

Analysis of the *in situ* digestibility growth of forage soybean varieties

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ABSTRACT

Objective: To evaluate the *in situ* digestibility during growth of four forage soybean (*Glycine max* L.) varieties in the dry tropics of Mexico.

Design/Methodology/Approach: Four soybean varieties SalCer, Ojo de Tigre, Valente, and Albina were evaluated over an 82-day growth period. The variables measured included ash content, dry matter, and *in situ* digestibility. A completely randomized block design with three replicates per subplot was used. Mean comparisons among treatments were conducted using Tukey's test at a significance level of $\alpha=0.05$.

Results: The highest *in situ* digestibility was observed at 26 days of growth (68%), while the lowest occurred at day 54 (57%). On average, the Valente and Albina varieties exhibited the highest digestibility values, with 65% and 63%, respectively ($p>0.05$).

Limitations/Implications: Leguminous species enhance forage quality for ruminants in tropical systems, yet their use in animal feed remains limited. Forage soybeans represent a promising alternative due to their favorable nutritional characteristics.

Findings/Conclusions: The Valente variety is recommended for forage use in the dry tropics, as it demonstrated superior and stable *in situ* digestibility. For optimal forage quality, cutting is advised after 68 days of growth, when dry matter content increases and ash concentration declines.

Keywords: *Glycine max* L. Merr., legume, forage quality, dry matter.

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INTRODUCTION

In tropical regions, livestock productivity improves significantly when high-nutritional-value forage is available to meet the dietary requirements of grazing herds. Due to their high yield potential and nutritional quality, annual and perennial legumes represent a viable alternative (Sosa *et al.*, 2020; Cristóbal-Santiago *et al.*, 2024). However, most research to date has focused on grain production, with limited studies on soybean as a forage crop, despite its promising yield and quality characteristics (Ríos-Hilario *et al.*, 2023).

In 2024, a total of 156,979 hectares of soybean were cultivated in Mexico, yielding 246,019 metric tons of grain (SIAP, 2025). Soybean is widely used as an ingredient in the formulation of compound feeds and various industrial products (Tosquy *et al.*, 2009; Wilson *et al.*, 2011). The vegetative parts of the soybean plant can be used as high-quality forage in animal nutrition, offering a higher protein content and better quality compared to grasses, along with a rich supply of essential minerals (Tobía & Villalobos, 2004). Açikgöz *et al.* (2013) evaluated the Derry, Donegal, and Tyrone varieties, reporting, on average, 13.3% crude protein (CP), 8.2% degradable protein, and 60.6% *in vitro* dry matter digestibility (DMD) at 75 and 89 days of growth.

Efficient forage production and profitability from soybean depend on selecting varieties well-adapted to regional climatic conditions. Therefore, it is crucial to evaluate genotypes that can thrive in specific environments while delivering high biomass yields and nutritional quality (Tobía *et al.*, 2006). Given the limited research in Mexico on forage soybean varieties, the aim of this study was to evaluate organic matter, ash content, and *in situ* digestibility during the growth of soybean (*Glycine max* L. Merr.) varieties under dry tropical conditions in Guerrero, Mexico.

MATERIALS AND METHODS

Study site

The sowing of soybean (*Glycine max* L.) varieties was carried out on September 1, 2020, in the locality of El Pitahayo, Cuajinicuilapa, Guerrero, Mexico. The climate is classified as warm sub-humid with summer rainfall, an average annual temperature of 26 °C, annual precipitation ranging from 1100 to 1300 mm, and an elevation of 50 m above sea level. The coordinates are 16° 32' 5.49" N and 98° 30' 28.87" W (PIGM, 2009). The analysis of organic matter, ash content, and *in situ* digestibility was conducted at the Animal Nutrition Laboratory of the Faculty of Veterinary Medicine and Animal Science No. 2 of the Universidad Autónoma de Guerrero, located in the municipal seat of Cuajinicuilapa, between September 26 and December 4, 2020.

Experimental plots

The evaluated varieties SalCer, Ojo de Tigre, Valente, and Albina were developed through various selection processes at the Centro de Estudios Profesionales of the Colegio Superior Agropecuario del Estado de Guerrero. Among them, SalCer is the only variety registered with the National Seed Inspection and Certification Service, while the others are still under evaluation. The experimental design consisted of three blocks, each subdivided into four 10×10 m plots. The experimental unit was established on sandy loam soil with a 15 cm slope. Land preparation included one plowing, two harrowings, one furrowing, and marking. Sowing was carried out on the ridge in a double-row configuration on September 7, 2020, during the rainy season, with a planting density of 230,000 seeds ha⁻¹. The planting layout was 80 cm between furrows, 10 cm between rows, and 12 cm between seeds. Chemical fertilization was applied manually at 20 and 30 days after sowing using a 60-40-00 (N-P-K) formula. Ammonium sulfate (FERTIQUIM[®]) was used as the nitrogen source and diammonium phosphate (DAP 18-46; FERTIQUIM[®]) as the

phosphorus source, applied in a band 5 cm from the stem. Foliar fertilization was carried out at 20, 30, and 40 days after sowing using Gro Green 20-30-10 (CAMPBELL[®]) and Supra[®] Fe (ARVENSIS[®]). Bean leaf beetle (*Epilachna varivestis*) was controlled through three applications of cypermethrin (CIMA[®]) at a dose of 1 mL L⁻¹ of water. Weeds were managed both manually and chemically, using Paraquat at a dose of 2 mL L⁻¹ of water.

Recorded Variables

Ash and organic matter

Ash content (Ash) was determined from whole-plant samples using method 942.05 of the AOAC (2005), and organic matter (OM) was calculated by subtracting the ash percentage from 100. Measurements were taken at 26, 40, 54, 68, and 82 days after sowing.

In situ digestibility

In situ digestibility was determined for the four soybean forage varieties at 26, 40, 54, 68, and 82 days after sowing, following the methodology described by Rosero and Posada (2007). The analysis was conducted using a 450 kg live weight Suiz-bu crossbred cow fitted with a permanent ruminal cannula. The animal was housed in a covered individual pen equipped with a feeder and water trough. A seven-day adaptation period was implemented, during which the animal was fed a 50:50 diet consisting of ground whole maize plants and 82-day-old whole soybean plants. Each sample was incubated for 72 h in the rumen. Water was provided *ad libitum*. A galvanized iron chain (1.5 cm diameter, 1.0 m length) modified with a safety hook was used to ensure the samples remained in the ventral sac of the rumen and was secured to the ruminal cannula cap. Samples (3.0 g) were placed in polyester-silk bags (10×20 cm, 40 μm pore size) previously dried to a constant weight. Bags were sealed with 100 mm × 2.5 mm plastic ties, soaked in 39 °C water for 10 minutes prior to incubation, and then placed in the rumen for 72 h. After retrieval, bags were rinsed with cold running water until the rinse water ran clear, dried at 55 °C for 72 h, and weighed to determine dry matter disappearance by weight difference.

Statistical analysis

The collected data were analyzed using a completely randomized block design arranged in split-split plots with three replicates. Statistical analysis was performed using the PROC GLM procedure of SAS version 9.2 (2011), considering harvest time as a fixed effect. Multiple comparisons of means were conducted using Tukey's test at a significance level of $\alpha=0.05$.

RESULTS AND DISCUSSION

Dry matter (DM) content increased as the soybean (*Glycine max* L.) plants matured. On average, the four varieties contained 16.5% DM at 26 days after sowing, reaching a maximum of 28.5% at 82 days ($p>0.05$; Table 1). The Valente variety exhibited the lowest DM content at day 26 with 15%, whereas SalCer and Ojo de Tigre showed the highest values at day 82, both reaching 29% DM ($p>0.05$). Cioffi *et al.* (2012) reported DM contents of 18.53% at 55 days and 25.34% at 85 days in a forage soybean variety

Table 1. Dry matter of four varieties of forage soybeans at different cutting times.

Age of the plant (days)	%				Average
	Salcer [®]	Ojo de tigre	Valente	Albina	
26	17 Ca	17 BCa	15 Db	17 Ca	16.5 C
40	16 Db	16 ACb	16 Db	19 Ba	17.8 B
54	18 Cb	18 Bb	18 Cb	19 Ba	18.3 B
68	23 Bb	24 Aa	23 Bb	24 Ba	23.5 A
82	29 Aa	29 Aa	28 Ab	28 Ab	28.5 A
Averages	21 a	21 a	20 a	21 a	

ab=Means with the same lowercase letter in the same row are not different ($p>0.05$); ABC=Means with the same uppercase letter in the same column are not different ($p>0.05$).

in Costa Rica values that closely align with those observed in the present study at comparable plant ages. Similarly, Martínez *et al.* (2010), who evaluated maize and soybean monocultures and mixtures for forage in Spain, reported average DM contents of 27%, consistent with the results obtained in this study for 82-day-old plants. In contrast, Trujillo *et al.* (2016) analyzed moisture content and soil compaction in relation to the nutritional characteristics of soybean in Venezuela, reporting significantly higher DM values, averaging 89.7% at 75 days, far exceeding the maximum 29% recorded at 82 days in this study.

The ash content of the four forage soybean (*Glycine max* L.) varieties at 26, 40, 54, 68, and 82 days of growth is presented in Table 2. On average, the highest ash content across all varieties was observed at day 26, with 11.58%, decreasing to 8.3% by day 82 ($p>0.05$). The Albina variety recorded the highest ash content at day 40, with 11.45%, while the lowest value was found in the SalCer variety at 9.37% ($p<0.05$). Díaz *et al.* (2003) conducted a bromatological analysis of four forage soybean varieties at different plant ages in Cuba and reported average ash contents of up to 8.0%, values comparable to those found in the present study at day 82 (8.33%). Tobía and Villalobos (2004), in their evaluation of the yield and nutritional quality of a forage soybean variety under tropical conditions, reported an ash content of 5.5% at 75 days lower than the 10.52% recorded in this study at day 68. Similarly, Cioffi *et al.* (2012) conducted a bromatological assessment of soybean forage at

Table 2. Ash content in four forage soybean varieties at different cutting ages.

Age of the plant (days)	%				Averages
	Salcer [®]	Ojo de tigre	Valente	Albina	
26	11.58 Aa	10.64 ABa	11.45 Aa	11.58 Aa	11.57 A
40	10.20 ABa	11.22 Aa	11.22 Aa	9.18 Ab	10.20 B
54	9.09 BCa	10.10 ABa	10.10 Ba	9.09 Aa	10.10 B
68	8.33 Ca	8.33 BCa	8.33 BCa	16.66 Aa	10.52 B
82	6.38 Db	7.29 Cab	8.24 Cab	9.18 Aa	8.33 C
Averages	9.37 c	9.92 c	10.33 b	11.45 a	

ab=Means with the same lowercase letter in the same row are not different ($p>0.05$); ABC=Means with the same uppercase letter in the same column are not different ($p>0.05$).

various stages and reported maximum average ash contents of 12.3%, values that are in line with those observed in this research.

The *in situ* digestibility of dry matter from four forage soybean varieties at different plant ages is shown in Table 3. The highest *in situ* digestibility was obtained at 26 days, with 68%, and the lowest at 54 days, with 57% ($p>0.05$); however, the Valente and Albina varieties showed the highest percentages of *in situ* digestibility with 65% and 63%, respectively ($p>0.05$). Similar digestibility values were obtained by Romero *et al.* (2013), who evaluated *in vitro* digestibility in soybean forage for grazing, with average percentages of 68% and 77% for the whole plant. Contreras *et al.* (2019) evaluated the degradability of red clover associated with Italian ryegrass in Peru and reported 71.44% for this variable at 84 days, a percentage higher than that reported in the present study with 63% at 82 days. Sosa *et al.* (2020) reported the *in situ* digestibility of four forage legumes in the tropics of Mexico and obtained up to 80% at 30 days, whereas in the present study it was lower, with 68% *in situ* digestibility.

Table 3. *In situ* dry matter digestibility in four forage soybean varieties at different cutting ages.

Age of the plant (days)	%				Average
	Salcer	Ojo de tigre	Valente	Albina	
26	67 Aa	68 Aa	69 Aa	69 Aa	68 A
40	65 Aa	62 Aba	65 ABa	64 Aa	64 A
54	57 Ba	56 Ba	60 Ba	56 Ba	57 B
68	64 Aa	62 Aba	65 ABa	63 ABa	64 A
82	62 Aa	61 Aba	65 ABa	64 Aa	63 A
Averages	63 b	62 b	65 a	63 b	

ab=Means with the same lowercase letter in the same row are not different ($p>0.05$); BC=Means with the same uppercase letter in the same column are not different ($p>0.05$).

CONCLUSIONS

The soybean varieties that showed the highest dry matter percentages were SalCer and Ojo de Tigre, while the highest ash content was obtained by Albina. However, the Valente variety reported the highest *in situ* digestibility; therefore, any of the evaluated varieties can be used at 68 days without affecting digestibility.

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