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Evaluation of the Nutritional Content of Two Varieties of Fresh and Silage-Processed Pitahaya Stems as an Alternative Animal Feed

Evaluación del contenido nutricional de dos variedades de penca de pitahaya en estado fresco y ensilado como alimento alternativo animal

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Abstract: The pitahaya (*Selenicereus* spp.) crop is notable for its adaptation to arid conditions and its productive potential. The objective of this study is to evaluate the nutritional content of pitahaya stems (*Selenicereus undatus* and *Selenicereus costaricensis*) in both fresh and silage forms. The study was conducted using a completely randomized design with a 2×2 factorial arrangement, considering variety and preservation state as factors, and analyzing bromatological variables such as moisture, dry matter, ash, fat, carbohydrates, fiber, organic matter, Brix degrees, and protein. The results showed that in the fresh state, *S. costaricensis* had higher moisture (93.7%) and protein (0.74) content, while *S. undatus* had higher values for dry matter (9.78%), carbohydrates (7.08%), and ash (0.34%). Regarding the ensiled state, both varieties showed an increase in nutrient concentration, with *S. undatus* standing out for its higher dry matter content (11.4%), carbohydrate content (8.29%), and Brix degrees (7.5°), indicating an improvement in the material's energy value. analysis of variance revealed highly significant differences ($p < 0.0001$) for variables such as moisture, dry matter, and Brix degrees, influenced by both the variety and the silage process. It was concluded that pitahaya stems have high moisture content and low protein levels; their use is intended as an energy supplement that is rich in fiber and low in protein.

Keywords: food, energy, fiber, water, nutrients.

Resumen: El cultivo de pitahaya (*Selenicereus* spp.) destaca por su adaptación a condiciones áridas y su potencial productivo. El objetivo de la investigación es evaluar el contenido nutricional de la penca de pitahaya (*Selenicereus undatus* y *Selenicereus costaricensis*) en estado fresco y ensilado. El estudio se desarrolló bajo un diseño completamente aleatorizado con arreglo factorial 2×2, considerando como factores la variedad y el estado de conservación, analizando variables bromatológicas como humedad, materia seca, ceniza, grasa,

carbohidratos, fibra, materia orgánica, grados Brix y proteína, los resultados evidenciaron que en estado fresco, *S. costaricensis* presentó mayor contenido de humedad (93,7%) y proteína (0,74), mientras que *S. undatus* registró mayores valores de materia seca (9,78%), carbohidratos (7,08%) y cenizas (0,34%). En cuanto al estado ensilado, ambas variedades mostraron un incremento en la concentración de nutrientes, destacándose *S. undatus* con mayor contenido de materia seca (11,4%), carbohidratos (8,29%) y grados Brix (7,5°), lo que indica una mejora en el valor energético del material, el análisis de varianza reveló diferencias altamente significativas ($p < 0,0001$) para variables como humedad, materia seca y grados Brix, influenciadas tanto por la variedad como por el proceso de ensilaje, concluyendo que la penca de pitahaya posee un alto contenido hídrico y bajo nivel proteico, su uso se orienta como suplemento energético, rico en fibra y bajo en proteína.

Palabras clave: alimento, energético, fibra, hídrico, nutrientes.

Introduction

Global pitahaya production is led by Asia (94%), with China and Vietnam as the main producers, followed by Latin America. Production exceeds 2.1 million metric tons annually, and the fruit is grown primarily in tropical regions (García and Medina, 2021). Pitahaya production in Ecuador has grown rapidly, reaching approximately 1,528 hectares in 2022, with cultivation taking place in provinces such as Manabí, Guayas, Morona Santiago, and Santo Domingo de los Tsáchilas. In Manabí, there are 64 cultivation areas, 38 of which are certified, and 225 hectares under monitoring (López-Rodríguez, 2024).

Pitahaya (*Selenicereus* spp.) is a non-traditional crop that has gained importance in Ecuador due to its ability to adapt to arid conditions and its physicochemical properties, with the red-fleshed pitahaya (*Selenicereus costaricensis*) and the white-fleshed pitahaya (*Selenicereus undatus*) being the most notable, both of which show potential as functional foods and as a profitable alternative for national producers (Vallester et al., 2025; Conforme et al., 2026).

In the province of Manabí, particularly in areas such as Puerto Cayo, pitahaya production has grown in recent years, leading to an increase in plant waste from pruning—mainly cladodes or stems—which have a high mucilage content and can be utilized in animal feed (Lucas, 2024; Granoble and Acuria, 2022).

Drought is a major constraint on livestock production due to the reduction in forage resources, creating a need to evaluate new feed sources; pitahaya stalks represent a potential alternative; however, there is limited information on their nutritional composition, especially in different states of preservation, which limits their inclusion in efficient animal diets (Rubio, 2024; Mastian, 2025)

No relevant scientific information is available on the use of the leaf stalk as an alternative animal feed, which could be useful for ruminants due to its fiber and moisture content and is currently wasted. According to Vera (2025), it could also be used for bioplastics or pectin from the peel.

This study evaluates the nutritional content of the stems of two pitahaya varieties, *Selenicereus undatus* and *Selenicereus costaricensis*, in both fresh and silage forms, with the aim of determining their viability as an alternative feed for animal nutrition, thereby contributing to the utilization of agricultural waste, the reduction of feed costs, and the strengthening of production systems in areas affected by water scarcity.

Methodology

This study was conducted at the OrganiFruit farm, located in the Montecristi canton, Manantiales site, on the road leading from Manta to Puerto Cayo, at georeferenced coordinates 17M 1255675, -UTM 80747795.

Four treatments were established based on the combination of two factors: varieties (*Selenicereus undatus* and *Selenicereus costaricensis*) and preservation method (fresh and silage).

Bromatological variables such as moisture, dry matter, ash, fat, carbohydrates, fiber, organic matter, Brix degrees, and protein were analyzed, expressed as percentages based on the sample.

Sampling for bromatological analyses.

The raw material was harvested from a commercial pitahaya crop belonging to the company OrganiFruit in the province of Manabí. *Selenicereus undatus* and *Selenicereus costaricensis* were selected. Sampling was conducted in the morning to minimize moisture loss, using mature, healthy plants that were uniform in size and ripeness. The pads were cut with disinfected tools, weighed (22.7 kg per treatment), and transported under controlled conditions to prevent changes in their composition.

Subsequently, the material was disinfected and divided into two fractions: fresh and ensiled. For the fresh treatment, the samples were transported to the food science laboratory at the Southern Manabí State University (UNESUM), where they were cut into 2–3 cm pieces and blended in an industrial blender to obtain a homogeneous sample.

For the silage treatment, the stalks were cut into 2–3 cm pieces, mixed with 5% molasses, compacted into plastic bags, and sealed to create anaerobic conditions; they were then stored for 30 days, 1-kg samples were taken, and subsequently sent to the aforementioned laboratory for food science analysis.

The experiment was set up using a completely randomized design with a 2×2 factorial arrangement. Analysis of variance (ANOVA) was used to determine the effect of the factors and their interaction; for the comparison of means, a 5% Tukey significance level was applied.

Results

Verification and analysis of the data to confirm compliance with the necessary assumptions revealed that, in the Shapiro-Wilk test, the values obtained (between 0.8 and 1.0) indicate that the data are normally distributed. Therefore, it is assumed that the data follow a normal distribution, allowing for the use of analysis of variance (ANOVA) to compare treatments.

The corresponding results are presented below, aimed at determining the nutritional content of the pitahaya stem in its two varieties when fresh.

Table 1. *Nutritional content of the two varieties in their fresh state*

FRESH STATE	S. Undatus	S. Costaricensis
	%	%
% Moisture	90.23	93.7
%Dry Matter	9.78	6.3
% Ash	0.34	0.14
%Fat	1.85	1.41
% Carbohydrates	7.08	4.02
% Fiber	11.3	10.29
% Organic Matter	2.01	0.64
Brix	4	3
Protein	0.51	0.74

It was determined that there are compositional differences in terms of moisture content: *S. costaricensis* had a moisture content of 93.7% compared to *S. undatus* (90.23%), which translates to a lower percentage of dry matter. In this line of research, Márquez et al. (2024) confirm the physiological nature of these species, consistent with the findings reported by Castagnino and Castro (2021) and Luycho (2026), who establish that this behavior is characteristic of succulent tissues, where water content directly influences the concentration of other nutritional components.

Regarding dry matter and carbohydrates, *S. undatus* exhibited higher values (9.78% and 7.08%, respectively) compared to *S. costaricensis* (6.3% and 4.02%), consistent with the findings of Rojas et al. (2019), who determined that lower moisture content favors the concentration of energy compounds, which explains these results; consequently, Yanchatipan (2024) indicates that differences between varieties can be attributed to genetic and physiological factors that influence the accumulation of reserves.

On the other hand, the ash content was higher in *S. undatus* (0.34%) than in *S. costaricensis* (0.14%), suggesting a higher concentration of minerals, consistent with the findings of Oliva (2024), who established

that the mineral composition in cacti can vary depending on the species and growing conditions.

Regarding fat, both varieties showed low values, although slightly higher in *S. undatus* (1.85%), which is consistent with the findings reported by Pérez (2023), who noted that cladode tissues have a low lipid content. Fiber content was comparable between the two species, with slightly higher values in *S. undatus* (11.3%).

Regarding soluble solids, *S. undatus* had higher Brix degrees (4°) compared to *S. costaricensis* (3°), indicating a higher concentration of soluble sugars. In this regard, Cardona et al. (2022) state that soluble sugars are directly related to the energy content of plant material.

Protein content was low in both varieties, although slightly higher in *S. costaricensis* (0.74%), which aligns with the findings of Castagnino and Castro (2021), who determined that the cladodes of succulent species are not a source of protein; therefore, their use in animal feed must be supplemented with other protein sources.

Table 2. *Nutritional content of the two varieties in silage form*

SILAGE STATE	S. Undatus	S. Costaricensis
	%	%
% Moisture	88.6	91.3
%Dry Matter	11.4	8.73
% Ash	0.35	0.16
%Fat	2.14	1.7
% Carbohydrates	8.29	6.01
% Fiber	10.99	9.78
% Organic Matter	2.57	1.2
Brix degrees	7.5	6.88
Protein	0.63	0.84

Analysis of the silage revealed nutritional differences between the two varieties evaluated. *S. undatus* had higher levels of dry matter (11.4%), ash (0.35%), fat (2.14%), carbohydrates (8.29%), fiber (10.99%), and organic matter (2.57%) than *S. undatus*, indicating a higher nutrient concentration. This suggests greater potential as an energy source in

animal diets, given the direct relationship between dry matter and nutrient density. This trend is accentuated after the silage process, where Camacho et al. (2023) note that reduced moisture content favors the relative concentration of components such as carbohydrates, fats, and organic matter—a finding also described by Castaño et al. (2023), who confirm that ensiling triggers biochemical transformations that increase the availability of energy compounds.

Meanwhile, *S. costaricensis* recorded higher moisture content (91.3%) and protein content (0.84%). Furthermore, Brix degrees increased in both varieties, reaching 7.5° in *S. undatus* and 6.88° in *S. costaricensis*, reflecting changes associated with the silage process.

The observed increase in the silage material of up to 7.5° Brix in *S. undatus* can be attributed to the hydrolysis of structural polysaccharides into simple sugars during anaerobic fermentation, Mesa (2025) identifies this as a key phenomenon in improving feed palatability, which could promote its acceptance by animals, as noted by Bustamante (2023), who emphasizes that fermentation plays a crucial role in enhancing the quality of preserved forages.

The protein content remained low in both varieties, which is consistent with the typical composition of cactus cladodes; thus,, Villalba et al. (2024) based on this backgroundinfer that the slight increase in the silage material could be related to the relative concentration of nutrients or to microbial activity during fermentation, In this regard, it is understood that the pitahaya stem should not be considered a primary source of protein, but rather an energy and hydration supplement within the animal diet, which is consistent with Mesa (2025), who emphasizes that the final product possesses the necessary attributes to fulfill its purpose as a dietary supplement.

Table 3. ANOVA and coefficient of variation

VARIABLES	T1	T2	T3	T4	FACTOR A	FACTOR B	FACTOR A × FACTOR B
	90.23 ± 0.9	88.6 ± 0.9	93.7 ± 0.9	91.3 ± 0.9	**0.0001	**0.0001	*0.001
% Moisture	(0.33)	(0.26)	(0.09)	(0.18)			
	9.78±0.09	11.4 ± 0.09	6.3±0.09	8.73 ± 0.09	**0.0001	**0.0001	*0.001
% Dry Matter	(2.88)	(2.12)	(1.28)	(2.13)			
	0.34±0.01	0.35±0.01	0.14 ± 0.01	0.16 ± 0.01	**0.0001	0.09	0.54
% Ash	(8.13)	(3.64)	(13.36)	(13.54)			
	1.85±0.16	2.14 ± 0.16	1.41 ± 0.16	1.7 ± 0.16	0.025	0.117	0.98
% Fat	(35.6)	(23.5)	(25.7)	(20.8)			
	7.08 ± 0.22	8.29 ± 0.22	4.02 ± 0.22	6.01 ± 0.22	0.12	**0.0004	0.11
% Carbohydrates	(12.3)	(4.92)	(11.7)	(5.03)			
	11.36±0.25	10.99 ± 0.25	10.29 ± 0.25	9.78 ± 0.25	0.001	0.107	0.779
% Fiber	(11.3)	(6.87)	(5.02)	(3.76)			
	2.01 ± 0.04	2.57 ± 0.04	0.64 ± 0.04	1.2 ± 0.04	**0.0001	**0.0001	0.92
% Organic matter	(5.46)	(3.43)	(11.9)	(3.42)			
	4±0.12	7.5 ± 0.12	3 ± 0.12	6.88 ± 0.12	**0.0001	**0.0001	0.16
Brix degrees	(10.7)	(6.16)	(8.72)	(4.63)			
	0.51±0.04	0.63±0.04	0.74 ± 0.04	0.84 ± 0.04	0.002	0.052	0.82
Protein	(26.5)	(10.8)	(11.3)	(7.01)			

Statistical analysis (ANOVA) supports these observations, revealing highly significant effects ($p < 0.0001$) of the variety and condition factors on variables such as moisture content, dry matter, and Brix degrees. This allows for the partial rejection of the null hypothesis (H_0), confirming that there are significant differences both between varieties and due to the effect of silage. In contrast, some variables such as ash and fat showed dependence primarily on the variety factor, suggesting a predominant influence of genetic characteristics over postharvest management, consistent with the findings reported by (Coronado et al., 2023).

Conclusions

Pitahaya stems exhibit nutritional variations among varieties, with *Selenicereus undatus* standing out for its higher dry matter, carbohydrate, and ash content, as well as high moisture content and low protein level. Silage increases nutrient concentration and improves energy value without significantly affecting protein content.

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