



Genetic environment interaction on percent juniper in the diet of goats divergently selected for high or low juniper consumption

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Abstract

Diet selection by grazing animals is determined by genetic and environmental factors that interact and affect their efficacy for managing vegetation as targeted grazers and developing animals adapted to local grazing environments. The effect of rearing environments on the percentage of dietary juniper (*Juniperus* spp.) of goats, that for 15 years were divergently selected for high (J+) or low (J-) juniper consumption, was investigated using a factorial design 2 × 2 (rearing environment × selection line). Eighty pregnant does from both selection lines were grazed on either juniper-infested (JIR) or juniper-free (JFR) rangelands until their kids were weaned at about 75 days of age. Faecal samples were analysed with faecal near-infrared reflectance spectroscopy to determine the percent juniper in the diet. After weaning, kids from both rearing environments grazed JIR. The J+ does always consumed more ($P < 0.001$) juniper than J- does, demonstrating different maternal role models for kids reared in the JIR environment. The percentage of juniper in J- kid diets (7%) was the same regardless of the rearing environment. However, the rearing environment affected the percentage of juniper in the diet of J+ kids, resulting in a gene-environment interaction ($P=0.022$). The percentage of juniper in the diet of J+ kids reared in JFR (16%) and JIR (24%) were about two and three times higher than J- kids, respectively, indicating that genetics and the rearing environment contributed about equally to the increase in the percentage of juniper in the J+ kid diets. Regardless of the rearing environment, the J+ kids had a higher percentage of dietary juniper than J- kids ($P<0.001$). The ability to select animals with specific dietary preferences and proper rearing environments holds promise for targeted grazing strategies to restore degraded rangelands, with potential applications in conservation and ecosystem management.

Introduction

Livestock are valuable ecosystem engineers whose selective grazing habits affect the botanical composition and biodiversity of grazed ecosystems. There is much interest in methods for influencing grazing livestock botanical preferences to manage an ecosystem's trajectory. Diet selection and preference by grazing animals are determined by the genome, gene expression (epigenetics), and complex and variable learning environments of animals, and there is interest in using the variation within breeds to select animals that can utilize poor quality forages high in plant secondary compounds (PSC) that are common in arid environments. Determining to what extent foraging behaviour and diet preferences are genetically and environmentally determined and the interaction of these two

factors will aid in selecting animals better suited for use in conservation schemes, whether by employing different breeds or animals from different backgrounds.

Junipers are chemically defended woody plants that have encroached in the western U.S. rangelands. For 15 years, Texas A&M AgriLife Research divergently selected goat populations for increased (J+) or decreased (J-) juniper consumption (Mulim et al., 2024). This study aimed to determine the gene-environment interaction on preference for juniper (*Juniperus ashei* and *J. pinchotii*) by goats from the two selection lines. To accomplish this, J+ and J- does were reared from the end of breeding until weaning on rangelands with or without juniper, and the percentage of juniper in kid diets was compared post-weaning, when goats were grazing in the juniper-infested rangelands (JIR).

Methods

The experiment was conducted following a completely randomized 2 × 2 factorial design (selection lines × rearing environment), and individual animals were replicates. The study was conducted on rangelands in west central Texas, USA. The predominant ecological site for the JIR is a Low Stony Hill in an Oak/Mixed-brush Shortgrass seral state. The JFR is predominantly a Clay Loam ecological site in a Shortgrass Mesquite/Mixed brush Savannah ecological seral state.

Does from the two selection lines were joined to bucks of their respective selection line in separate JIR pastures in the fall of 2021. At the end of the breeding season, 20 does from each line were randomly selected and transported to a JFR, while similar does remained on JIR. Does from the two selection lines in both rearing environments remained in separate pastures until their kids were marked according to their selection line at 30 days of age. Then, they were combined to graze on a common pasture in their respective rearing environments. After weaning, goats from the two selection lines (J+ and J-) and from both rearing treatments (JIR and JFR) grazed common but different JIR pastures for does and kids (Figure 1).

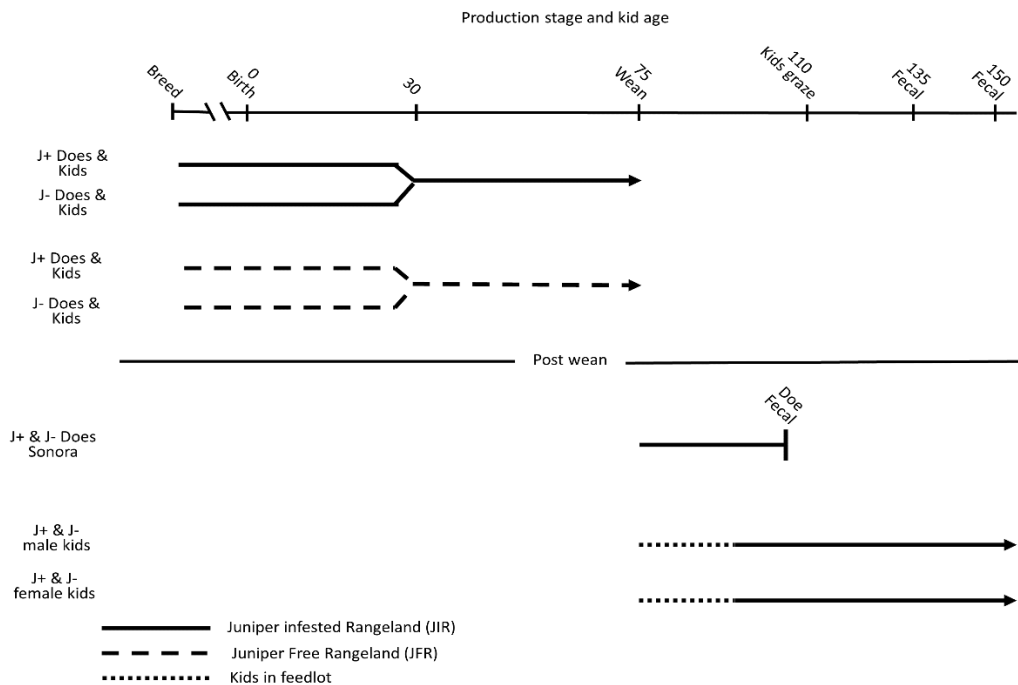


Figure 1. Diagram depicting rearing and grazing environment periods and fecal sample collections for goats divergently selected for high (J+) and low (J-) juniper consumption.

The percent juniper in the diet was determined on faecal samples (fNIR) using near-infrared spectroscopy (Walker et al., 2007). To document that does provide different maternal role models for their offspring faecal samples from does grazing JIR were collected when kids were 30 days old, at weaning, and 30 days post weaning. Post weaning following a 21-day adaptation period, 110-day-old kids from both rearing environments were grazed on JIR. Faecal samples were collected two or three days apart in the same pasture for does and kids, respectively, and averaged before statistical analysis because these samples were considered subsamples. Analysis of variance using the MIXED procedure of SAS 9.4 was used to determine treatment effects and their interactions. Tukey's test was used for mean separation when there were more than 2 means.

Results

When grazing JIR, the J+ does always had a higher percentage of juniper in their diets ($P < 0.001$) compared to J- does (Table 1). There was no effect of rearing environment ($P = 0.488$) or rearing environment \times selection line interaction ($P = 0.096$) when does grazed a common pasture.

The percent juniper in the J- kid diets was the same regardless of rearing environment, and J+ kids raised on JFR had twice as much juniper in their diet, while J+ kids raised on JIR had three times as much juniper in their diet compared to J- kids, resulting in a significant selection line \times rearing environment interaction ($P = 0.022$; Figure 2). Regardless of the rearing environment, the J+ kids had a higher percentage of juniper in their diets than J- kids ($P < 0.001$; Table 2). Compared to males, female kids had a higher percentage of juniper in their diets ($P = 0.002$).

Table 1. Percentage of juniper in the diet of goat does divergently selected for high (J+) or low (J-) juniper grazing juniper infested rangelands (JIR) or juniper free rangelands (JFR).

Doe treatment	JIR		JIR & JFR
Forage type	JIR	JIR	JIR
Days postpartum	30	75	110
Selection line			
J+	43	67	71
J-	-3	4	26
SEM	NA ¹	13	10
P-value	NA	<0.001	<0.001

¹ Because does grazed different pasture statistical comparisons were not made.

Table 2. The effect of selection line and sex on percentage juniper in the diets of post-weaned kids grazing juniper infested rangelands.

	Selection line		Sex	
	J-	J+	M	F
Juniper (%)	7	19	12	17
SEM	1		1	
P-value	<0.001		0.002	

Discussion

To our knowledge, these two lines of goats are the only livestock that have been selectively bred to change the botanical composition of their diet. The genetic-environment interaction, while often hypothesized (Rook et al., 2004), has little supporting empirical research on free-grazing ruminants. However, the rearing environment did affect the percentage of juniper in the diet of J+ kids, resulting in a genetic-environment interaction. The percentage

of juniper in the diet of J+ kids raised in the JFR and JIR environment were about two (16%) and three (24%) times higher than J- kids, respectively, indicating that genetics and the rearing environment contributed about equally to the increase in the percentage of juniper in the J+ kid diets. However, this study cannot explain the cause of the interaction. The rearing environment can cause epigenetic changes that increase an animal's ability to metabolize or eliminate xenobiotics (Zhu et al., 2023), and their ability to learn to sequence meals to mitigate PSC (Villalba et al., 2004). The rearing environment did not affect percentage juniper in the diet of J- kids, indicating that it is limited by their ability to metabolize PSC that act as feeding deterrents (Villalba et al., 2015).

The importance of the genetic influence on diet preference was shown by the higher percent juniper in the diets of J+ compared to J- kids and does regardless of rearing environment. The heritability estimates for the percent juniper in the diet of the goat lines used in this study was 43% (Mulim et al., 2024). Similar to this study in human twin studies the heritable of preference for vegetables that like juniper have a lower preference than other foods is about 45%, and the remaining variation is shared and nonshared environmental (Breen et al., 2006; Fildes et al., 2014). The need to use individual variation in diet preferences within breeds or species to develop animals more aligned with the botanical composition of the rangelands they are grazing has been recognized, and this study demonstrated that there is adequate variation and heritability within breeds to help accomplish this goal.

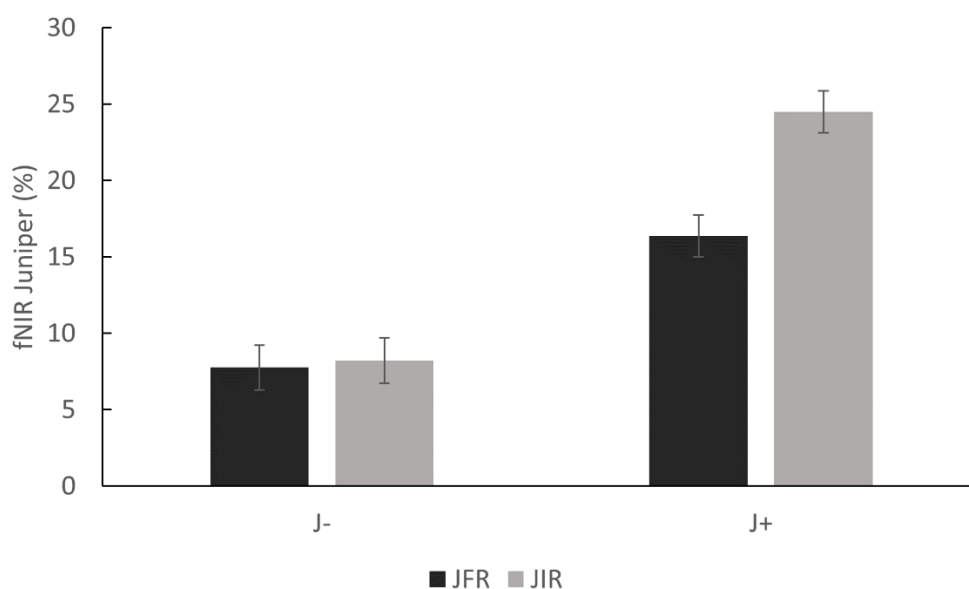


Figure 2. Selection line \times rearing environment interaction ($P = 0.022$) for percent juniper in the diet of weaned kid goats divergently selected for high (J+) and low (J-) juniper consumption and reared on juniper-free rangelands (JFR) or juniper infested-rangelands (JIR) free grazing a JIR.

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All experimental protocols adhered to guidelines for the ethical and humane use of animals for research according to the Guide for the Care and Use of Agricultural Animals in Research and Teaching (FASS, 2010) and were approved by the Texas A&M AgriLife Institutional Animal Care and Use Committee (AUP 2022-008A).

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