD) percentage of Taiwan grass, according to the harvesting interval. The following values were recorded: 62.7, 53.3, 43.0, 35.6, and 32.5% (stem) and 66.5, 62.7, 55.0, 47.9, and 43.5% (leaf) at 30, 60, 90, 120, and 150 days, respectively. All the values are statistically different among themselves ($P<0.05$). Santana *et al.* (2010) pointed out that protein diminishes as the fiber percentage increases. The protein percentage of Taiwan grass depends on nitrogen fertilization (Singh *et al.*, 2013).

Madera *et al.* (2013) conducted IVDMD studies of Taiwan grass in Yucatan. Their equations were used to estimate the following results: 64.6, 61.3, 58.0, 54.7, 51.4, and 48.0% (leaf) and 61.8, 55.6, 49.4, 43.2, 37.0, and 30.8% (stem), at 45, 60, 75, 90, 105, and 120 harvesting days, respectively. They proved that, as the harvesting interval increases, IVDMD diminishes, as a result of lignification and fiber increase in Taiwan grass (Santana

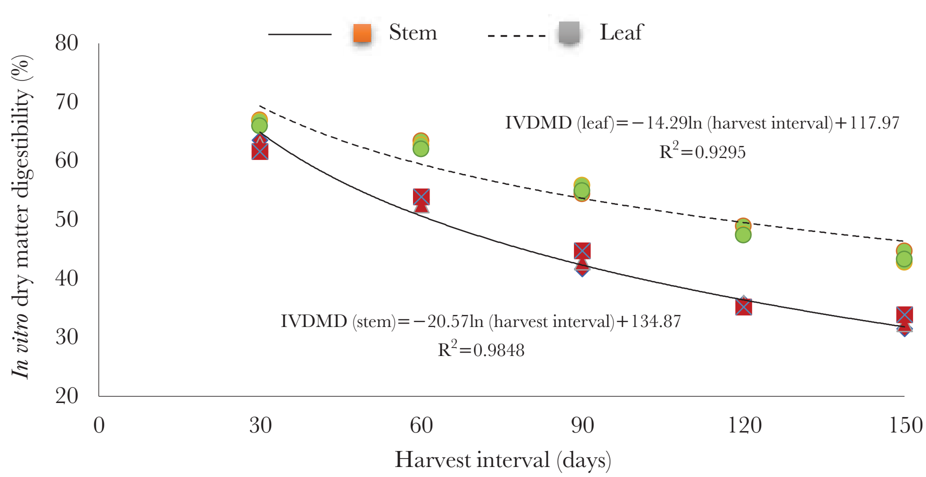

Figure 2. *In vitro* dry matter digestibility (IVDMD) percentage of the leaves and stems of Taiwan grass (*Pennisetum purpureum* Schum.), at different harvesting intervals.

et al., 2010). Chacón-Hernández and Vargas-Rodríguez (2009) reported the following IVDMD percentages 58.7, 55.9, and 52.0%, at 60, 75, and 90 harvesting days, respectively. Madera *et al.* (2013) obtained similar results, while Chacón-Hernández and Vargas-Rodríguez (2009) obtained lower percentages than those obtained in this research.

Lignin

Figure 3 shows lignin content at different harvesting intervals. Both in leaf and in stem, lignin showed a low content increase ($P<0.05$) after 30 days (11% leaf and 21% stem) and after 60 days (9.7% leaf and 11.0% stem). In Costa Rica, Chacón-Hernández and Vargas-Rodríguez (2009) reported different lignin content in whole plants: 12.2, 13.3, and 13.6%, at 60, 75, and 90 days, respectively. The lignin percentage obtained in that study at 60 days matches those found in this study, in which lignin percentage kept increasing as plants got older, until it reached 15.3% (leaf) and 18.3% (stem), at 120 days.

An increase in lignin content (Figure 3) entails a diminishing of forage digestibility, as a result of the formation of the lignin-carbohydrate complex, which embeds in cellulose and physically prevents the glucosidase enzyme action (Van Soest, 1983). Therefore, in this study, when lignin (Figure 3) increased, the IVDMD diminished (Figure 2).

Crude fiber

Figure 4 shows the crude fiber (CF) content of Taiwan grass, at different harvesting intervals. Leaf and stem had significative differences ($P<0.05$) between intervals. The following CF results were recorded: 33.4, 35.9, 38.5, 42.7, and 44.5% (stem) and 28.4, 32.9, 36.2, 38.9, and 41.1% (leaf), at 30, 60, 90, 120, and 150 harvesting days ($P<0.05$). Nevertheless, between days 120 and 150, no CF differences were recorded ($P>0.05$) in stem.

Both morphology components showed a CF increase as their age increased. Santana *et al.* (2010) reported 31.3 and 35.4% CF values at 30 and 60 days after the regrowth. These values are similar to those obtained in this study. Guerra-Medina *et al.* (2021) recorded

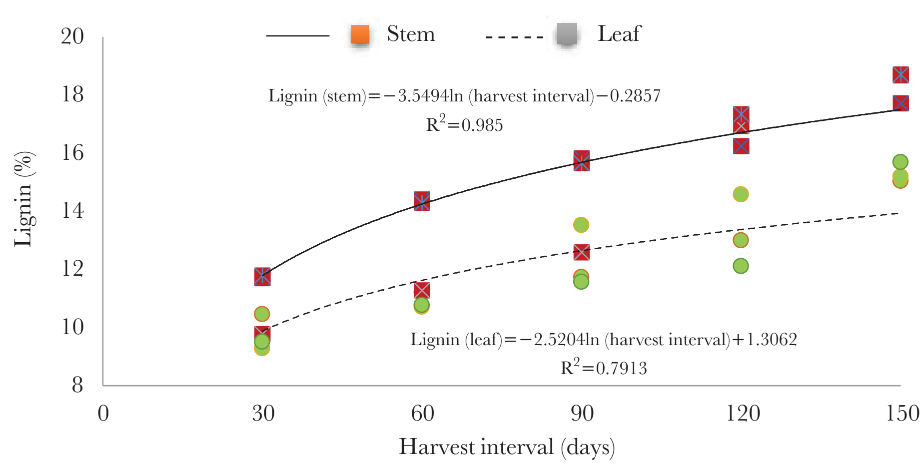

Figure 3. Lignin percentage of leaf and stem of Taiwan grass (*Pennisetum purpureum* Schum.), at different harvesting intervals.

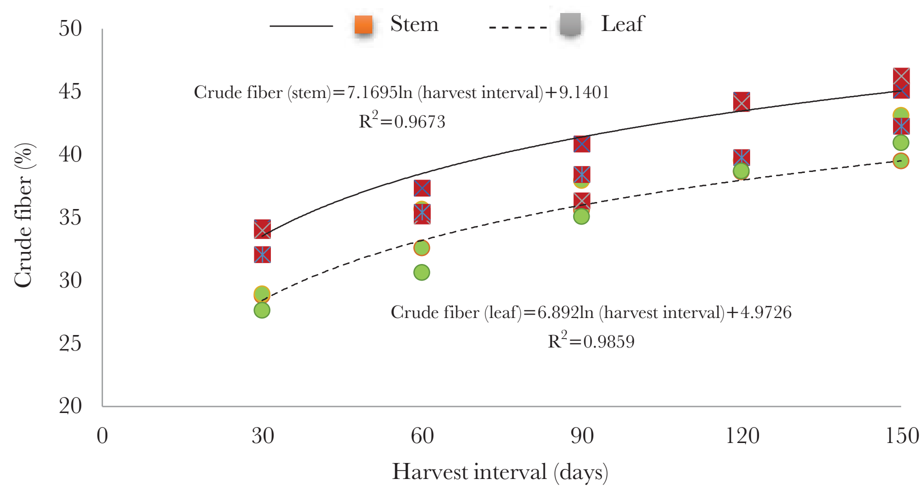

Figure 4. Crude fiber percentage of leaf and stem of Taiwan grass (*Pennisetum purpureum* Schum.), at different harvesting intervals.

38.2, 37.5, and 37.3% CF values in Taiwan grass, with and without fertilization, at 45 days after regrowth. These values are slightly higher than those found in this study.

Neutral detergent fiber

Figure 5 shows the neutral detergent fiber (NDF) content of Taiwan grass, at different harvesting intervals. Stem and leaf had significant differences ($P<0.05$). The following NDF contents were recorded in the stem: 63.8, 67.1, 69.5, 72.8, and 74.3%, at 30, 60, 90, 120, and 150 days of age, respectively. No significant differences were found with cuttings at 60 and 90 days, as well as 120 and 150 days ($P>0.05$). The following results were recorded for leaves: 60.4, 64.3, 67.3, 70.4, and 72.5%, at 30, 60, 90, 120, and 150 days of harvest. All the values are different among themselves.

Vivas-Quila *et al.* (2019) reported 58.7, 57.8, 60.6, 59.3, and 62.8% NDF content, at 50, 60, 70, 80, and 90 harvesting days, respectively. These values are slightly lower than those

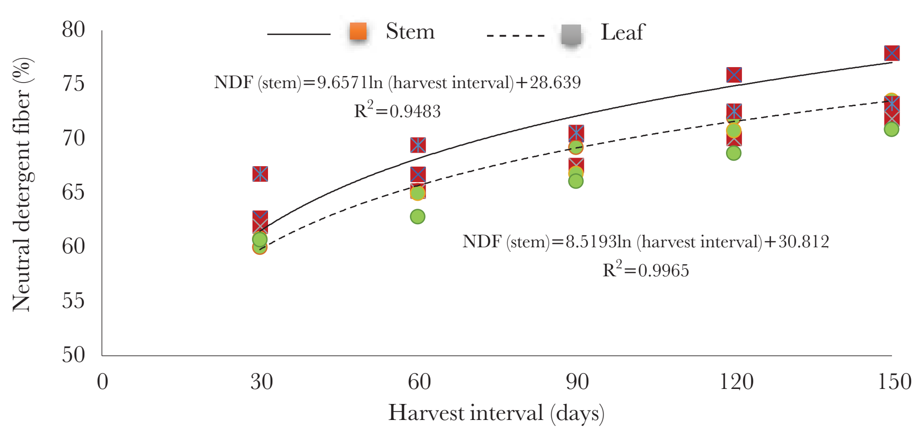

Figure 5. Neutral detergent fiber percentages of leaf and stem of Taiwan grass (*Pennisetum purpureum* Schum.), at different harvesting intervals.

obtained in this study. Gómez-Gurrola *et al.* (2015) recorded the following NDF content: 63.4, 69.0, 75.1, and 77.6%, at 30, 60, 90, and 120 harvesting days, respectively. The NDF data obtained by these authors increased as the harvesting interval increased. Their results match the findings of this study.

Acid detergent fiber

Figure 6 shows the acid detergent fiber (ADF) content. Leaf and stem recorded significant differences (P<0.05) and the ADF content increased as the harvesting interval increased.

The following ADF values were recorded: 34.6, 43.2, 46.2, 48.4, and 50.7% (stem) and 36.7, 40.4, 42.5, 44.2, and 46.8% (leaf), at 30, 60, 90, 120, and 150 harvesting days, respectively. ADF values were higher in the stem than in the leaves. Vivas-Quila *et al.* (2019) reported the following ADF content: 39.3, 41.7, 43.0, 44.3, and 44.9%, at 50, 60, 70, 80, and 90 harvesting days, respectively. Those results are similar to those obtained in this research. Guerra-Medina *et al.* (2021) recorded the following ADF values in Taiwan grass, 45 days after the regrowth: 44.1 and 50.2% (with fertilization) and 43.4, 44.1, and 50.2% (without fertilization). The values obtained without fertilization are similar to those obtained in this study, after 60 days (stem, 43.2%; leaf, 40.4%).

Ether extract

Figure 7 shows the ether extract (EE) content. Leaf and stem recorded significative differences (P<0.05) and the EE content diminished as the harvesting age increased. The following EE values were recorded: 1.4, 1.3, 1.1, 0.8, and 0.6% (stem) and 2.4, 2.1, 1.7, 1.5, and 1.4% (leaf), at 30, 60, 90, 120, and 150 harvesting days, respectively. EE values were higher in leaves than in stems.

Chacón-Hernández and Vargas-Rodríguez (2009) recorded similar values —1.4, 1.4, and 1.3%, at 60, 75, and 90 harvesting days, respectively— to those obtained in this study. Guerra-Medina *et al.* (2021) reported 1.0% EE at 45 days of age; this value is lower than

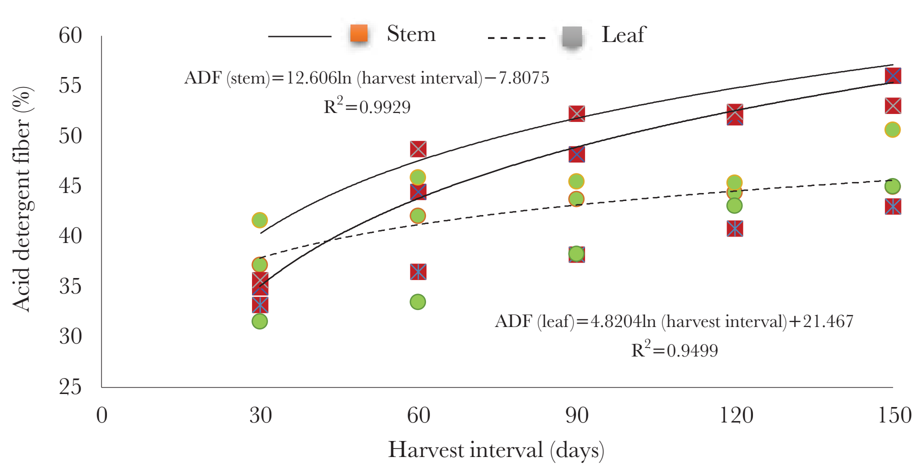

Figure 6. Acid detergent fiber percentage of leaf and stem of Taiwan grass (*Pennisetum purpureum* Schum.), at different harvesting intervals.

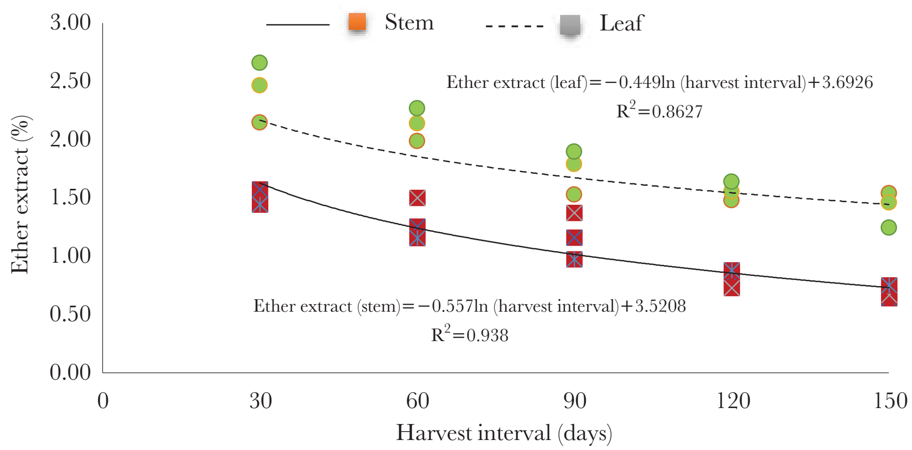

Figure 7. Ether extract percentage of leaf and stem of Taiwan grass (*Pennisetum purpureum* Schum.), at different harvesting intervals.

those found in this study. Umami *et al.* (2020) reported 3.3 and 3.5% EE values in three *Pennisetum purpureum* cultivars. These values are higher than those recorded in this study. Therefore, lipid concentration in forages tend to diminish, as the proportion of leaves or the leaf:stem ratio diminishes, which takes place when the plants grow older (Madera *et al.*, 2013).

Ashes

Figure 8 shows the ash content. Leaf and stem recorded significative differences ($P<0.05$) and ash content diminished, as the age of the plant increased. The following ash content was recorded: 10.9, 9.0, 6.9, 4.5, and 2.9% (stem) and 10.3, 9.2, 7.4, 6.3, and 6.1% (leaf), at 30, 60, 90, 120, and 150 harvesting days, respectively. Ash values were similar in leaves and stems.

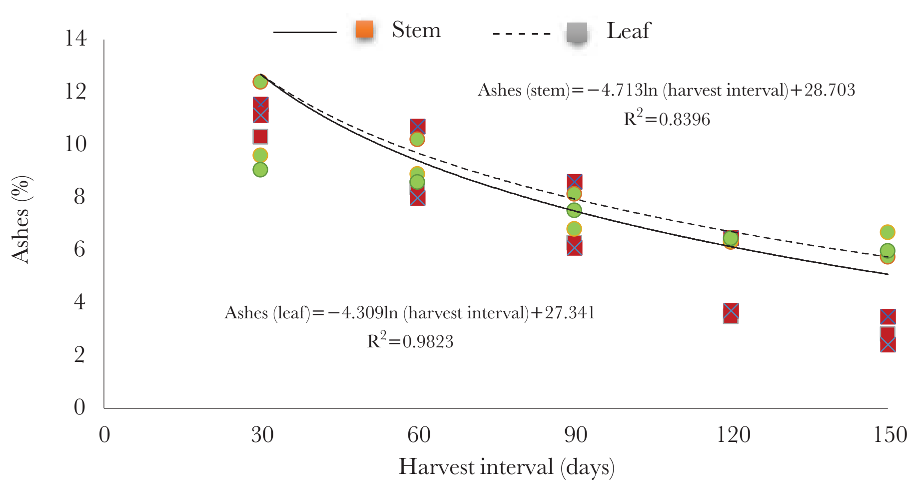

Figure 8. Ash content percentage of leaf and stem of Taiwan grass (*Pennisetum purpureum* Schum.), at different harvesting intervals.

Chacón-Hernández and Vargas-Rodríguez (2009) recorded 14.5, 13.9, and 13.6% ash values, at 60, 75, and 90 harvesting days. These values are higher than those obtained in this study. Gómez-Gurrola *et al.* (2015) reported the following values: 15.4, 11.9, 11.7, and 8.8% ash content, at 30, 60, 90, and 120 days after the cutting. Guerra-Medina *et al.* (2021) recorded 21.3% ash value, at 45 days of age. These values far exceed those found in this study. Umami *et al.* (2020) recorded 10.8% ash values in three *Pennisetum purpureum* cultivars. These values are similar to those obtained in this study at 90 days.

Overall discussion

Taking into account all nutrients, the CP, IVDMD, EE, and ash contents diminished and the CF, NDF, ADF, and lignin fiber contents increased, as the age of the plants increased. Consequently, the quality of the grass also diminishes; however, plant (Madera *et al.*, 2013) and hectare (Gómez-Gurrola *et al.*, 2015) yields increase as the age of the plant increases. Therefore, quality diminishes with a high yield of *Pennisetum purpureum* and vice versa. Using the eight logarithmic equations shown in Figures 1-8, the concentration per nutrient can be calculated, at any harvesting interval.

CONCLUSIONS

Regarding stem and leaf, protein, digestibility, ether extract, and ash content diminished, while the fiber components (crude fiber, neutral detergent fiber, acid detergent fiber, and lignin) increases, as the age of the plant increases. Consequently, the nutrient value of Taiwan grass (*Pennisetum purpureum* Schum.) also diminishes. Therefore, the recommendation is to harvest Taiwan grass at 60 days, when its yield is not so low and its nutrient value has not diminished too much.

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