

Growth Performance and Sensory Analysis in Rabbits (*Oryctolagus cuniculus* L.) Fed a Supplement Derived from Three Types of Foliage

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ABSTRACT

Objective: The aim of this study was to assess weight gain and meat quality in New Zealand rabbits supplemented with foliage from Ramon tree (*Brosimum alicastrum*), cocoite (*Gliricidia sepium*), and moringa (*Moringa oleifera*).

Design/methodology/approach: Fifteen weaned New Zealand rabbits were randomly allocated to one of the following treatments: T1, balanced feed plus fresh *B. alicastrum* foliage; T2, balanced feed plus fresh *G. sepium* foliage; and T3, balanced feed plus fresh *M. oleifera* foliage. Treatments were evaluated using a completely randomized design with five replicates per treatment. The study variables included foliage intake, balanced feed intake, live weight, hot and cold carcass weight, carcass yield, and sensory evaluation (odor, flavor, taste, and residual aftertaste).

Results: The highest intake of *G. sepium* (8.9 g dry matter [DM] day⁻¹) was associated with the lowest balanced feed intake (60 g day⁻¹). In contrast, supplementation with *M. oleifera*, together with balanced feed intake, resulted in greater live weight and higher hot and cold carcass yields. Moreover, meat from rabbits receiving *M. oleifera* obtained the highest scores in the sensory analysis.

Limitations on study/implications: Reducing feeding costs may enhance the efficiency of rabbit production systems and increase the overall output of high-quality meat.

Findings/conclusions: The findings suggest that foliage supplementation may represent a viable alternative for rabbit production under tropical conditions.

Keywords: weight gain, carcass quality, foliage, native plants, alternative fed.

INTRODUCTION

Rabbit production is a highly versatile livestock activity that has expanded notably due to its straightforward management, which has encouraged small- and medium-scale producers to engage in rabbit farming. In Mexico, total production is estimated to exceed



15,000 metric tons (SAGARPA, 2016). The primary output of the rabbit sector is meat; however, the hide, fur, feet, forelimbs, and tail can also be utilized as raw materials for processing in the apparel industry (Galán-Caballero *et al.*, 2021). Bones are used in the manufacture of handicrafts, and manure is applied as fertilizer for horticultural crops (SAGARPA, 2016). Given the relevance of this activity, sustainable rabbit production is essential. In this context, incorporating foliage from tree species available within local communities represents a practical alternative to reduce reliance on compound feeds (Guevara-Hernández *et al.*, 2014).

Supplementation with foliage from tropical species can contribute a substantial proportion of dietary protein, thereby increasing the potential for faster fattening (De La O-Michel *et al.*, 2015). Shrub and tree species generally exhibit greater temporal stability in the nutritional quality of their foliage because lignification occurs primarily in the stems rather than in the leaves, as is typical of most tropical grasses used for grazing (Mora-Valverde, 2010), as well as in aromatic plants used as dietary supplements in rabbits (Herrera-Soto *et al.*, 2018). Nieves (2009) notes that the use of arboreal components as forage resources constitutes a sound strategy for sustainable production systems, adding that the current trend toward using shrub- and tree-derived forages is driven by worldwide increases in the prices of cereal grains and oilseeds. The foliage of tree species contains substantial protein levels. In the Yucatán Peninsula, Ramon (*Brosimum alicastrum*) foliage contains approximately 11.2% crude protein (Hernández-González *et al.*, 2014), cocoite (*Gliricidia sepium*) foliage contains 24.1% (Costa *et al.*, 2009), and moringa (*Moringa oleifera*) foliage provides 20-30% (Yameogo *et al.*, 2011). Therefore, the objective of the present study was to evaluate weight gain and meat quality in New Zealand rabbits supplemented with foliage from the aforementioned trees, with the aim of proposing these resources as alternative dietary complements for rural rabbit production in the Yucatán Peninsula.

MATERIALS AND METHODS

The study was conducted over a 63-day period at the facilities of the Instituto Tecnológico de Chiná, located in Chiná, Campeche, Mexico (19° 45' 32" N, 90° 30' 39" W), with a mean annual temperature of and a total annual precipitation of 1100 mm (Candelaria-Martínez *et al.*, 2025).

Treatments and experimental design

Fifteen 21-day-old New Zealand rabbits were used. Animals were provided with an eight-day adaptation period to the rearing conditions and to diets supplemented with foliage from Ramón (*B. alicastrum*), cocoite (*Gliricidia sepium*), and moringa (*Moringa oleifera*). A completely randomized design was implemented, evaluating three treatments with five replicates per treatment; each replicate consisted of one rabbit housed in an individual cage. Rabbits had an initial mean body weight of 429.95 ± 4.55 g and were allocated such that each treatment included two females and two males. Animals were housed in metal cages (70×40×35 cm) equipped with drinkers providing continuous access to water and hopper-type metal feeders. The treatments were as follows: T1, commercial balanced feed supplemented with

ramon (*B. alicastrum*) foliage; T2, commercial balanced feed supplemented with cocoite (*G. sepium*) foliage; and T3, commercial balanced feed supplemented with moringa (*M. oleifera*) foliage. After the adaptation week, five rabbits were randomly assigned to each treatment, and foliage was offered ad libitum for 24 h. Foliage was manually harvested from the protein banks of the Laboratory for Research on Small Species (LIPAEM) at the Instituto Tecnológico de Chiná. In all treatments, 33 g of foliage per rabbit was initially offered and subsequently adjusted throughout the experiment to maintain approximately 20% refusal. In addition, rabbits received 150 g day⁻¹ of commercial balanced feed (Purina[®], Granja Familiar Conejos; 14.5% crude protein [CP]). The amounts of commercial feed and foliage offered, as well as refusals, were recorded daily for each rabbit across treatments. Rabbits were weighed every seven days at 08:00 h using a Rhino digital scale, model BAR-6 (20 kg capacity, 2 g precision; Rhino[®], Mexico).

Carcass evaluation

Rabbits underwent a fasting period, and live weight at slaughter was recorded using a digital scale (Ohaus[®] Defender™ 5000, Mexico). Slaughter was performed in accordance with the Mexican standard NOM-033-ZOO-1995 (Hernández-Bautista *et al.*, 2015). The limbs, tail, head, skin, and thoracic and abdominal organs were separated and individually weighed to determine carcass weight and the weight of each component (Hernández-Bautista *et al.*, 2015).

Sensory analysis of meat

A sensory panel was conducted with 20 untrained panelists to detect differences in meat quality among treatments. The attributes evaluated were odor, flavor, and residual flavor, with scores assigned for each parameter as well as an overall score. Panelists' qualitative observations were also recorded for each treatment. Meat samples were prepared following a standardized protocol for thawing, cutting, cooking, and presentation to the panelists. Collected data were organized into qualitative and quantitative sections.

Statistical analysis

Data were recorded in Microsoft Excel[®] 2016 (Microsoft Corp.) using templates designed specifically for the study variables and subsequently analyzed using STATISTICA[®] v7.0. A one-way analysis of variance (ANOVA) was performed for each variable, followed by Tukey's multiple comparison test ($P < 0.05$) to detect differences among treatments for intake, live weight, and carcass yield response variables.

RESULTS AND DISCUSSION

A higher intake of *Gliricidia sepium* (*G. sepium*) foliage was observed, averaging 8.9 g dry matter (DM) day⁻¹ ($P = 0.05$), followed by *Brosimum alicastrum* (*B. alicastrum*) and *Moringa oleifera* (*M. oleifera*), with mean intakes of 7.2 and 6.5 g DM day⁻¹, respectively (Figure 1). Foliage consumption in rabbits offered *G. sepium* increased exponentially, reaching 60 g on a fresh basis by the end of the experimental period, equivalent to 16.2 g on a DM basis, whereas intake of *B. alicastrum* foliage remained stable throughout the treatment without

noticeable variation. In rabbits supplemented with *M. oleifera* foliage, intake increased steadily over time, reaching 50 g on a fresh basis, equivalent to 9 g on a DM basis.

The results indicated a higher intake of commercial balanced feed in rabbits supplemented with *Moringa oleifera* (*M. oleifera*) foliage (86.5 g day⁻¹) and in those supplemented with *Brosimum alicastrum* (*B. alicastrum*) foliage (83.9 g day⁻¹). In contrast, balanced feed intake was lower in rabbits supplemented with *Gliricidia sepium* (*G. sepium*) foliage, with an average of 80.6 g day⁻¹ (Figure 2). Notably, foliage intake in the *G. sepium* treatment appeared to reduce balanced feed consumption, whereas no such effect was observed in the *B. alicastrum* and *M. oleifera* treatments.

Live weight

The results showed that the higher *Gliricidia sepium* (*G. sepium*) foliage intake (1,883.6 g) did not translate into greater weight gain over the evaluation period. In contrast, supplementation with *Moringa oleifera* (*M. oleifera*) promoted a higher final live weight, reaching 2,170.8 g per animal, despite exhibiting foliage and balanced feed intakes comparable to the other treatments. Rabbits supplemented with *Brosimum alicastrum* (*B.*

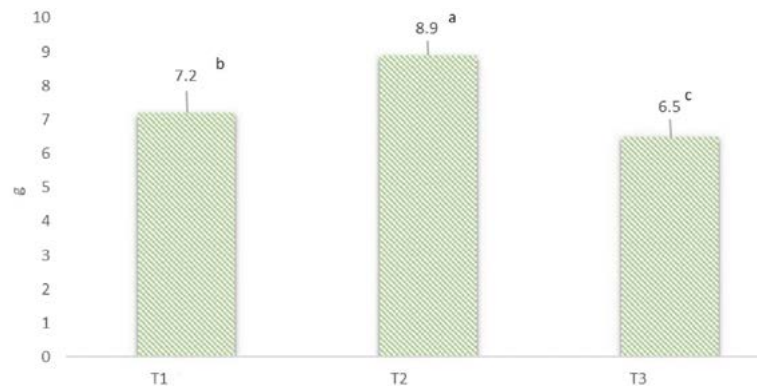


Figure 1. Foliage intake by New Zealand rabbits. Treatments sharing the same letter are not statistically different (Tukey, $P < 0.05$). T1: *Brosimum alicastrum*, T2: *Gliricidia sepium*, T3: *Moringa oleifera*.

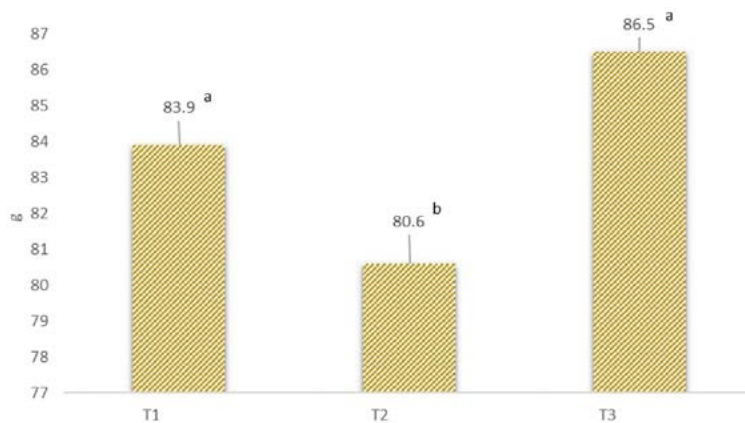


Figure 2. Balanced feed intake by New Zealand rabbits. Treatments sharing the same letter are not statistically different (Tukey, $P < 0.05$). T1: *Brosimum alicastrum*, T2: *Gliricidia sepium*, T3: *Moringa oleifera*.

alicastrum) foliage presented an intermediate final live weight between *G. sepium* and *M. oleifera*, with an average of 2,021.4 g (Figure 3). Calderón *et al.* (2021) evaluated rabbits fed foliage-based supplementation alongside commercial balanced feed and concluded that no differences were observed between supplementation with *Tithonia diversifolia* and balanced feed intake. They highlighted a rapid, exponential increase in rabbit body weight, indicating that higher commercial feed intake was associated with greater live weight gain. A similar pattern was observed in rabbits supplemented with *M. oleifera* foliage, which consumed a greater amount of balanced feed.

Carcass yield

Carcass yield was not affected by the experimental treatments; therefore, despite the differences observed in live weight, rabbits subjected to the different dietary treatments exhibited carcass yields consistent with those reported in the literature (Figure 4). No statistical differences were detected when comparing hot carcass weight with cold carcass

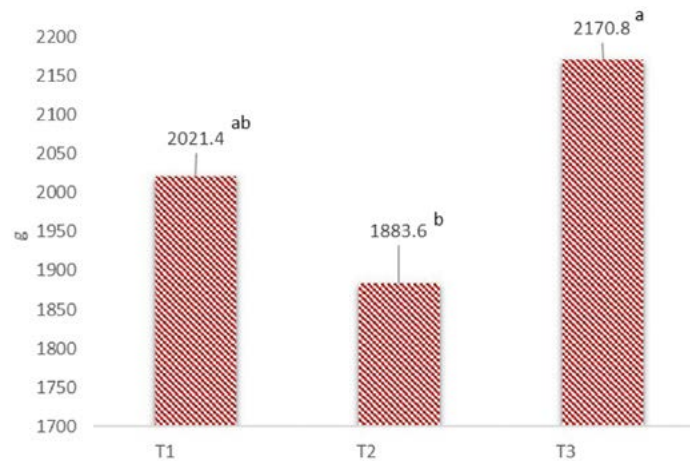


Figure 3. Live weight at slaughter of New Zealand rabbits. Treatments sharing the same letter are not statistically different (Tukey, $P < 0.05$). T1: *Brosimum alicastrum*, T2: *Gliricidia sepium*, T3: *Moringa oleifera*.

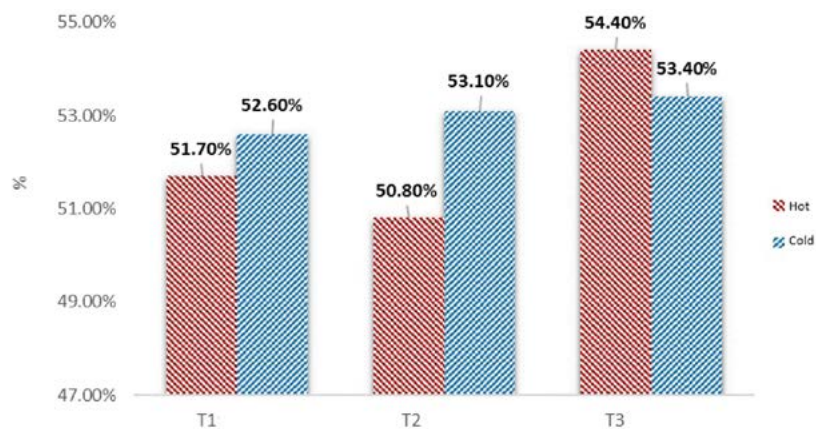


Figure 4. Hot and cold carcass weights of New Zealand rabbits. T1: *Brosimum alicastrum*, T2: *Gliricidia sepium*, T3: *Moringa oleifera*.

weight. Nevertheless, carcasses from the *Brosimum alicastrum* (*B. alicastrum*) treatment showed a cold-weight increase of 0.9 g; similarly, the *Gliricidia sepium* (*G. sepium*) treatment exhibited a cold-weight increase of 2.8 g, whereas the *Moringa oleifera* (*M. oleifera*) treatment showed a 1 g decrease after chilling (Figure 4). Montes *et al.* (2020) evaluated carcass yield in rabbits fed a balanced-feed diet and reported values ranging from a maximum of 59.3% to a minimum of 39%. In the present study, the highest yield was obtained with *M. oleifera* (54.4%), which suggests a satisfactory carcass performance within a notable range for commercialization. Likewise, the *B. alicastrum* and *G. sepium* treatments were also satisfactory, as no statistically significant differences were observed among treatments ($P>0.05$).

The head, total viscera, liver, and stomach components did not differ statistically among treatments ($P>0.05$). In contrast, the cecum showed a significant difference and was higher in rabbits supplemented with *Gliricidia sepium* (*G. sepium*) foliage, with a mean value of 6.5%, compared with 4.8% and 4.6% in rabbits supplemented with *Brosimum alicastrum* (*B. alicastrum*) and *Moringa oleifera* (*M. oleifera*) foliage, respectively (Figure 5). This pattern may be attributed to the reported high content of secondary metabolites in *G. sepium* foliage particularly tannins and saponins which could interact with fiber digestibility at the cecal level. Consequently, digesta may remain longer in the cecum, promoting an increase in its size. According to Vázquez *et al.* (2018), rabbit digestive physiology is closely associated with dietary fiber supply, because high fiber intake generally reduces transit time, an effect attributed to increased gastrointestinal

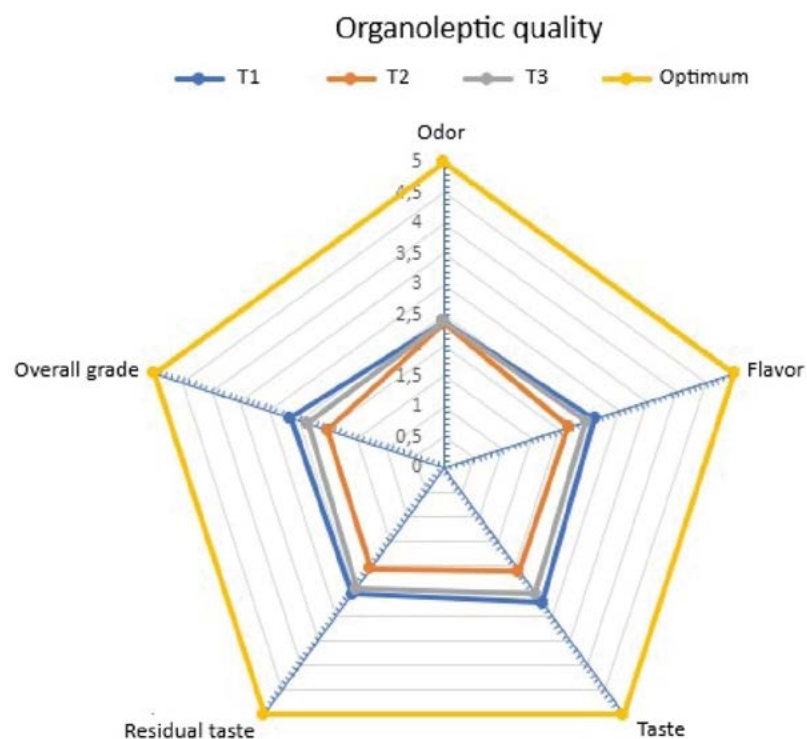


Figure 5. General organoleptic characteristics for rabbit meat. T1: *Brosimum alicastrum*, T2: *Gliricidia sepium*, T3: *Moringa oleifera*.

motility. Despite the above, and consistent with Vázquez *et al.* (2018), we consider the use of foliage-based alternative feeding strategies to be feasible.

Sensory analysis of meat

The sensory evaluation results for rabbit meat were compared against optimal reference values for odor, flavor, taste, residual flavor, and overall acceptability. The moringa (*M. oleifera*) treatment was closest to the optimal profile; however, the odor attribute displayed a similar pattern across all three treatments (Figure 5). Sánchez *et al.* (2010) noted that sensory analysis correlations are useful for identifying quality parameters through instrumental measurements and for establishing relationships among attributes, thereby enabling an overall assessment of meat quality in terms of consumer acceptance within the target region. For the odor attribute, panelists selected among the descriptors: cardboard, linseed, sulfurous, fresh meat, greasy, grass, and nuts, with “fresh meat” being the predominant descriptor across all treatments (Figure 6). Diets containing excessive amounts of oils, or oils of poor quality, can negatively affect fat color and lead to excessively soft or liquid fat (Cruz-Monterrosa *et al.*, 2019). According to Cruz-Bacab *et al.* (2018), a fresh odor is preferable in rabbit-meat sausages, although maturation can increase acceptance among a very specific consumer segment. For the general meat and fillet market, a fresh-meat odor is typically preferred across animal-derived protein products (Sánchez *et al.*, 2010). Rabbits fed cocoite (*G. sepium*) exhibited greater odor diversity as perceived by the panelists, which may be explained by the higher crude protein content of cocoite forage compared with ramon tree and moringa (Bolaños *et al.*, 2024).

In the flavor section, panelists selected among the following descriptors: cooked meat, fresh meat, fishy, and rancid. The results indicated that “cooked meat” flavor predominated across all three treatments; “fresh meat” flavor was also reported, although to a lesser extent in the *B. alicastrum* treatment (Figure 7). In this regard, Villanueva-Díaz *et al.* (2023) emphasized the importance of rabbit meat being perceived as high quality and properly

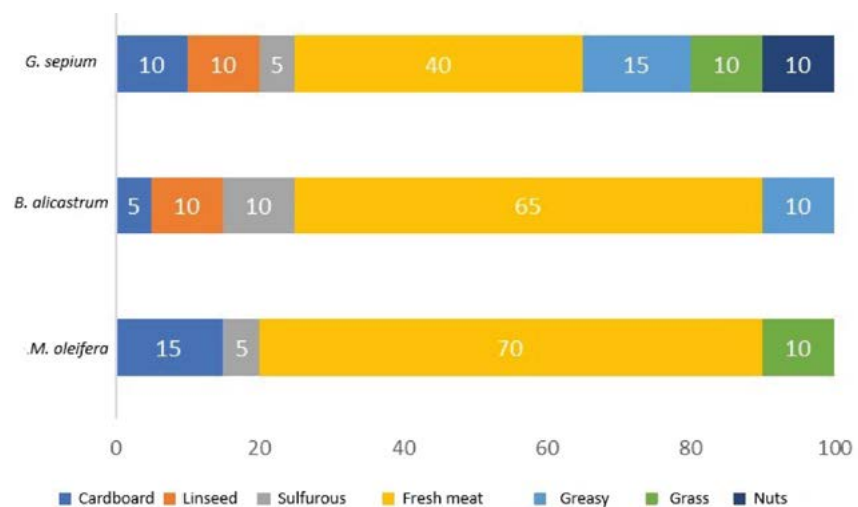


Figure 6. Odor of rabbit meat from animals supplemented with *G. sepium*, *B. alicastrum*, and *M. oleifera*.

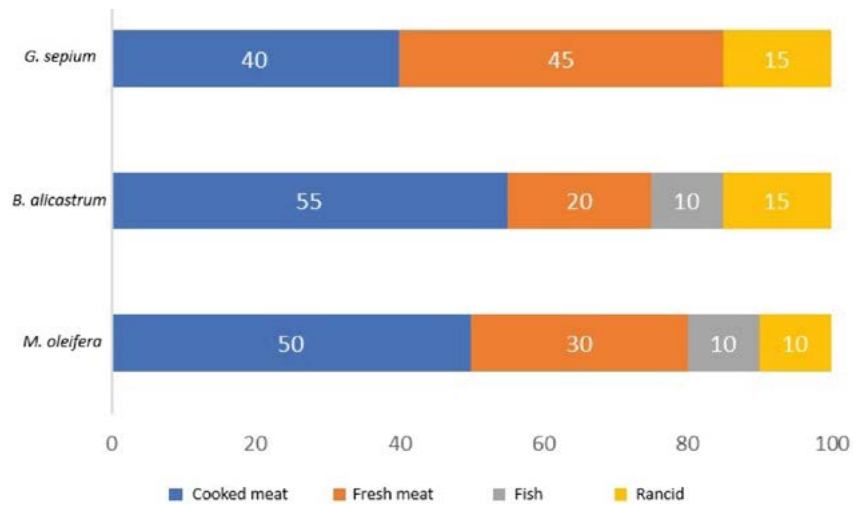


Figure 7. Flavor of rabbit meat from animals supplemented with *G. sepium*, *B. alicastrum*, and *M. oleifera*.

cooked to enhance its competitiveness against more established meats. They further noted that a positive overall perception of the product can even evoke memories and the comforting sensation of eating something “homemade” or “familiar”.

In the taste section, panelists were given the following options: umami (savory), metallic, bitter, sweet, salty, and sour. Responses varied across the three treatments. Umami (savory) was unanimously identified and showed the highest incidence in the *B. alicastrum* treatment. In the *M. oleifera* treatment, sourness was notable, accounting for 30% of the responses (Figure 8). According to Lang (1981), moringa has excellent nutritional value and is therefore considered a high-quality forage. Forages containing less than 8% crude protein (CP) on a dry matter basis are regarded as low quality. These findings are consistent with Hernández *et al.* (2015), who reported that rabbits receiving forage supplementation produced meat with improved taste compared with rabbits fed commercial diets. Likewise, Gutiérrez-Negrín (2018) reported higher acceptance of rabbit meat from animals fed diets including rosemary compared with meat from rabbits

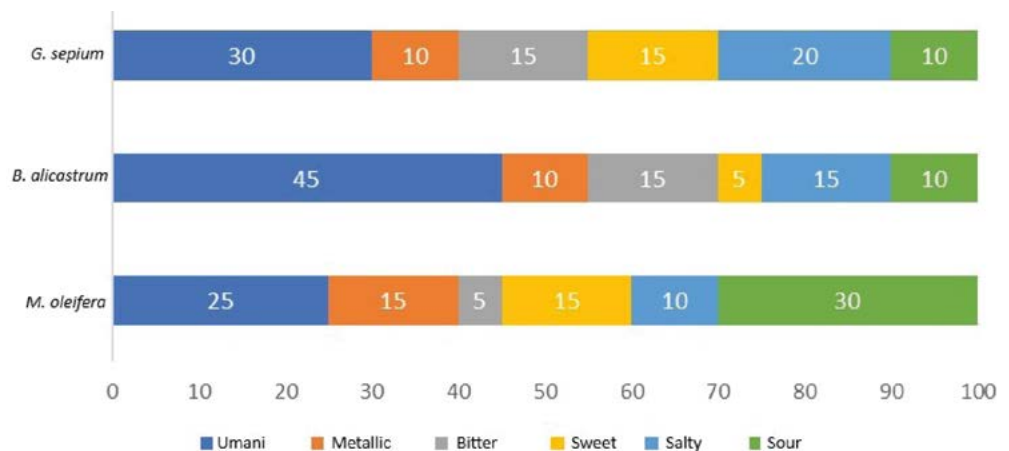


Figure 8. Taste of rabbit meat from animals supplemented with *G. sepium*, *B. alicastrum*, and *M. oleifera*.

fed commercial diets or diets supplemented with thyme. Changes in meat taste may be largely attributable to the incorporation of saturated and unsaturated lipid sources in animal diets (Cruz-Monterrosa *et al.*, 2018).

For residual taste, panelists selected between two options: astringent or none. Assessing residual taste is important to ensure that consumers have a pleasant eating experience, free from any lingering off-flavors. In this section, the results were similar between the *B. alicastrum* and *M. oleifera* treatments. In contrast, the *G. sepium* treatment stood out, with 45% of responses indicating an astringent residual taste (Figure 9).

The absence of residual taste is advantageous because it enhances eating satisfaction and increases the likelihood of consumer recommendation, as it is generally associated with good nutritional quality (Barragán-Hernández *et al.*, 2021). Conversely, when flavor is excessively intense, it can generate a lingering aftertaste that tends to reduce rabbit meat consumption (Villanueva-Díaz *et al.*, 2023).

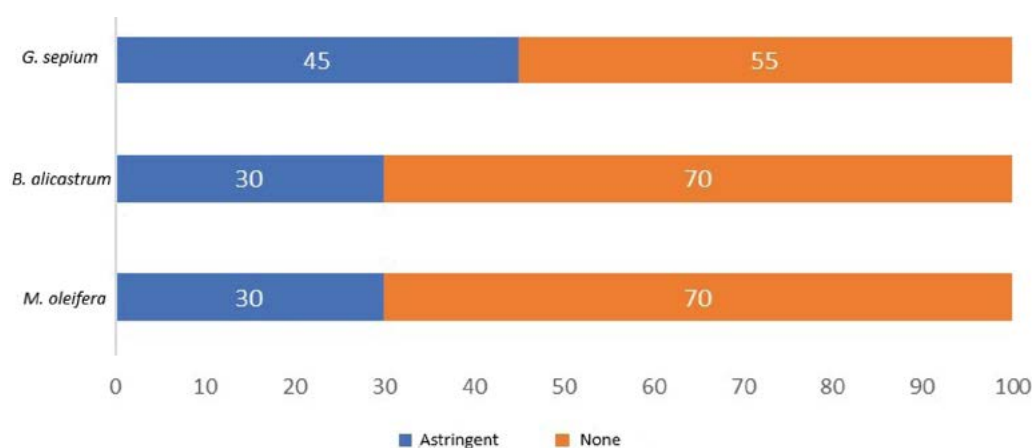


Figure 9. Residual taste of rabbit meat from animals supplemented with *G. sepium*, *B. alicastrum*, and *M. oleifera*.

CONCLUSIONS

Under the study conditions, cocoite (*Gliricidia sepium*; *G. sepium*) was the most readily accepted foliage by rabbits and was associated with reduced balanced feed intake. However, moringa (*Moringa oleifera*; *M. oleifera*) foliage in combination with balanced feed produced the best meat yield and favorable meat characteristics; therefore, it may be considered a promising alternative for sustainable rabbit production. These findings should be regarded as preliminary, as several factors remain to be evaluated, including a broader diversity of plant species and their nutritional characteristics, animal acceptance, and the optimal balancing of foliage with the most suitable commercial feed.

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This section is optional and should not exceed five lines, acknowledging individuals and institutions that contributed to the completion of the study.

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