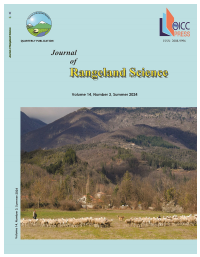

Volume 14, Issue 3, 142421 (1-7)

Journal of Rangeland Science (JRS)

https://dx.doi.org/10.57647/j.jrs.2024.1403.21

Impact of deferment on grassland condition and diet quality of cattle under a short-duration grazing system

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Research and Full Length Article

Received:
4 April 2023
Revised:
2 July 2023
Accepted:
15 July 2023
Published online:
15 July 2024

Abstract:

Rest and deferred rotation grazing treatments have proven to be effective tools that improve range condition, but little is known about their effect on range animal's diets. The purpose of the present research was to evaluate the impact of deferment in a short-duration grazing on vegetation and diet quality of heifer in a context of a Puna grassland ecosystem of Peru. The study was conducted using a completely randomized design with two replications, where treatments resulted from the combination of two grazing systems (short duration grazing with and without deferment) evaluated over three years from 2016 to 2018. Forage yield (4.9 vs. 4.5 ton/ha DM/year) and range condition (55.5 vs. 50.7 %) improved with a deferment. Conversely, diet quality was negatively affected ($P < 0.05$) as result of deferment as an evidenced by a lower in vitro digestibility of dry matter (IVDDM) (40.6 vs. 45.5 %), a higher Neutral Detergent Fiber content (NDF) (79.0 vs. 74.6 %) and also a lower Crude Protein content (CP) (10.0 vs. 11.4 %). The results revealed that deferred grazing improves range condition and forage yield of Puna grasslands when managed under a short duration grazing scheme; however, at the cost of reducing the quality of the diet selected by heifers. When combined with short-duration grazing, deferment improved range condition and increased forage yield at the expense of diet quality, although, with no failure to meet the minimum recommended CP level for a bacteria ruminal function.

Keywords: Range plants; Short duration; Grazing; Deferment; Diet composition and quality

1. Introduction

The Peruvian Puna rangeland includes tussock grasslands, shrublands and wetlands, in order of geographical importance. Currently, an important part of the rangelands presents a high degree of degradation and more than 40 % is in poor condition (Flores, 2016). The application of poor livestock management practices, the absence of policies for the improvement and conservation of rangelands by the national government, and climate change have been determinant factors of its current ecological status (Ventura, 2003). Based on ecology and agronomic criteria, range scientists have designed extensive (burning, grazing systems, and water management) and intensive strategies (fertilization, control of undesirable species, and revegetation) in order to improve the ecological status of rangelands (Herbel, 1983). Among these, grazing management has been considered a priority option by Puna herders and rangeland extension workers due to its low cost, low risk, and ease of adoption by Puna herders (Zarria and Flores, 2016).

There are different grazing systems such as rest-rotation, deferred rotation, short-term and mixed grazing which have been used to improve range condition and carrying capacity (Verdoodt et al., 2009; Locke et al., 2021). However, the response of vegetation and animals to grazing systems shows contradictory results. While some scientists recommend its use for an effective recovery of range condition (Yayneshet et al., 2009; Dong et al., 2013) and the improvement of hydrological function (Van Uytvanck et al., 2008; Tácuna et al., 2021), some others do not find differences with continuous grazing (Briske et al., 2008; Adema et al., 2016). These findings, somehow contradictory, reveal the need to compare grazing systems under similar conditions of carrying capacity, forage allocation and grazing pressure (Da Trindade et al., 2012). These variables are considered essential in determining forage intake and animal response,

but are often not reported or properly managed in experimental trials.

The ability of grazing systems to improve grassland ecological status and carrying capacity can be enhanced by rest and deferred rotation grazing (Waterman and Vermeire, 2011). However, the disadvantage of postponing grazing until the species have matured and dispersed seeds is the loss of quality of the ingested forage, a situation that worsens as the days of paddock occupation progresses (Olson et al., 1989), forcing the animals to increase selectivity. In the past, rest and deferral grazing has been commonly applied in combination with high-intensity, low-frequency grazing systems (Kothmann, 1984), and to a lesser extent in short-duration grazing systems. Hence the importance of generating information on the effects of deferred short-duration grazing on vegetation condition and the quality of the diet consumed by the animals is crucial. The objective of this study was to evaluate the impact of deferred grazing on range condition, forage yield and the quality of the diet of heifers, grazing Puna grasslands under a short-term grazing scheme.

2. Materials and Methods

2.1 Study Site

The study was carried out in the SAIS Tupac Amaru Campesino organization, located in the province of Jauja, Junín, Peru, at an altitude of 4168 m.a.s.l. The climate is cold and semi-arid, with a moderate thermal amplitude. The average annual temperature is 8 °C and the average annual rainfall is 713 mm. There were no significant differences in these two variables throughout the study period (SENAMHI, 2018). Phytogeographically, the area belongs to the Humid High Andean Pajonal ecosystem (Josse et al., 2009). The vegetation is dominated by the association *Festuca humilior - Calamagrostis spicigera - Plantago tubulosa*, and is composed of 78.6 % grasses, 10.1 % grass like plants (sedges and rushes), and 11.3 % herbs. On average, the vegetation cover is 86 %, the mulch cover is 5 %, and the bare soil cover is 9 %. Physiographic characteristics reveal a slightly sloping topography, with a slope variation between 2 and 5 %. The soils are superficial (0-50 cm) and have a predominantly sandy loam texture. They have a pH of 4.27, an electrical conductivity of 0.74 dS/m, cation exchange capacity of 29.6 meq/100 g, phosphorus 4.3 ppm, potassium 281 ppm, and organic matter 9.97 %. The surface stoniness is 10 %, and there is no evidence of soil erosion.

2.2 Experimental Treatments

The experimental treatments were short-term grazing with deferral and short-term grazing without deferral, applied on experimental paddocks of 1250 m^2 at a rate of 2 replicates per treatment. The paddocks were previously fenced and excluded from the utilization system used by the campesino organization. The short-term grazing treatment with deferral was applied only during the months of April to September, consecutively during the three years of the study, after key plant forage species had set seed. On the other hand, the short-term grazing treatment without deferral was applied every two months consecutively throughout the study. In both systems, grazing was carried out with four two-year-old Brown Swiss heifers, which grazed from 08:00 am to 06:00 pm daily, with access to water from 12:00 to 01:00 pm. Grazing management contemplated three days of grazing and 60 days of rest, a stocking rate of 0.4 AU/ha/year, and a grazing density of 8.4 AU/ha.

2.3 Evaluated Variables

The experiment contemplated evaluating three attributes: range condition at the beginning of March each year, availability of forage at the beginning of each grazing period, and the botanical composition of the diet right after first morning grazing from April to September. The plant species were recorded using permanently fixed transects of 30 m ($n = 1$) inside each paddock. Range condition (*RC*) was estimated based on the percentage of desirable plant species, forage plants, plant cover, and vigor of *Festuca humilior* (key plant species) using the following equation:

$$RC(0-100\%) = 0.5(\%D) + 0.2(\%FI) + 0.2(\%PC) + 0.1(\%VI)$$

Where:
RC = Range condition,
D = the desirable species,
FI = forage index represented by desirable species + undesirable species,
PC = the plant cover, and
VI = the vigor index of *Festuca humilior* (Florez and Malpartida, 1987).

Aerial biomass was estimated by cutting the aboveground plant biomass from 5 quadrants of 1 m^2 randomly placed on each paddock, making sure they do not overlap sampling locations used for estimating forage availability and animal diet composition. Forage availability was the difference of biomass minus undesirable plants and was obtained using a cutting and plant separation technique (Kent, 2012). Five quadrants of 1 m^2 were systematically placed every 6 m along each 30-meter transect and cut at ground level. The locations of these quadrants did not coincide with the sampling points of previous years. All the samples obtained were carried to the Laboratory of Ecology and Range Management of the National Agrarian University La Molina (UNALM) for dehydration at 105 °C for 24 hours to express the results in Kg. DM/ha (AOAC, 2001).

Diet chemical and botanical composition was evaluated for both grazing systems from April to September, after the deferment treatment ended. Using four tamed heifer cattle. The samples were pulled by hand in places adjacent to feeding stations, mimicking the process of forage harvest in the composition of species and plant parts (Austin et al., 1983). A total of 10 feeding stations per animal ($n = 4$) was sampled. The samples obtained manually were separated into two equal parts, one to estimate the botanical composition and the other to evaluate the nutritional quality of the diet selected by the animals.

The botanical composition of hand simulated diets was determined using the point microscopy technique (adapted from Harker et al., 1964), which consisted of a 100 square (5×5 cm) board where the vegetal material located in the center is classified according to its functional class into

grasses, grass like or herbs, and also whether it is green or senescent material (Quispe et al., 2021). In the other hand, the nutritional quality of the diet was determined from the in vitro digestibility of dry matter (DMD) (Tilley and Terry, 1963), crude protein content (CP) (AOAC, 2001), and neutral detergent fiber content (NDF) (Goering and Van Soest, 1970). For the purpose of chemical analysis, the samples were dried, grounded to 1 mm particle size, and then combined into two composite samples of 200 g each per treatment and grazing period ($n = 24$ per year).

2.4 Statistical Analysis

The data were analyzed by ANOVA using a completely randomized design, with two management schemes during short duration grazing (with and without deferment), with two replications and evaluated during three consecutive years (2016 to 2018). Parametric model assumptions validation was verified trough the Shapiro-Wilk test in order to assess the normality of the data, and the Bartlett test to confirm variance homogeneity (Gutiérrez and De la Vara, 2008). A least significant difference, LSD ($\alpha = 0.05$), was used to separate parameters means. All the statistical tests were analyzed with the software SAS v.9.2 (SAS Institute Inc., 2004).

3. Results

The results revealed that range conditions improved by the effect of deferment ($P < 0.05$), which was quantitatively evidence for an increased accumulation of biomass and forage production (Table 1, Figure 1). The proportion of grasses in the animal's diet was lower ($P < 0.05$), and grasslike and herbs larger ($P < 0.05$) in short duration grazing without deferment as compared to short duration grazing with deferment (Table 1).

Animals included both green and senescent material in their diets, but the proportion of green material increased when grazing under short duration without deferment ($P < 0.05$). Grasses accumulated a higher proportion of senescent material than grasslike and herbs which remained greener than the former during the grazing season (Figure 2).

Animal diets under the short-duration grazing with deferment were of lower quality ($P < 0.05$) than those corresponding to grazing with no deferral, as was evidenced by the lower in vitro digestibility of dry matter as well as for its high content of neutral detergent fiber and a low crude protein content (Table 1, Figure 3).

4. Discussion

The results confirm that deferment combined with short-duration grazing improves range condition and could increase forage production, but at the expense of a drop in the diet's nutritional value. Grazing deferment increased the vegetation cover, the number of desirable species, and the vigor of the key species, as revealed by the vegetation censuses of the experimental paddocks. Increment levels however, occurred at a low rate (Tácuna et al., 2021), and were attributable in part to the limitations Puna climate imposes to rangeland productivity such us low temperatures and variable precipitation (Martínez et al., 2011). Similarly, in a deferred grazing study, Yalli et al. (2020) studying the response of Puna rangelands to cattle and llama grazing under deferred rotation grazing, observed an increase in plant cover, biomass accumulation, and litter cover in paddocks of regular condition; however, the increment of forage pro-

Table 1. Variations in yield, range condition, and botanical and chemical composition of the diet on short-duration grazing without and with deferment.

Variables	Short duration grazing	Short duration + deferment
Yield and range condition		
Range condition (%)	50.7 ± 1.4^{b}	55.5 ± 1.7^{a}
Aboveground biomass (kg/DM ha/year)	$5,397.5 \pm 516.7^{a}$	$5,656.1 \pm 602.1^{a}$
Forage species (%)	84.0 ± 1.7^{a}	87.3 ± 0.9^{a}
Yield (kg/DM ha/year)	$4,551.3 \pm 529.2^{a}$	$4,949.6 \pm 572.2^{a}$
Diet botanical composition		
Grasses (%)	79.0 ± 2.3^{b}	86.0 ± 1.3^{a}
Pseudo grasses (%)	11.6 ± 1.2^{a}	7.8 ± 0.9^{b}
Herbs (%)	9.4 ± 1.4^{a}	6.2 ± 1.4^{b}
Diet chemical composition		
IVDDM (%)	45.7 ± 2.6^{a}	40.6 ± 2.7^{b}
NDF (%)	74.6 ± 2.1^{b}	79.0 ± 1.2^{a}
CP (%)	11.4 ± 0.5^{a}	10.0 ± 0.9^{a}

Different letters in each row reveal differences between treatments ($P < 0.05$). Values are average + standard error.

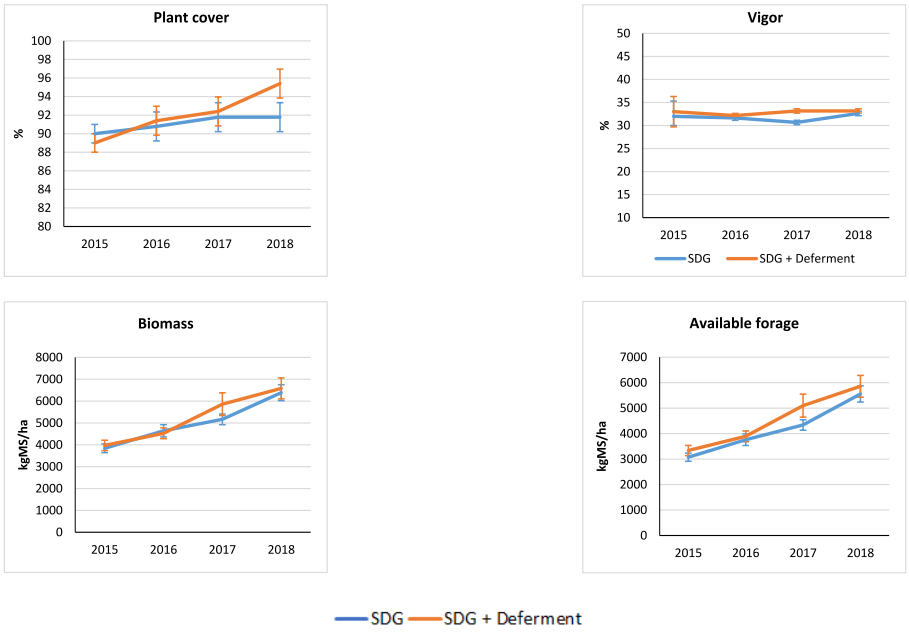

Figure 1. Means of Plant cover, vigor, biomass and available forage variation over time on short-duration grazing (SDG) and SDG with deferment (vertical bars represent ± standard error).

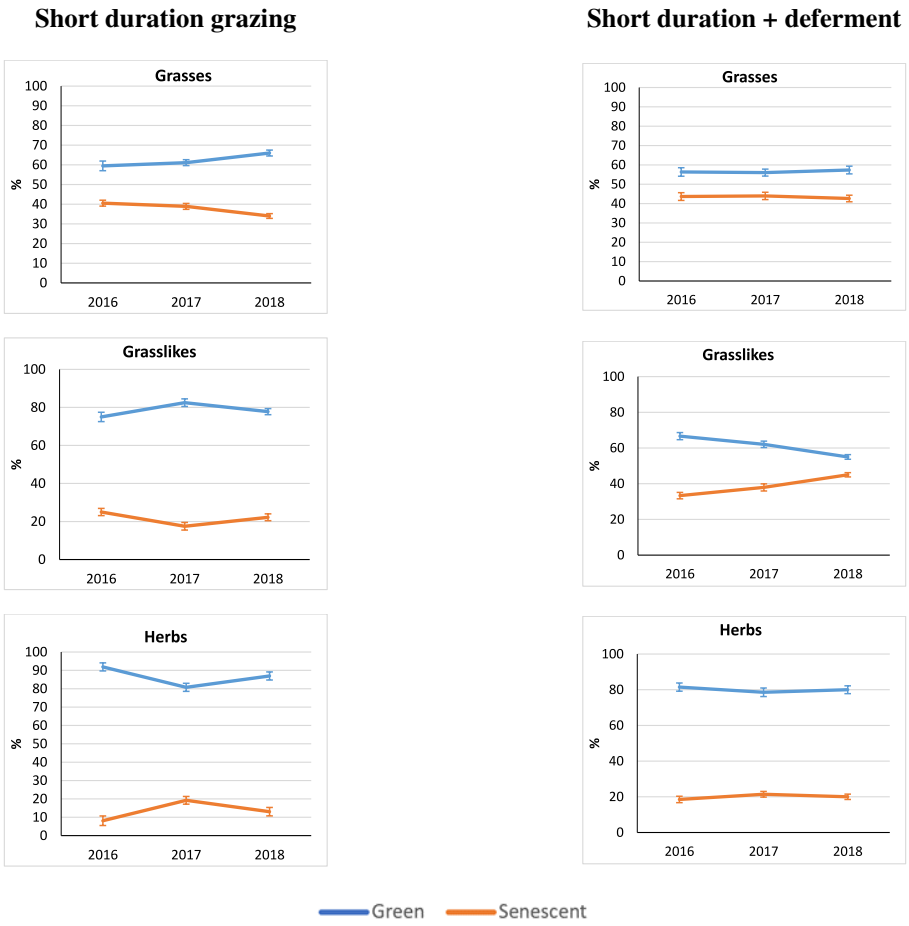

Figure 2. Variation over time of green and senescent fraction in grasses, pseudo-grasses and herbs on short-duration grazing (SDG) and SDG with deferment (vertical bars indicate ±SE).

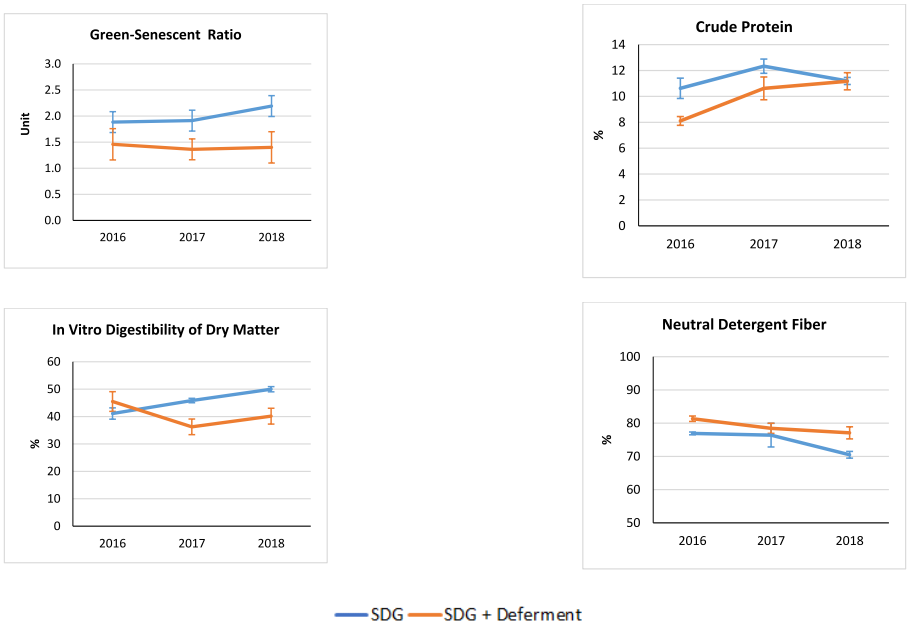

Figure 3. Variation over time of the senescent-green proportion and nutritional value of diet on short-duration grazing (SDG) and SDG with deferment (vertical bars represent ± standard error).

duction and range condition scores occurred, as in this study, at a relatively slow rate, 2 % per year on the average.

In this regard, there is evidence that shows that domestic ruminants can be used to reverse environmental damage caused by mismanagement (Teague et al., 2013) and this allows managing grazing lands sustainably using short grazing periods. Duration or long recovery periods of adaptively varied post-grazing plants requiring multiple paddocks per herd to ensure adequate residual biomass and adjustment of animal numbers as environmental and economic conditions change. Using this approach, farmers and ranchers have achieved superior ecosystem and profitability outcomes (Teague and Kreuter, 2020).

In both grazing systems, the animals' diet was composed mainly of grasses, in concordance with that observed in other Andean rangeland studies (Cruz, 2008). However, comparatively, the proportion of grasses in cattle diets under the short-term grazing with deferment was higher than under short-duration grazing without deferment. Deferment favored a greater dominance of grasses in the plant community at the expense of reductions of low-size functional groups such as herbs, sedges, and rushes, suggesting that the initial grazing pressure exerted by cattle on tall grasses would have opened the opportunity for an increase in the abundance low growing plants. Similar effects have been observed in other plant communities with dominant grasses and presence of herbs (Waterman and Vermeire, 2011; Locke et al., 2021; Tácuna et al., 2021), when either deferment or prolonged rest periods were applied.

The loss of diet quality due to deferred grazing can be attributed to some level, to the increased availability of mature forage from all functional groups, mainly grasses, as well as to the lower availability and accessibility of herbs and grasslike species due to tall grass interference. Mature forage contains a high content of senescent material and stems, which chemically translates into high fiber and low protein content and biologically into a lower digestibility and intake rate (Wilson, 1994; Harper and McNeill, 2015). Even more, in both grazing schemes the nutritional values were above those considered critical for animal nutrition (NASEM, 2021), more than 7 % of protein and cell wall content higher than 70 %, a fiber component considered critical in determining forage intake. In addition, Puna grasses are known for their relatively low nutritional levels that fall rapidly with the advance of maturity (Rodríguez et al., 1986), a process somewhat favored by deferment. However, in both grazing systems, animals were able to compensate by selecting diets whose nutritional values were above those considered critical for animal nutrition (NASEM, 2021).

5. Conclusion

When combined with short-duration grazing, deferment improved range condition and increased forage yield at the expense of diet quality, although, with no failure to meet the minimum recommended protein level for a bacteria ruminal function. Nevertheless, the application of deferment in a short-duration grazing system to improve range condition may need the design of a strategic protein supplementation program to increase dry matter digestibility and intake.

Authors Contributions

All authors have contributed equally to prepare the paper.

Availability of Data and Materials

The data that support the findings of this study are available from the corresponding author upon

reasonable request.

Conflict of Interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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