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Article

Bromatological profile of undifferentiated and prematurely sprouted garlic in Zacatecas

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Abstract

The objective was to determine the nutritional profile of undifferentiated and prematurely sprouted garlic in a semi-arid climate of Zacatecas, Mexico. The garlic was obtained from a farm located in Calera de Víctor Rosales, Zacatecas, Mexico. Ten randomly selected samples of each garlic type were used. The variables determined were ash, crude protein, neutral detergent fiber (NDF, % DM), acid detergent fiber (ADF, % DM), net energy for maintenance (Mcal kg^{-1}), and net energy for gain (Mcal kg^{-1}). Crude protein was 22.6 *vs* 10.7, NDF averaged 38.1 *vs* 19.3, ADF 24.4 *vs* 13.2, NEm 0.74 *vs* 0.87 and NEg 0.47 *vs* 0.58; respectively, for undifferentiated garlic and prematurely sprouted garlic. It was concluded that undifferentiated garlic and prematurely sprouted garlic provide a sufficient amount of protein to be used in supplementation programs and contain energy amounts to meet maintenance requirements and moderate gain rates in small ruminants.

Palabras clave:

drought, energy, forage alternative, garlic, protein.

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Introduction

Garlic (*Allium sativum* L.), native to Central and South Asia, is a bulbous plant from the *Alliaceae* family. Every year, 27 million tons are produced worldwide; the largest producing countries are China, India, South Korea, Egypt, and the United States of America (Lee *et al*., 2020; Rouf *et al*., 2020). Mexico ranks eleventh, registering a production of 94 748 t in 2022, and Zacatecas is the primary national producing state, with 49 748 t, contributing 52% of production (SIAP, 2022).

Garlic has been widely recognized for its medicinal properties and benefits in food and human and animal health. Traditionally, it has been used for its culinary properties, prized for its distinctive flavor and its ability to enhance the flavor of other ingredients. Likewise, it has been employed as a food supplement as it improves human health, due to its antibacterial, antiviral, antiparasitic, and immune-stimulating properties (Vieira *et al*., 2015; Juárez-Segovia *et al*., 2019; Qiu *et al*., 2020).

Some studies have tested its antiparasitic effects on animals. Plants of the genus *Allium* have a high content of minerals, essential amino acids, fibers, vitamins, and phenolic compounds. Organosulfur compounds are among the main secondary metabolites of this genus, responsible for its bioactive properties. Allicin is a sulfur compound extracted from garlic that inhibits the growth of several fungal strains through its antimicrobial, antifungal and antioxidant effects (Juárez *et al*., 2019). The chemical composition of garlic varies with the crop, growing conditions, plant density, soil type, fertilizers, application rates and processing method of these products (Petropoulos *et al*., 2018; Chen *et al*., 2019; Kewan *et al*., 2021).

The ideal garlic bulbs should have a circular, compact, globose perimeter, with large cloves and in small numbers, which gives them market value. However, malformations that reduce the commercial value of garlic occur frequently, and the garlic is usually discarded, which can have a negative environmental impact. There is a phenomenon known as escobeteado or rebrotado (premature sprouting), where garlic is harvested with open bulbs (space between cloves) that are not very firm and irregular. One or more shoots appear between the blade of a leaf and the pseudostem, associated with an excess of vigor. Among the causes of premature sprouting of garlic is exposure of seeds to low temperatures, both before and after sowing, which promotes sprouting. The lower the temperature or the longer the exposure time during storage, the greater the number of plants with premature sprouting (escobetado). Premature sprouting is the tendency of bulbs to sprout early, as the harvest date approaches, which decreases their commercial value (Reveles-Hernández *et al*., 2009).

Another frequent problem is when the cloves in the garlic bulbs are not completely distinguishable, as some outer cataphylls obtain a thick firmness, with an onion-like appearance (acebollado) (Macias *et al*., 2000). Also known as ajo bombón, ajo cebolla, or ajo porro, they are garlic with tunicate bulb formation that does not have cloves or bulbils, or may have two or three bulbils, resulting in a single round bulb resembling a small onion. It is attributed to a photoperiod lower than that required by the genotype, excess nitrogen or available moisture, as well as to periods of heat or cold during the differentiation process, although it may also be related to the presence of viruses (Olmedo, 2003; Saluzo, 2003).

Recurrent droughts have caused producers to use crop residues and forage alternatives in feeding their livestock. In 2023, an extreme drought was recorded in the state of Zacatecas and practically throughout the country, where the lack of rainfall prevented adequate forage production or the development of grasses in rangelands and grasslands. Zacatecas, being the leading national producer of garlic, with more than 50% of the national volume, had large amounts of garlic harvest residues. The problems of prematurely sprouted and undifferentiated garlic affected between 10 and 30% of the production of producers in the state of Zacatecas and, due to the drought, producers offered garlic harvest residues to small ruminants, unaware of the nutritional contribution of these forages.

The protein content of garlic powder is approximately 22.90%, whereas garlic skin contains 13.5%, and the leaves have 12.8% protein on a dry matter basis (Kongmun *et al*., 2011; Wang *et al*., 2013; Panthee *et al*., 2017). Garlic powder has a high total carbohydrate content, with approximately

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74.25% on a dry matter basis (Drszczyk *et al*., 2019; Kewan *et al*., 2021). It is reported that the content of neutral detergent fiber on a dry matter basis is 31.81% in garlic skin, 59.8% in leaf and 51.18% in straw; for its part, the content of acid detergent fiber is 29.85% for garlic skin, 23% for leaf, and 43.81% for garlic straw (Panthee *et al*., 2017; Li and Fen, 2019; Wang *et al*., 2021a, 2021b). The neutral detergent fiber and acidic detergent fiber contents of garlic skin, leaf and straw are higher than those of powder; they can be used as a substitute for forage in a basic ruminant diet (Wang *et al*., 2021a, 2021b). Garlic skin, leaves, and straw have a high ash content due to their high content of epidermal cells, which contain large amounts of silica (Redoy *et al*., 2020).

There is no bromatological information on prematurely sprouted garlic and undifferentiated garlic, and studies are needed to establish their use in livestock nutritional supplementation programs and to make efficient use of this alternative forage. They are used as forage sources in ewe feeding, as they are accessible and economical in certain garlic-growing regions. This is especially common under drought conditions, where access to traditional agricultural forage sources for livestock is limited. In addition, their use makes it possible to utilize forage resources that would otherwise be thrown away and wasted, and cause pollution. Due to the lack of bromatological information and the need to provide feasible recommendations for livestock producers in their use, the objective was to evaluate the bromatological and nutritional profiles of undifferentiated and prematurely sprouted garlic in a semi-dry climate of Zacatecas, Mexico.

Materials and methods

Location

Garlic was planted in a plot located in Calera de Víctor Rosales, Zacatecas, Mexico, in 2022 and harvested in 2023; the plot is located at longitude 102° 42' 08", latitude 22° 56' 57" with an altitude of 2 169 m, with an average annual temperature of 14.6 °C and average annual rainfall of 416 mm, which occurs in a greater proportion in summer (June to September) (Medina *et al*., 2023).

Soil characteristics, genetic material, and tillage system

The characteristics of the soil used for planting were medium texture (sandy-clay loam), 19.1% moisture at field capacity, 11.4% moisture at permanent wilting point, with a saturation point of 36%, a bulk density of 1.35 g cm^{-3}, pH of 8.16, 2.44% of organic matter, salinity (EC extract) 0.58 dS m^{-1}, and 2.04% of total carbonates. The soil was prepared on August 1, 2022, by breaking it with a chisel subsoiler. After breaking the soil, it was harrowed four times with a 24-disc harrow to reduce clod size. The terrain levelled with a clod-breaking roller and a rail attached to the back of the roller.

Subsequently, the beds were marked and fertilized simultaneously with 600 kg ha^{-1} of the Entec (3S) 20-10-10 fertilizer. Then the beds were formed, drip tape was laid, and a garlic planting marker board was used to mark a six-row bed; the bed was irrigated with three drip tapes for six rows of garlic spaced 18 cm apart. In sowing, garlic seed of the Prosur variety with a sowing density equivalent to 850 000 plants ha^{-1} was used, at a rate of 3 t of garlic grain per hectare. The plantings were carried out on August 5, 2022. Garlic sowing was done manually, with a spacing of 4 cm between grains and a depth of 3 cm.

The plot was irrigated with black irrigation for 8 to 10 h. Then irrigation was repeated after eight days for 5 h. The garlic was left to germinate, a process that took 10 to 15 days. After the garlic emerged and rooted, two bottles of 300 ml ha^{-1} of Biogea (mycorrhizae, *Azospirillum brasilense*, and *Bacillus subtilis*) were used, which helps strengthen the plant's root. After 15 days, Biogea was applied at a dose of one bottle of 300 ml ha^{-1}. Subsequently, irrigation was provided at a rate of 1 h ha^{-1} every 10 days for two months. Afterwards, the following was applied: two and a half 500-ml bottles of GoalTender herbicide to finish weeds, one and a half 250-ml bottles of Grasadin, and 300 ml of Surfare (adherent).

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Then, on September 30, 2022, irrigation was applied via drip tape with 2 L of Inovextar and 1 L of Raigreen Gruindag 10-30-00. On October 6, 25 kg of ammonium sulfate, 12.5 kg of MAP, 12.5 kg of NKS, and 3 L of Fitomicrox Gruindag were used. On October 15, irrigation was applied for 1 h using water only. On October 23, 12.5 kg of calcium nitrate, 12.5 kg of magnesium nitrate, and 4 L of Germi calcio were administered. Similar nutrition and irrigation dynamics continued systematically during the months of November, December, January and February, using rotations with calcium and magnesium nitrates, ammonium sulfate, Ducor Mix, Citafrut Zn and K, Bionare, among other agrochemicals and micronutrients, with regular irrigation intervals.

For pest and disease management, on December 17, fumigation was done with a sprayer, applying half a liter of Tornado, 2 kg of Manto insecticide, 1 L of Bionare, half a liter of Germi Max, 1 L of dimethoate and 300 ml of Surfare adherent; on February 11, fumigation was carried out with a 600 L sprayer applying half a liter of Enable fungicide, 1.5 L of Tropa, 1 L of Bionare, half a liter of Germi MAX, and 300 ml of Sulfare ha^{-1}. From March 25 to April 30, irrigation was applied with water alone for 3 h every three days.

On May 2, two consecutive weedings were carried out to remove moisture from the plot. Then a garlic-harvesting machine was brought into the plot so that the garlic could be manually sheafed (covered with its own leaves); the garlic remained to dry in the fallow plot for 8 to 10 days. Afterwards, the root and stem were cut; the stem was left 4 cm long. The harvest was obtained on May 1, 2023. The garlic was collected manually in plastic boxes, which were stored for selection by size and then packed in cardboard boxes. At this stage, samples of undifferentiated and prematurely sprouted garlic were randomly selected for laboratory analysis.

Techniques and procedures used

The bromatological evaluation was conducted in the Animal Nutrition Laboratory of the Academic Unit of Veterinary Medicine and Zootechnics of the Autonomous University of Zacatecas. The soil studies were carried out at the Agricultural Analysis Laboratory (FERTILAB), Celaya, Guanajuato. Random samples of undifferentiated and prematurely sprouted fresh garlic were taken during the selection of garlic from the plot. Subsequently, the prematurely sprouted and undifferentiated garlics were cut from the root and stem; only in the fresh garlic were the bulbs cut into parts of 3 cm in length. They were placed in paper bags and dehydrated in an oven at 65 °C for 48 h or until constant weight was obtained. The dry matter samples from each treatment were ground in a Wiley mill with a 1 mm screen and stored in Ziploc bags for subsequent bromatological analysis.

The amount of ash was determined by incinerating the samples at 550 °C for 4 h. The crude protein (CP, %) was determined by quantifying total nitrogen by combustion analysis using a Leco® equipment, with ultrapure helium (Leco FP-428, Leco Corporation, St. Joseph, MI) as the carrier gas, and multiplying the nitrogen content by the correction factor of 6.25. The neutral detergent fiber was obtained using the Ankom200® equipment, F57 bags, a neutral detergent fiber solution, and thermostable alpha amylase enzyme from the same company; then the acid detergent fiber was determined sequentially, with the company's solutions and the same equipment (Ankom Technology, Macedon, New York, USA). All laboratory tests were performed in duplicate.

Statistical analysis

The analysis was performed with the Proc Glm procedure of the SAS statistical package using Tukey's test with probability <0.05. The experimental unit was the garlic sample (SAS Institute, 2011).

Results and discussion

Determining the bromatological profile of forage alternatives allows improving their use in times of drought when access to conventional forages is limited. The bromatological and nutritional results are presented in Table 1. A statistical difference ($p < 0.001$) was observed in all variables. There was a 159% increase in ash and a 110% increase in CP in undifferentiated garlic compared to prematurely sprouted garlic.

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Table 1. Bromatological and energy profile of undifferentiated and prematurely sprouted garlics from semi-arid regions of Zacatecas, Mexico.

Variables	Undifferentiated garlic	Prematurely sprouted garlic	SE	P
Ash	10.96	4.23	0.44	0.001
Protein	22.57	10.71	0.78	0.001
NDF	38.06	19.29	1.74	0.001
ADF	24.36	13.22	0.84	0.001
NEm	1.03	1.04	0.01	0.001
NEg	0.67	0.68	0.01	0.001

NDF= neutral detergent fiber; ADF= acid detergent fiber; NEm= net energy for maintenance; NEg= net energy for gain; SE= standard error; P= probability.

NDF and ADF levels were 97% and 84% higher, respectively, in undifferentiated garlic compared to prematurely sprouted garlic. In contrast, the energies presented similar values, with little biological difference, although there were statistical differences of 85% and 81% for NEm and NEg in undifferentiated garlic compared with prematurely sprouted garlic.

Garlic ash shows great variation. The ash level can influence forage quality. Usually, ash contains calcium, phosphorus, magnesium, potassium, and other trace elements. Garlic skin, leaves, and straw have high ash content due to their high content of epidermal cells that contain large amounts of silica (Redoy *et al*., 2020). The greater amount of protein observed in undifferentiated garlic could be because it retains nitrogen, whereas in prematurely sprouted garlic, nitrogen accumulates in other parts of the garlic (Saluzzo, 2003).

As undifferentiated garlic has more than 20% protein, it is considered within the international food classification as a protein concentrate and can be established in protein supplementation programs. CP requirements in ewes in maintenance are 8-10%, in gestation 10-14%, and in lactating females and growing lambs, they can reach 14-16% (NRC, 2007). Considering these levels, undifferentiated garlic can be used in supplementation programs and as a concentrate. In grazing ewes, especially during periods where forage quality or quantity is low (in winter and in times of drought), supplementation with concentrates may be necessary to meet nutritional requirements.

During dry seasons, protein in grasses decreases drastically to 3-6% levels, compromising livestock productivity and health (Abusuwar and Ahmed, 2010). Optimal protein levels improve the fermentation of low-quality forages, as the low protein ingested limits the digestibility of the fiber consumed. Given the protein levels of prematurely sprouted garlic, it can be used in sheep maintenance programs and in the early stages of gestation. Protein supplementation in livestock is expensive, due to the price that oilseed meals and other protein concentrates can reach; however, using agricultural waste drastically reduces costs. The amount of supplementary concentrate depends on the quantity and quality of the forage available; in practice, it starts with 0.5% of the body weight of the ewes. It is important to avoid malnutrition and unproductive livestock in the herds.

NDF mainly includes cellulose, hemicellulose, and lignin, and is an indicator of the amount of fiber in the feed, which is important for stimulating rumination and salivation. In addition, it regulates or limits feed intake due to the space it occupies in the rumen. The amounts observed in undifferentiated garlic are considered adequate to stimulate rumination. For dairy cattle, levels of 25 to 35% NDF were recommended, depending on the level of intake and the amount of milk produced (NRC, 1989). Nevertheless, in prematurely sprouted garlic, NDF levels are low. ADF is a part of FDN, which primarily includes cellulose and lignin but not hemicellulose. It is usually used as an indicator of forage digestibility, where as its value increases, digestibility decreases. The NRC (1989) recommended levels of 19-27% of ADF, depending on milk production. Undifferentiated

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garlic has recommended amounts for dairy animals; however, prematurely sprouted garlic has low ADF levels. Some nutritionists recommend that levels not exceed 25% of ADF to avoid affecting forage digestibility. The energy needs of ewes and other ruminants vary according to their weight, physiological state, body condition, and physical activity. Taking as a reference the energy content of straw and stover, from 0.65 to 0.67 Mcal kg^{-1} of NEm, the values observed in garlic are 56%higher.

Conclusions

It is shown that both undifferentiated and prematurely sprouted garlic can be used as forage supplements in the feeding of small ruminants under drought conditions. Undifferentiated garlic showed a significantly higher crude protein content (22.6%), which places it as a viable protein concentrate for supplementation programs, especially during physiologically demanding stages such as gestation, lactation and growth.

In contrast, prematurely sprouted garlic, with a lower protein concentration (10.7%), is adequate to meet maintenance requirements and stages of low nutritional demand. Both types of garlic had net energy for maintenance and gain contents similar to those of conventional forages, reinforcing their potential as an alternative resource in extensive sheep production systems. In addition, their utilization contributes to reducing the environmental impact derived from agricultural waste while improving the efficiency of the production system. It is suggested that these findings be complemented with studies of *in vivo* digestibility, animal acceptance, effects on productive and health parameters, and economic analyses to establish more precise inclusion protocols in practical diets under different management conditions.

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