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Article

# Importance of sheep social hierarchy on feeding behavior and parasite load in silvopastoral and grass monoculture grazing systems

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**Abstract:**

In sheep the interaction between social hierarchy, forage preference and parasite load effects production. A study was done of this interaction in two grazing systems (silvopastoral, SSP; star grass monoculture, PE) with twenty-two Pelibuey sheep per system. Tests were done of social hierarchy to calculate dominance index values, of forage plant species (*C. nlemfuensis, L. leucocephala*, *G. sepium*, *G. ulmifolia* and *H. rosa-sinensis*) preference, of parasite load (gastrointestinal nematode egg count per gram of feces), and of hematocrit levels. A generally nonlinear hierarchy was present in both systems, with linear dominance (h=0.75) in the SSP and bidirectional dominance (h=0.5) in the PE. In both systems the most dominant individuals had the highest number of aggressive behaviors (SSP: $r_s$= 0.790909, *P*=0.05; PE: $r_s$= 0.845455, *P*=0.05) and the lowest parasite loads (SSP: $r_s$= -0.909091, *P*=0.05; PE: $r_s$ = -0.727273, *P*=0.05). In the SSP, the animals had greater preference for *C. nlemfuensis* but those that consumed more *L. leucocephala* had higher hematocrit levels ($r_s$=0.694269, *P*=0.05). Sheep grazing in silvopastoral systems consume more arboreal and shrub species foliage which helps to control parasite load and maintain stable hematocrit levels regardless of group social rank.

**Key words:** Animal behavior, Feeding preferences, Parasites, Small ruminants.

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# Introduction

The estimated worldwide sheep population is 1,173 billion[1], which represents a per capita consumption level of 2.5 kg[2]. Breeding occurs mainly in Europe, Asia, South America, Australia and New Zealand. There are approximately 8.7 million head of sheep in Mexico[3], a portion of which accounts for the 55,605 t of annual meat production in 2017[4]. Sheep production in the state of Yucatan is currently growing at one of the fastest rates in the country[5], although producers struggle with problems such as herd management, nutrition and health[6]. Herd management involves important aspects such as herd hierarchical structure, which requires understanding the traits, functions and characteristics of animal social organization[7,8]. This helps to promote efficient handling of the groups within a flock[9], and optimal management of production systems. In sheep, flock hierarchy determines access to food resources, consequently affecting the quality and quantity of harvested forage species and nutrient intake[10].

As part of an integrated strategy, manipulating feed type during grazing provides useful options for controlling gastrointestinal parasites in sheep[11]. Selection of non-grass forage species in silvopastoral systems has been reported to improve animal health by reducing intake of nematode larvae via infested grasses[4]; this is reflected in lower fecal egg counts[12]. Optimizing forage resource use by grazing ruminants requires quantification of forage selection[13].

With the goal of increasing production system efficiency, the present study objective was to evaluate the relationship between flock hierarchy, food preference and degree of nematode parasite infestation in Pelibuey sheep grazing either a silvopastoral system or star grass pastures.

# Material and methods

## Study area

The study was carry out in sheep flocks in Conkal, Yucatán, México (21°04'30.1" N; 89°30'18.4" W). With an altitude of 8 m asl, the region has a warm subhumid climate (Awo), a 26.5 °C average annual temperature, and 900 mm annual average precipitation. Soils are calcareous and shallow, with high rockiness (Lithosols and Rendzinas)[(14)].

The experimental animals were 22 Pelibuey sheep, divided into two groups of 11 animals (five males and six females) per treatment. Average animal age was 78 d and average weight was 19.2 ± 1.4 kg. The sheep were individually marked and identified. They were managed in accordance with the Official Mexican Standard (NOM-062-ZOO-1999), which follows technical specifications for the production, care and use of experimental animals. Prior to the experiment, the animals were vaccinated with 2.5 ml triple typhoid bacterin and deparasitized with Ivomec® (0.2 mg per kilo live weight).

Two grazing systems were tested. The silvopastoral system (SSP) covered a 130 x 24 m area and was planted with a mixture of forage species: African star grass (*Cynodon nlemfuensis*) as a base forage, *Leucaena leucocephala* established in rows (0.5 m between plants, 3 m between rows); a living fence consisting of *Hibiscus rosa-sinensis* sown every 0.25 m and interspersed with *Gliricidia sepium* every 2 m; and a centerline of *Guazuma ulmifolia* planted at 3 m intervals. The African star grass (*C. nlemfuensis*) pasture (PE) covered a 130 x 24 m area and contained only this forage species.

The total area of each grazing system (3,120 $m^2$) was divided into eleven paddocks measuring 9 x 22 m each. These were bounded by a mobile electric fence. Before it was grazed, each paddock was homogenized by pruning tree and shrub species to 50 cm height and star grass to 10 cm above ground level. The animals were rotated through the paddocks using a 3-d occupation to 30-d fallow ratio, with an animal load equivalent to 1 AU/ha. Over a five-month period (August-December) the animals were grazed daily from 0700 to 1400 h. When not grazing they were kept in individual pens, fed a commercial balanced feed (1% live weight) and provided free access to water.

## Social hierarchy tests

Sheep behavior was evaluated using a list of behaviors with forms of dominance expression[15,16]. Dominance tests were done by placing two sheep from the same lot in a test pen after 18 h food restriction. They were then offered 20 g of commercial balanced feed and conflicts allowed to occur between them. For five minutes, the frequency of each conduct in the catalogue was observed and recorded using focal-animal sampling for each sheep[17], and dominance and subordination attitudes documented for each animal. This test was done once a month with all sheep in each group (SSP and PE), and results synthesized in a contingency table of paired tests[18].

## Forage selection

Using direct observation[19], records were made of the first 100 bites taken by sheep of forage plants in the paddocks. Observations were made every 15 d over two consecutive days between 0700 and 1200 h in each paddock. The data collected also included time, day and animal identification number. In the SSP system, the bites were classified by the species consumed: *C. nlemfuensis; L. leucocephala; G. sepium*; *G. ulmifolia*; and *H. rosa-sinensis*. In the PE system, the bites were classified as star grass or weeds.

## Eggs per gram feces (EPG)

Samples (10 g) of fresh feces were collected every 15 d directly from the rectum of each animal and placed in previously marked polyethylene bags. The manure from each animal was homogenized and processed individually to quantify gastrointestinal nematode egg counts per gram of feces using the McMaster technique[20].

## Hematocrit quantification (HT)

A blood sample (3 ml) was taken directly from the jugular vein of each animal every fifteen days. Each sample was placed in a previously marked test tube containing disodium EDTA and processed with the capillary microhematocrit technique[21].

## Group social hierarchy analysis

Group hierarchy linearity was estimated with the Landau hierarchy[18], which allows calculation of the degree of stratification in a lot using the linearity formula:

$$h = [12/(n^3 - n)]\ \Sigma\ [Va - (n-1)/2]^2,$$

**Where**:

**h**= linearity index,

**n**= number of animals in group,

**Va**= number of animals dominating each individual.

Aggressiveness, dominance and movement efficiency were estimated using equations applied in grazing ruminants[22]. Values in these indicators range from 0 to 1, with 1 representing absolute linearity, maximum aggressiveness, absolute dominance and maximum movement efficiency.

Aggressiveness was estimated with the equation:

$$(Ag = \frac{Agi}{Agt}),$$

**Where**:

**Ag**= aggressiveness index,

**Agi**= aggressions initiated by individual,

**Agt**= total aggressions participated in.

Dominance was calculated with:

$$(DI = D^{*}\text{Exr})$$

**Where**:

**DI**= dominance index,

**D**= intragroup dominance index,

**Exr**= relative movement success.

The intragroup dominance index (D) was calculated using:

$$D = \frac{Do}{Do+Don},$$

**Where**:

**Do**= individuals dominated,

**Don**= individuals not dominated

Relative movement success (Exr) was calculated with:

$$Exr = \frac{Dz}{Dz+Dzo},$$

**Where**:

**Dz**= number of times the individual moved,

**Dzo**= number of times the individual was moved.

Movement efficiency was calculated with the formula:

$$Efdz = \frac{Dz}{Dz+Ndz},$$

**Where**:

**Efdz**= individual movement efficiency,

**Dz**= number of times the individual moved,

**Ndz**= number of times the individual did not move.

Social rank level was estimated based on the dominance index (DI); high= dominated ≥50 % of adversaries; medium = dominated 10 to 49 % of adversaries; and low = dominated <10 % of adversaries.

The variables of dominance, feed preference, hematocrit level, EPG and the interactions between them were analyzed with a mixed linear model for repeated measurements over time, using the MIXED procedure[23]. Spearman correlation tests were also run ($P$< 0.05) to identify the relationships between food preferences, parasite infection levels, hematocrit levels, dominance, movement efficiency and aggression. Data were analyzed with the SAS® ver. 9.0 statistical package.

# Results and discussion

## Dominance tests

Dominance test results identified a linear hierarchy (1 dominant and 10 subordinates) in the SSP and a bidirectional hierarchy (2 dominants and 9 subordinates) in the PE (Figure 1). In small groups containing animals of the same sex and size, social structure is often linear or nearly linear[24].

Hierarchy level exhibited only slight linear tendencies in the two systems: SSP, h= 0.75 and $r^2$ = 0.9198; PE, h = 0.50 and $r^2$ = 0.9822 (Figure 1). A hierarchy is considered linear when its Landau index value surpasses 0.9. This occurs in groups of male animals[17,18], stabled goats, which exhibit clear hierarchical gradation (h= 0.92 and 0.99)[25], and lambs, which have a significantly hierarchical social structure[26]. Buffalo heifers have largely semi-linear hierarchies, with 55.24% unidirectional dominance when in large pastures, and 54 to 63% in small pastures[27]. Worth noting is that no prior reports exist of hierarchical ranks in mixed groups of sheep under grazing conditions.

The most dominant sheep in both studied groups showed a greater amount of aggressive behaviors (F1, 21= 0.65256, $P$= 0.000154) involving attacks or threats[28]. In combination with knowledge of the function of each animal, an understanding of the characteristics of social organization is essential to more efficient management of animal groups and development of optimum production systems[29]. Social hierarchy in a group of animals is influenced by different factors and defined as inhibition of the behavior of a submissive animal by a dominant animal through threats, butting and other aggression[30]. A notable effect of being dominant in the present study was a lower parasite load (Figure 2). This coincides with a report of higher EPG values in animals belonging to middle and low (i.e. subordinate) hierarchical categories[31].

**Figure 1**: Social hierarchy in grazing flocks in a silvopastoral system (SSP) and a star grass pasture

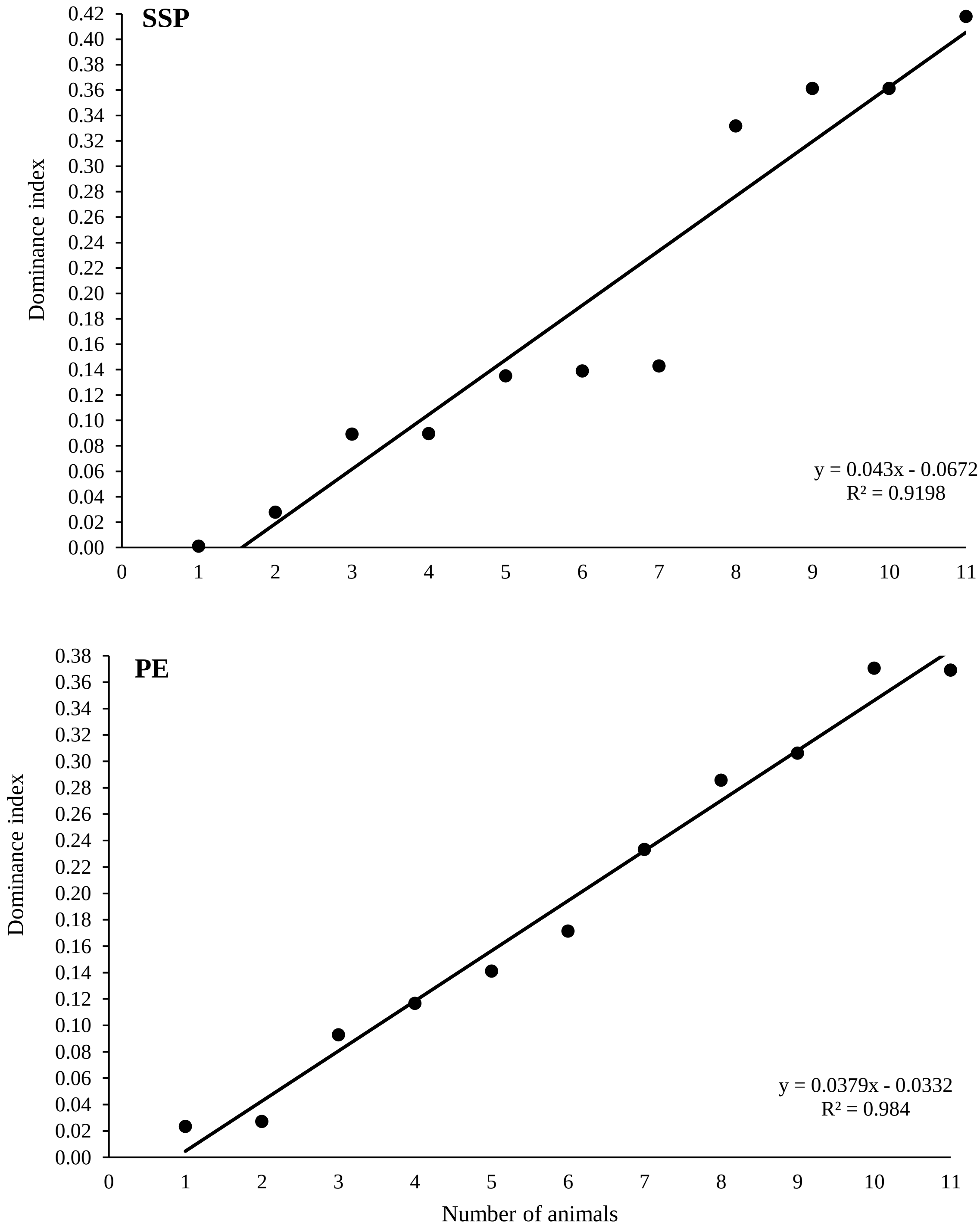
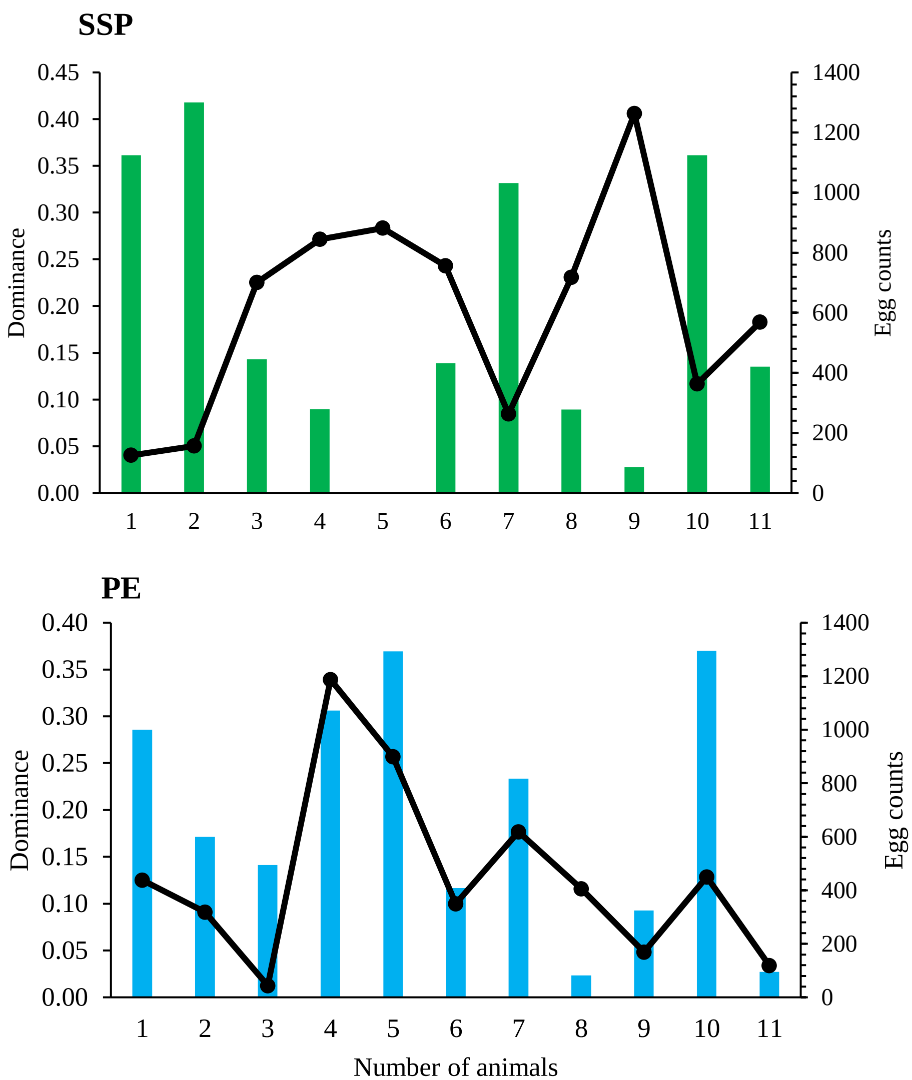


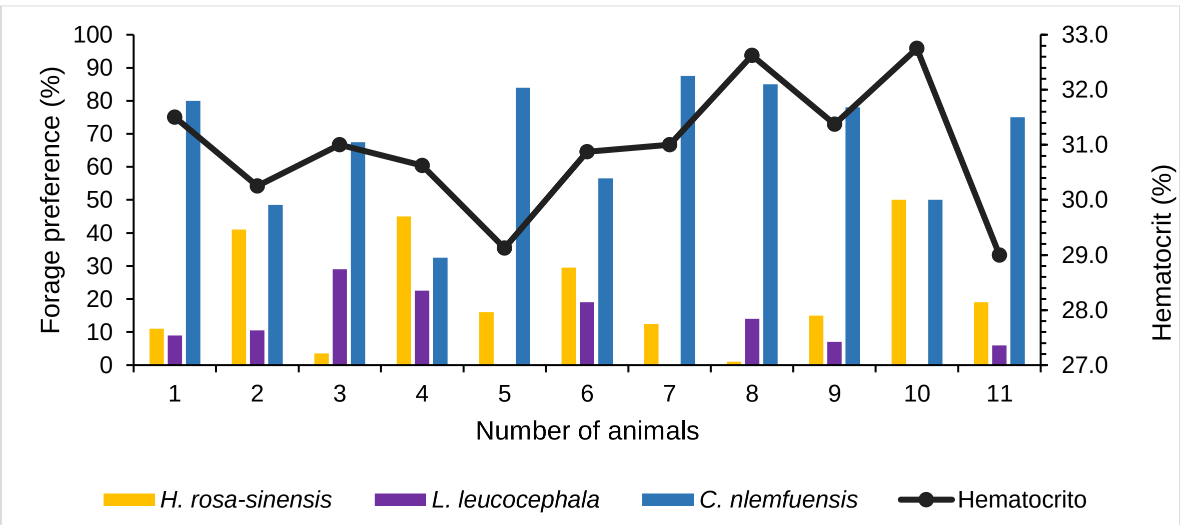
**Figure 2**: Dominance level (▬) and gastrointestinal nematode egg counts per gram feces (▮) in sheep in silvopastoral (SSP) and star grass monoculture pasture (PE) grazing systems




## Forage selection

Animal forage preference in the SSP was highest for *C. nlemfuensis* (68 %), followed by *H. rosa-sinensis* (22 %) and *L. leucocephala* (10 %)($F_{2, 11}$= 15.95349, P= 0.00034); neither *G. sepium* nor *G. ulmifolia* were consumed. This same trend in species preference has been reported in empty adult ewes in the same kind of silvopastoral system(32). This coincides with reported sheep grazing behavior in that they are intermediate-selectivity consumers that prefer ground grasses, but will occasionally graze trees and bushes(33). Forage selection in sheep is also heavily influenced by social interactions; indeed, these can communicate aversion to certain plants that have caused unpleasant effects in the past(34). Of note is that animals which consumed the most *H. rosa-sinensis* had a lower number of bites of *C. nlemfuensis* ($r_s$= -0.763636, $P$= 0.05) (Figure 3), even though *C. nlemfuensis* had greater biomass availability in the system(32). This was most probably due to the fact that *H. rosa-sinensis* foliage contains fewer antinutritional compounds(35,36,37), which strongly influence rejection behaviors(38).

**Figure 3**: Forage preference and hematocrit levels in sheep in a silvopastoral system




The sheep in the SSP that consumed the most *L. leucocephala* exhibited higher amounts of hematocrit ($r_s$= 0.694269, $P$= 0.05). This coincides with a report of hematocrit values higher than 28 in Pelibuey sheep grazed in silvopastoral systems containing *L. leucocephala*, *G. sepium*, *A. lebbeck* and *P. maximum* grass. It is also similar to the higher hemoglobin and cell volume values reported for Pelibuey ewes and lambs that had consumed a diet supplemented with *L. leucocephala* or *L. pallida* foliage(39,40). These are favorable indicators for progeny growth and breeder health(41), and therefore have a positive impact on system productivity and sustainability(42). Part of this impact may be due to the iron (Fe) content of *L. leucocephala* (average= 381.30 mg Fe $kg^{-1}$ DM)(43). Consumption of 94.38 g DM *L. leucocephala* by sheep provides 200 ppm Fe(44), an amount higher than the 30 to 50 ppm required by sheep(45). Adequate Fe intake promotes accelerated growth; increased resistance to infection; absence of anemia (reflected in the hematocrit), lethargy and increased respiratory rate; and decreased mortality rates from Fe deficiency(46). An additional benefit of *L. leucocephala* consumption is the reduction in gastrointestinal nematode EPG values in response to its secondary metabolites content (total phenols and saponins)[(47)]; in fact, it has an inhibitory effect >50% (at 100 mg/ml) on third stage larvae (L3)[(48)].

A consequent effect in the present results for the SSP was that the dominant sheep, which had more access to forage, also exhibited greater resistance to parasites and increased hematocrit levels. This agrees with the established knowledge that higher social status individuals tend to have higher productivity[(49)].

## Conclusions and implications

The sheep in the studied silvopastoral and star grass pasture systems exhibited no significant linear tendencies in their hierarchical levels. However, when correlated with parasite egg count in feces it was observed that those animals with the highest dominance index values also had lower parasite loads. In the silvopastoral system, the sheep preferred *C. nlemfuensis*, followed by *H. rosa-sinensis* and *L. leucocephala*. Those that consumed *L. leucocephala* had higher hematocrit levels due to the contribution of iron from this legume.

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