

UNIVERSIDAD AUTÓNOMA AGRARIA ANTONIO NARRO

SUBDIRECCIÓN DE POSTGRADO



INFLUENCIA DEL RANGO SOCIAL SOBRE LAS CONDUCTAS SEXUALES
DE CARNEROS Y PARÁMETROS REPRODUCTIVOS EN
BORREGAS DORPER.

Tesis

Que presenta ANDREA GONZÁLEZ TAVIZÓN
como requisito parcial para obtener el Grado de
DOCTOR EN CIENCIAS EN PRODUCCIÓN AGROPECUARIA

Torreón, Coahuila

Marzo, 2022

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Marzo 2022

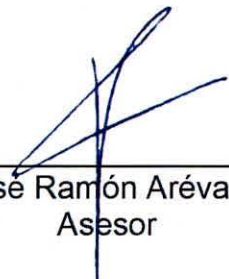
INFLUENCIA DEL RANGO SOCIAL SOBRE LAS CONDUCTAS SEXUALES DE
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Tesis

Elaborada por ANDREA GONZÁLEZ TAVIZÓN como requisito parcial para
obtener el grado de Doctor en Ciencias en Producción Agropecuaria con la
supervisión y aprobación del Comité de Asesoría



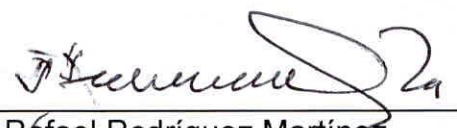
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Dedicatoria

A Dios por permitirme llegar a este momento, gracias por guiarme.

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RESUMEN

INFLUENCIA DEL RANGO SOCIAL SOBRE LAS CONDUCTAS SEXUALES DE CARNEROS Y PARÁMETROS REPRODUCTIVOS EN BORREGAS DORPER

ANDREA GONZÁLEZ TAVIZÓN

Doctor en Ciencias en Producción Agropecuaria
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Dra. Viridiana Contreras Villarreal

Se evaluó el efecto de la influencia rango social de carneros Dorper, dominante (HHR) y subordinados (LHR)) y la respuesta de ovejas en anestro a estos estímulos. Se evaluó el rango social durante dos días (ESR; n = 36); los carneros fueron expuestos a ovejas estrogenizadas en una prueba competitiva. Según la respuesta reproductiva, las ovejas anovulatorias (n = 76) se dividieron en dos grupos: LHRe (n = 38; ovejas expuestas a cuatro carneros de baja jerarquía (LHR)) y HHRe (n = 38; ovejas expuestas a cuatro carneros de alta jerarquía (HRH)). Con respecto a las conductas agresivas, HHR mostró una mayor proporción ($p < 0,05$) de carneros que mostraban conductas de amenaza, golpe y bloqueo que LHR. El comportamiento apetitivo fue mayor ($p < 0,05$) en los carneros HHR que en los LHR ($3576 \pm 0,7$ vs. $3054 \pm 0,7$ número de eventos). El comportamiento sexual consumatorio fue mayor ($p < 0,05$) en HHR que en LHR ($499 \pm 0,3$ vs. $205 \pm 0,1$ número de eventos). Los indicadores de inactividad sexual (SRI) fueron similares entre HHR y LHR ($499 \pm 0,3$ vs. $433 \pm 0,1$; $p > 0,05$). La respuesta estral ($>80\%$; $p > 0,05$) y ovárica (70%, $p > 0,05$) fueron similares para ambos grupos de ovejas. Se concluyó que los LHR son igualmente efectivos que los HHR para inducir la actividad sexual en ovejas que presentan anestro posparto.

Palabras clave: Rango social; Oveja en anestro; Comportamiento sexual.

ABSTRACT

INFLUENCE OF SOCIAL RANK UPON SEXUAL BEHAVIOR OF DORPER RAMS AND REPRODUCTIVE PARAMETERS OF DORPER EWES

ANDREA GONZÁLEZ TAVIZÓN

Doctor of Science in Agricultural Production

AUTONOMOUS AGRARIAN UNIVERSITY ANTONIO NARRO

PhD. Viridiana Contreras Villarreal

The effect of the social rank influence of Dorper rams, dominant (HHR) and subordinate (LHR)) and the response of anestrus sheep to these stimuli was evaluated. Hierarchy was evaluated during two days (ESR; n = 36); the males were exposed to estrogenized ewes in a competitive test. Regarding reproductive response, ewes (n = 76; anovulatory) were divided into two groups: LHRe (n = 38; ewes exposed to four low hierarchy rams (LHR)) and HHRe (n = 38; ewes exposed to four high hierarchy rams (HHR)). HHR showed a higher ($p < 0.05$) proportion of rams showing Aggressive behaviors such as threatening, knocking, and blocking than LHR. Appetitive sexual behavior was higher ($p < 0.05$) in HHR than LHR rams (3576 ± 0.7 vs. 3054 ± 0.7 number of events). Consummatory sexual behavior was higher ($p < 0.05$) in HHR than LHR (499 ± 0.3 vs. 205 ± 0.1 number of events). Indicators of sexual inactivity (SRI) were similar between HHR and LHR (499 ± 0.3 vs. 433 ± 0.1 ; $p > 0.05$). The ewes estrus and ovarian responses ($>80\%$ and 70% , respectively; $p > 0.05$) were similar in both groups. In conclusion, LHR are as effective as HHR when inducing sexual activity in ewes during postpartum anestrus.

Keywords: Social rank; Anestrus ewe; Sexual behavior

I. INTRODUCCIÓN

A los ovinos les gusta vivir en sociedad, por lo que tienden a formar grupos, con una estructura jerárquica muy definida (Founier y Festa-Bianchet, 1995).

Se describe la jerarquía como la estructura social dentro de un grupo, donde podemos encontrar animales dominantes y animales subordinados (Craig, 1981; Barroso *et al.*, 2000; Álvarez *et al.*, 2003). Con esta definición se puede concluir que el rango social, es la posición que ocupa un individuo dentro de esa estructura social (Côté, 2000; Pelletier y Festa-Bianchet, 2006). Los animales dominantes, son aquellos que corresponden a un rango alto, por el contrario, los animales subordinados pertenecen a un rango bajo y su comportamiento es sumiso (Côté, 2000). El rango social puede afectar la actividad reproductiva en los pequeños rumiantes, tanto en machos como en hembras (Côté, 2000; Pelletier y Festa-Bianchet, 2006; Aguirre *et al.*, 2007; Álvarez *et al.*, 2007).

En los ovinos, la jerarquía se establece a una edad temprana (es decir, cuando son corderos) esta influye en desarrollo morfológico y de comportamiento de los carneros (Ungerfeld *et al.*, 2008). En estado salvaje, la mayoría de las hembras se aparean con el macho dominante (Fabre-Nys y Geles, 2007).

II. HIPÓTESIS Y OBJETIVO GENERAL

Hipótesis

Los carneros de raza Dorper de rango social bajo, con peso y condición corporal homogéneos, en presencia de machos de rango social alto, mostrarán mayor comportamiento sexual e inducirán una mayor respuesta en los parámetros reproductivos en hembras anovulatorias

Justificación

Los pequeños rumiantes presentan estacionalidad reproductiva, esto es un problema para la economía de los productores ya que genera una gran fluctuación en los precios de los productos obtenidos de los mismos. Por décadas se han utilizado diversos protocolos hormonales para solventar esta situación, sin embargo, la sociedad actual cada vez solicita con mayor ahínco que la

producción sea "verde, limpia y ética", lo cual hace necesario establecer nuevas técnicas que disminuyan o eliminen el uso de hormonas exógenas.

Objetivo general

- Evaluar el rango social en carneros y el efecto que tiene en los parámetros reproductivos de borregas Dorper durante la época de reposo sexual.

Objetivos específicos

- Establecer el rango social de carneros Dorper.
- Determinar la respuesta reproductiva de hembras estimuladas con machos de alto y bajo rango social.
- Evaluar los comportamientos sexuales (apetitivo y consumatorio) de carneros Dorper de alto y bajo rango social.

III. REVISIÓN DE LITERATURA

3.1 Origen e historia de la oveja domestica

La oveja doméstica (*Ovis aries*) es descendiente del muflón asiático y esta fue domesticada en el cercano oriente. Una vez domesticada esta se diseminó hacia el oeste del continente africano (Aguilar-Martínez *et al.*, 2017).

Al principio se pensaba que las ovejas habían evolucionado a partir de varios grupos ancestrales y que su procedencia eran tres ovinos silvestres: el urial (*Ovis vignei*), el argalí (*Ovis ammon*) y el muflón euroasiático (*Ovis musimon / Ovis orientalis*). Por medio de una determinación cromosómica se llegó a la conclusión de que el ancestro silvestre más probable es el muflón euroasiático, esto debido a que esta especie al igual que la oveja doméstica, posee 54 cromosomas, esto aunado a que algunos trabajos de genética molecular permitieron esclarecer que la especie urial y argali nunca contribuyeron a la formación de la oveja domestica (Aguilar-Martínez *et al.*, 2017).

3.2 Domesticación de la oveja

Se sabe que la domesticación de la oveja sucedió hace aproximadamente 10,000 años (Zeder *et al.*, 2008; Meadows, 2014; Aguilar-Martínez *et al.*, 2017), principalmente en los territorios de Turquía, Iran, Irak y Siria, en una región denominada “Creciente Fertil”. Una vez que la oveja fue domesticada, esta fue diversificándose esto gracias a que sufrió mutaciones, adaptación a ambientes e intensa selección hacia diversos propósitos. En la actualidad existen aproximadamente 1,400 razas distintas de ovejas (Aguilar-Martínez *et al.*, 2017).

3.3 Diseminación de la oveja

La oveja al igual que otras especies domésticas, fue llevada a lo largo de Europa por poblaciones humanas, posteriormente siguiendo el trayecto del Danubio y las costas del mar Mediterráneo. Los restos más antiguos de una oveja datan de

hace aproximadamente 7,500 años, estos restos fueron encontrados en el delta del río Nilo, el Sahara y las colinas del Mar Rojo (Aguilar-Martínez *et al.*, 2017).

3.4 La oveja doméstica en México

La oveja doméstica fue introducida por los españoles a América en el año de 1493 y posteriormente a México en 1522. Es así como las poblaciones ovinas en México fueron originadas a partir de razas españolas (Churra, Latxa, Manchega, Rasa Aragonesa, Canaria y Merino Española). Mediante la mezcla de estas poblaciones es que se originó la raza conocida como Criolla en América. De esta forma en poco tiempo, la raza criolla estaría evolucionando en distintos ecotipos los cuales fueron adaptándose a diversos sistemas de producción y ambientes (Pit *et al.*, 2019).

En el siglo XVI la oveja doméstica fue introducida a México, y es entonces, a finales de este siglo cuando la producción de lana, leche y cordero definieron la economía del país.

3.5 Situación actual del ganado ovino en México

Es importante enfatizar que esta situación cambió ya que en la actualidad la ganadería ovina mexicana está basada principalmente en la carne de cordero y la lana para su utilización en la industria textil. La introducción de razas de alto rendimiento del exterior a México ha contribuido al incremento de la productividad y por consiguiente ha llevado al reemplazo de las ovejas criollas en los últimos 82 años. Hasta el año 2018, México contaba con un aproximado de 8.7 millones de cabezas de ganado ovino (Campos *et al.*, 2020).

En México la ganadería ovina se desempeña fundamentalmente en tres sistemas (Intensivo, Agricultura mixta y Extensivo). El estado de México representa la mayor producción ovina (Campos *et al.*, 2020).

3.6 Importancia del ganado ovino en México

En México la producción ovina tiene gran relevancia ya que esta representa una importante fuente de producción de carne para este país, esto ha ido en aumento en el transcurso de los últimos años. La producción de cordero, sin embargo, ha sufrido algunos cambios, ya que se han introducido al país algunas razas con la finalidad de incrementar la tasa de crecimiento de los mismos. Es por esto que en los últimos años ha habido un incremento en la producción de corderos mestizos, utilizando para ello hembras de la raza Pelibuey y Criolla y sementales de la raza Dorper y Katahdin (Mellado *et al.*, 2016).

3.7 El ganado ovino Dorper en México

Se ha demostrado que los carneros de la raza Dorper son eficientes como sementales para la finalidad productiva de carne de cordero de calidad, esto debido a que la cruce con dichos sementales trae como resultado la producción de corderos cuyas características como la tasa de crecimiento previo al destete, ganancia de peso diaria post destete, eficiencia de alimentación y características de la canal guardan similitudes con las características de los corderos mestizos Suffolk (Mellado *et al.*, 2016).

Es por todo lo anteriormente mencionado, que ha incrementado la demanda de ovejas de la raza Dorper, esto con la finalidad de mejorar las características productivas de los corderos como el rendimiento y crecimiento de los mismos, ya que estas características son determinantes para eficiencia y la productividad. Conjuntamente, en los últimos años ha incrementado la población de hembras de la raza Dorper, esto debido a características como la alta supervivencia de sus crías al destete, alta fertilidad independientemente de la temporada, la ganancia de peso y con ello la calidad de la canal, esto aunado a cierta producción de lana y pelo (Mellado *et al.*, 2016).

Bajo condiciones intensivas, la crianza de ganado Dorper está basada en características como su conformación, fertilidad, masculinidad y feminidad para

garantizar que la raza tenga las bases para una ganadería ovina eficiente, productiva y económicamente rentable (Mellado *et al.*, 2016).

En los últimos años se ha mostrado un creciente interés en razas ovinas mexicanas cuyo crecimiento sea rápido, tengan un excelente rendimiento de carne y distribución de grasa, con facilidad de manejo y fertilidad, todas las anteriores son características de la raza Dorper (Mellado *et al.*, 2016).

3.8 Estacionalidad reproductiva

Es sabido que los pequeños rumiantes, como son cabras y ovejas, la reproducción presenta cambios estacionales. A grandes rasgos, la época reproductiva comienza en el otoño y concluye durante invierno, con un periodo de anestro en primavera/verano, el inicio y fin de la época reproductiva son regulados por el ritmo endógeno circanual, el cual está regulado a su vez por el fotoperiodo. No obstante, el inicio y duración de la estación reproductiva depende de otras circunstancias como la interacción del fotoperiodo con otros factores como la raza, el origen, estado nutricional, interacciones sociales, entre otras (Brunet *et al.*, 2011).

Un aspecto muy importante es que las variaciones estacionales de la época reproductiva, provocan variaciones a su vez sobre la producción de leche y carne, así como su disponibilidad en el transcurso del año, afectando así el rendimiento, la producción y la economía de productor ya que hay fluctuaciones en los precios de estos productos y como consecuencia de ello afecta la economía del consumidor (Brunet *et al.*, 2011).

Como se ha mencionado, la ganadería ovina suele estar enfocada hacia la producción de carne o leche, no obstante, algunas razas pueden desempeñar doble propósito. La época reproductiva se extiende regularmente desde el verano/otoño hasta el final del invierno, presentándose el periodo de anestro durante la primavera (Brunet *et al.*, 2011).

Los pequeños rumiantes como los ovinos tienen una estación determinada para la propagación de su especie. Esta restricción de la actividad reproductiva a una

estación o época específica de año es un rasgo común de los animales que viven fuera de los trópicos. En el caso particular de los rumiantes salvajes se presenta una breve época reproductiva seguida de un largo periodo de inactividad o anestro. En las especies domésticas en cambio, la época reproductiva se ha ampliado (Brunet *et al.*, 2012).

Las ovejas fueron domesticadas por primera vez hace aproximadamente 10,000 años. La ubicación geográfica y las condiciones climáticas son factores determinantes si de actividad reproductiva se trata, ya que las razas de latitudes altas y climas fríos tienen una época reproductiva más corta que las razas que se encuentran próximas a los trópicos. A pesar de que el fotoperiodo es un factor crucial que influye en dicha estacionalidad, se ha demostrado que hay factores que influyen en esta fotorrespuesta como la genética, es por ello que se pueden observar diversas gamas de periodos de actividad reproductiva entre las razas (Brunet *et al.*, 2011).

3.9 Estacionalidad reproductiva en ovejas

La temporada reproductiva en la oveja, se presenta durante la época de días cortos y esta está caracterizada por la presencia de ciclos regulares, así como por conducta estral y ovulación. En el hemisferio esta temporada se presenta en el periodo transcurrido entre agosto y enero, sin embargo, existen variaciones dependientes de la ubicación geográfica y la raza (Arroyo, 2011). Las ovejas son poliéstricas estacionales y su actividad reproductiva está caracterizada por la alternancia entre la época reproductiva y el anestro. Dicha época de actividad reproductiva está caracterizada por una sucesión del comportamiento estral y la ovulación, esta sucesión tiene intervalos regulares de entre 16-17 días, mientras tanto, durante el anestro se presenta una interrupción de la actividad ovulatoria cíclica (Brunet *et al.*, 2011).

El principal factor ambiental que regula la reproducción estacional es el cambio en la duración del día. La máxima actividad reproductiva se presenta en los días cortos, así mismo el mayor porcentaje de hembras presentan estro y ovulación a finales de verano, otoño y principios de invierno. Las razas que se encuentran

cerca de los trópicos presentan temporadas de actividad reproductiva más extendidas que las que presentan las que se encuentran en latitudes templadas altas. Para las razas de las latitudes de $>40^{\circ}\text{N}$, la época reproductiva se presenta al comienzo del otoño, en el momento que los días se vuelven más cortos, y esta termina a mediados de invierno, cuando los días se vuelven más largos. Es entonces cuando la oveja deja de ovular y permanece anovulatoria durante los días largos de primavera-verano (Brunet *et al.*, 2011).

A pesar de que la reproducción estacional se ve directamente influenciada y regulada por el fotoperiodo, existen muchos otros factores determinantes que interaccionan con dicha estacionalidad. Como lo son la raza, el estado nutricional, la lactancia, además de las interacciones sociales y la época de parto, estos factores influyen en el momento y duración de la época de actividad reproductiva (Brunet *et al.*, 2011).

Los carneros en las regiones templadas también suelen mostrar cambios estacionales en el comportamiento sexual, secreción de testosterona, peso testicular, así como también estos cambios se ven reflejados en la cantidad y la calidad del espermatozoides (Brunet *et al.*, 2011).

En algunas investigaciones se ha demostrado que, bajo condiciones artificiales, los días cortos tienen a estimular la actividad reproductiva, mientras que los días largos la inhiben (Chemineau *et al.*, 1992b).

El fotoperiodo es el principal factor que impulsa el ciclo reproductivo de estas especies e independientemente del régimen de luz seguido, es la glándula pineal la que regula el cambio en la función reproductiva, esto por medio de su actividad endocrina, la cual está sincronizada con el ciclo luz-oscuridad. A grandes rasgos, la información del fotoperiodo es percibida o recibida por medio de los ojos, posteriormente esta se transmite a través de una vía multisináptica a la glándula pineal, es ahí donde la luz se traduce en un ciclo diario de secreción de melatonina, presentándose altos niveles de secreción de melatonina durante la noche y bajos niveles durante el día (Brunet *et al.*, 2011). La duración de la secreción nocturna de melatonina, que a su vez refleja la duración de la noche,

es la que regula la secreción pulsátil de la hormona liberadora de gonadotropina (Gn-RH) por parte del hipotálamo. Es así como los cambios en la secreción de Gn-RH inducen cambios en la secreción de LH y FSH, determinando así la presencia o ausencia de la ovulación en la hembra y la actividad sexual en el macho (Cheminineau *et al.*, 2010).

La duración de los niveles elevados de melatonina que se presenta durante los días largos de primavera-verano proporciona la señal para que la duración del día sincronice el ritmo de la actividad neuroendocrina reproductiva, propiciando así que la actividad reproductiva comience en el otoño (Brunet *et al.*, 2011).

Toda transición reproductiva se genera endógenamente, como un reflejo de un ritmo circanual que es sincronizado por el fotoperiodo (Brunet *et al.*, 2011).

Durante los últimos años, se han desarrollado una serie de estrategias para conseguir que la actividad reproductiva se produzca fuera de temporada reproductiva habitual para ser utilizadas en ovejas. Algunas de estas estrategias están basadas en la implementación de protocolos hormonales, administrando hormonas exógenas como progesterona/progestágeno, gonadotropina coriónica equina (eCG), y/o prostaglandina F₂ α (PGF₂ α) o sus análogos, otras estrategias están basadas en la manipulación ambiental como la manipulación de la duración del día, implantes de melatonina o el efecto macho (Brunet *et al.*, 2011).

3.10 Ciclo estral de la oveja

La oveja es poliestrica estacional, ya que presenta varios ciclos estrales durante su época de actividad reproductiva, en dichos ciclos estrales esta presenta ciclos ovulatorios normales, en la mayor parte de las razas en el hemisferio norte esto ocurre durante el otoño y el invierno (Bartlewski *et al.*, 2011). Así mismo el ciclo estral en la oveja tiene una duración de aproximadamente 17 días (Arroyo, 2011).

El ciclo estral depende de una secuencia de eventos endocrinos los cuales se interrelacionan y son regulados por el hipotálamo el cual se encarga de producir GnRH; la glándula pituitaria que secreta FSH, LH y oxitocina; los folículos antrales

por su parte secretan estrógenos e inhibina; el cuerpo luteo secreta progesterona y oxitocina; además el endometrio que es el encargado de producir $\text{PGF2}\alpha$ (Bartlewski *et al.*, 2011).

Las gonadotropinas hipofisarias se encargan de controlar el desarrollo y maduración de folículo ovárico, la esteroidogénesis, la ovulación, así como también de la formación del cuerpo lúteo. Existe una compleja interacción entre diversos factores tanto internos como externos de la cual depende la regulación de la secreción y biodisponibilidad de las hormonas gonadotróficas. En primera instancia los factores internos son los aminoácidos producidos localmente y las hormonas peptídicas/protéicas, esteroides ováricos, así como también hormonas foliculares como la inhibina, activina y folistatina, neurotransmisores y neuromoduladores (Bartlewski *et al.*, 2011).

Los factores externos por otra parte, incluyen las señales fotoperiódicas, las feromonas del macho, la nutrición y el estrés, estos afectan la función del eje hipotálamo-hipófisis-ovario. Esto puede ocurrir de forma directa través de los efectos sobre la secreción de GnRH, o de forma indirecta alterando la respuesta hipofisaria a la GnRH, o bien alterando la sensibilidad del ovario a las gonadotropinas, así como también la heterogeneidad de la LH y FSH, ya que se puede generar una glicosilación hormonal (Bartlewski *et al.*, 2011).

Se presenta una descarga pre-ovulatoria de GnRH, sucedida por una de descarga de LH y FSH, las cuales alcanzan un pico aproximadamente 14 horas antes de la ovulación. La oleada de gonadotropinas es desencadenada y sostenida por una disminución en la secreción de progesterona, así como por un incremento de la secreción de estradiol, esto durante la etapa final del ciclo estral (Bartlewski *et al.*, 2011).

Los pulsos de LH desencadenados por la GnRH predominan en cada estado reproductivo de las ovejas, antes, durante y después del aumento pre-ovulatorio de gonadotropinas. El incremento en la frecuencia y amplitud del pulso de LH precede al pico pre-ovulatorio de LH (Bartlewski *et al.*, 2011).

La progesterona y el estradiol por otra parte actúan conjuntamente modulando tanto la frecuencia como la amplitud de los pulsos de LH. La liberación de LH se relaciona inversamente con los niveles de progesterona circulantes de progesterona del cuerpo lúteo. En las fases metaestro y diestro, disminuyen gradualmente las concentraciones basales séricas de LH y la frecuencia de pulso de la misma, mientras tanto la duración del pulso de LH y la frecuencia del pulso de FSH incrementan (Bartlewski *et al.*, 2011).

La amplitud en el pulso de LH incrementa hacia el final de la fase de crecimiento de los folículos al comienzo de la fase lútea, la amplitud y pulsos de LH se incrementan, un día posterior al aumento de las concentraciones séricas de progesterona superiores a los niveles basales. Las concentraciones séricas de FSH se ven incrementadas al momento en que se aparece la oleada folicular. Durante la fase de crecimiento de los folículos antrales que se desarrollan en el diestro temprano, se incrementa la frecuencia del pulso de FSH, la formación del cuerpo lúteo está asociada con la disminución transitoria de los niveles y frecuencia de pulso de FSH (Bartlewski *et al.*, 2011).

3.11 Sincronización del estro

La sincronización del estro se refiere a cuando las hembras tienen un cuerpo lúteo (CL) funcional, que están ciclando, y que se busca homogenizar grupos de hembras con el uso de diversas hormonas disponibles utilizadas para el control de la reproducción en hembras de diferentes especies, entre ellas incluida la especie ovina. Principalmente se hace uso de los progestágenos, prostaglandinas, hormona liberadora de gonadotropina (GnRH) y gonadotropina coránica equina (Ecg) (Abecia *et al.*, 2012).

Una ventaja de sincronizar el estro es que no es necesario detectarlo, se puede realizar la inseminación artificial (IA) o la monta directa en un tiempo previamente establecido en relación con el tratamiento hormonal aplicado. Existe cierta variación entre hembras en cuando al tiempo, sin embargo, la mayoría de las

hembras presenta estro entre las 36 y 48 horas y la ovulación 60 horas después de retirar el dispositivo intravaginal impregnado con progestágeno. El momento de la IA varía según el sistema que se utilice, ya sea intrauterina o cervical (Duran, 2008).

La sincronización de la ovulación y estro en borregas no depende solamente del control durante la fase lútea del ciclo estral, sino también de la fase folicular (Uribe-Velásquez *et al.*, 2008), ya que el crecimiento folicular durante las oleadas foliculares es independiente de la fase del ciclo estral (Goodman y Inskeep, 2006).

3.12 Señales sociosexuales´

Las señales socio-sexuales como el “efecto macho” son una estrategia interesante para mejorar los resultados reproductivos, ya que representa un importante enfoque para inducir a las hembras (Flores-Najera *et al.*, 2010; Luna-Orozco *et al.*, 2012).

Anteriormente se pensaba que estos estímulos eran solo una señal del carnero hacia la oveja. Sin embargo interactúan otros estímulos sociales que pueden estar presentes simultáneamente y logran ser necesarios para obtener una mejor respuesta en las hembras (Hawken *et al.*, 2008). Las ovejas en celo estimulan a los carneros, este estímulo es tan fuerte que estimula a las ovejas antroestrópicas (Zarco *et al.*, 1995).

La respuesta de las ovejas a la introducción del macho puede ser fluctuante, esto se debe a varios factores como, la calidad del estímulo del macho, la intensidad del olor, las vocalizaciones y el comportamiento del macho (Delgadillo *et al.*, 2009; Hawken *et al.*, 2009).

Esta interacción del macho a la hembra son el conjunto de diversas señales, incluidas señales visuales, olfativas, auditivas y táctiles-comportamentales, que

funcionan de forma sinérgica, para inducir a la hembra a un nuevo ciclo reproductivo (Fabre-Nys, *et al.*, 2015).

Esta respuesta también puede diferir por otros factores relacionados con las hembras, como por las reservas de energía corporal y la jerarquía (Alvarez *et al.*, 2007). Existen trabajos que mencionan el efecto que tiene el rango social sobre la actividad reproductiva, los individuos de alto rango social tienen mayor éxito reproductivo en general que los de rangos inferiores (Miller *et al.*, 1998).

3.13 Efecto Macho

La primera vez que se reportó el "efecto macho" en borregos fue en la década de 1940, donde se describía que el macho era capaz de producir un aumento en la secreción de las hormonas reproductivas y de inducir la ovulación en la hembra (Hawken y Martin, 2013).

Se conoce como "efecto macho", al estímulo que los carneros son capaces de ejercer sobre las borregas durante el anestro poco profundo, o en aquellas que se encuentran cercanas al inicio de la estación reproductiva (Ochoa y Urrutia, 1995). El introducir carneros de manera repentina en un rebaño de hembras estimula un proceso fisiológico que provoca la ovulación y la presentación de estro (Alvarez, 2002). Este efecto estimulante por parte del macho es bien reconocido desde hace años como una forma eficiente y económica para el control del empadre. También ha sido utilizado como forma de inducir el inicio de la actividad reproductiva en hembras jóvenes (Urrutia *et al.*, 2000).

La introducción del macho produce un aumento en las pulsaciones de secreción de LH en las ovejas y esta puede desencadenar una oleada de LH seguida de la ovulación. Esta ovulación por lo general, no está asociado con el comportamiento estral. En algunas ovejas, la primera oleada, el celo aparece junto con la segunda ovulación, 17-20 días después de la introducción del carnero. En otras, hay un cuerpo lúteo corto inicial fase de 4-5 días, luego una segunda ovulación sin signos de estro, seguido de una fase lútea de duración normal. Después de eso, se produce una tercera ovulación asociada con el celo (Alvarez *et al.*, 2002).

La respuesta de las hembras al efecto macho depende de la intensidad del estímulo y la capacidad de respuesta de la oveja a este, hay ovejas que no responden, independientemente de la fuerza del estímulo (por ejemplo, se reproduce con un fuerte patrón estacional). Otras ovejas, por el contrario, responden a un estímulo muy ligero, por ejemplo, se reproduce con un anestro/ligero/ poco profundo cerca del inicio de la temporada de reproducción (Luna-Orozco *et al.*, 2012).

3.14 Factores asociados al estímulo.

Inicialmente, se pensó que el estímulo consistía solo en una señal de carneros a ovejas. Sin embargo, otros estímulos sociales pueden estar presente simultáneamente y puede ser necesario para obtener una respuesta en las ovejas. Las ovejas en celo estimulan a los carneros, a su vez provocándolos para fortalecer el estímulo para ovejas antro-estrópicas. Algunos experimentos han demostrado que si hay un contacto cercano entre ellos, las ovejas pueden estimular la ovulación en ovejas en anestro (Zarco *et al.*, 1995).

El carnero estimula ovejas a través de feromonas y señales visuales, conductuales o táctiles que actúan de manera sinérgica. Varios experimentos tienen resultados diferentes, y a veces contradictorios, con respecto a la importancia de las diferentes señales, pero esto puede ser una consecuencia del uso de ovejas en diferentes estados de respuesta (Flores *et al.*, 2000).

3.15 Jerarquía social

El efecto que el comportamiento social ejerce sobre la producción animal es poco tomado en cuenta en la actualidad, no obstante, algunas investigaciones han demostrado la relevancia que este aspecto tiene en algunas especies domesticas. A pesar de que la ciencia animal se ha enfocado los últimos años al efecto que puedan ejercer sobre la producción aspectos tales como el estado nutricional, reproductivo y sanitario, es de gran importancia conocer a detalle aspectos como los mecanismos del comportamiento animal y con ello favorecer

el desarrollo de técnicas eficientes para el manejo de los mismos, lo cual conduce además a una producción eficiente y al bienestar animal retirando en la medida de lo posible la administración de productos exógenos (Barroso *et al.*, 2000).

En el año de 1983 se definió a la conducta dominancia-subordinación como una relación guardada entre dos individuos en donde uno de ellos tiende a ser el subordinado, diferenciado del otro ejemplar quien sería el dominante, estableciéndose una situación de competencia. Es habitual que en el término de dominación social existan discrepancias ya que en muchos casos esto se tiende a ser confundido con una conducta de agresividad (Kaufmann, 1983).

En términos generales, la jerarquía social pretende propiciar la exitosa coexistencia en comunidades sociales, aunque es innegable que las interacciones sociales entre animales suelen implicar cierto grado de conflicto ya que el rango ejerce un efecto marcado en el individuo. El bajo rango suele afectar al animal que lo ejerce ya que esto puede implicar una restricción o acceso limitado a recursos tales como la alimentación, lugares de descanso, entre otros. En contraste, los animales que ejercen la dominancia o el alto rango social cuentan con el acceso prioritario a los recursos de los cuales los animales con bajo rango social se ven privados o limitados (Barroso *et al.*, 2000).

El principal objetivo de la jerarquía en los animales es el establecer una posición social de dominancia o sumisión, lo cual en términos de comportamiento se traduce en la tendencia a amenazar o evitar. Como se abordó con anterior la dominancia conlleva algunos privilegios, para esto los animales en algunos casos suelen luchar con el otro por su posición de dominio. Estos ejemplares son seleccionados y clasificados en diferentes grupos de acuerdo con su rango social (Sotysiak y Nolgalski, 2010).

3.16 Influencia del rango social sobre la actividad reproductiva

Como las relaciones jerárquicas entre individuos de la misma especie y diferente rango social propician el acceso desigual a recursos como el alimento y lugar de descanso, esto se ve traducido o reflejado en un mayor éxito reproductivo en los

animales dominantes o de alto rango social que en los animales subordinados o d bajo rango social que tienen acceso limitado a estos recursos (Villagran *et al.*, 2017).

En algunas investigaciones se ha demostrado como un factor tan importante como la jerarquía social tiende a modificar la respuesta sexual tanto en las ovejas como en los carneros, incluso se ha observado en pequeños rumiantes como las hembras de alto rango social expuestas al efecto macho tienen un mejor desempeño reproductivo ya que expresan el estro y tienden a ovular antes que las hembras con bajo rango social (Álvarez *et al.*, 2007).

Así como en las hembras se logra un mejor desempeño reproductivo cuando se tiene un rango social alto, en los machos ovinos las relaciones jerárquicas también ejercen un efecto positivo sobre la actividad productiva y reproductiva de los mismos. En algunas investigaciones se ha demostrado como los corderos del alto rango social suelen tener una mayor ganancia de peso, circunferencia escrotal y con ello suelen ser más precoces y se desempeñan mejor en el ámbito reproductivo que los que son subordinados (Aguirre *et al.*, 2007).

Por todo lo anteriormente mencionado es preciso investigar acerca del efecto que el rango social de los carneros de la raza Dorper puede ejercer sobre el comportamiento y desempeño reproductivo de hembras ovinas anovulatorias, esto con la finalidad de demostrar la importancia de las relaciones sociales en el ganado ovino en México. Esto aunado a que se pretende reducir en la medida de lo posible la administración de sustancias exógenas como las hormonas y con ello propiciar una producción limpia y verde que beneficie tanto ser humano como a los animales.

IV. CONCLUSIÓN

Los carneros de jerarquía baja o subordinados son igualmente eficientes que los de jerarquía alta al inducir el estro en hembras durante el periodo de anestro, sin embargo, su respuesta es mas lenta cuando son expuestas a machos de jerarquía baja. Así mismo, el rango influye en la capacidad de copular, la circunferencia escrotal y calidad seminal de los carneros Dorper. Además, la

presencia y tamaño de los cuernos influyen al momento de establecer las jerarquías, pero existen otros factores, como las señales químicas, que son cruciales para modular el comportamiento sexual.

V. LITERATURA CITADA

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VI. ARTÍCULOS

Artículo 1



Article

Effect of Dorper Rams' Social-Sexual Hierarchy on Their Sexual Behavior and Capacity to Induce Estrus in Ewes

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Abstract: This study aimed to assess the influence of the social rank of rams and quality of stimuli to ewes between dominant and subordinate Dorper rams joined to anestrus ewes. Social rank was evaluated for two days (ESR; $n = 36$); rams were exposed to estrogenized ewes in a competitive test. According to the reproductive response, anovulatory ewes ($n = 76$) were divided into two groups: LHRe ($n = 38$; ewes exposed to four low hierarchy rams (LHR)) and HHRRe ($n = 38$; ewes exposed to four high hierarchy rams (HHR)). Regarding aggressive behaviors, HHR showed a higher ($p < 0.05$) proportion of rams showing threatening, knocking, and blocking behaviors than LHR. Appetitive behavior was higher ($p < 0.05$) in HHR than LHR rams (3576 ± 0.7 vs. 3054 ± 0.7 number of events). Consummatory sexual behavior was higher ($p < 0.05$) in HHR than LHR (499 ± 0.3 vs. 205 ± 0.1 number of events). Indicators of sexual inactivity (SRI) were similar between HHR and LHR (499 ± 0.3 vs. 433 ± 0.1 ; $p > 0.05$). The estrus response ($>80\%$; $p > 0.05$) and ovarian response (70% , $p > 0.05$) were similar for both groups of ewes. It was concluded that LHR are equally effective as HHR in inducing sexual activity in ewes showing postpartum anestrus.

Keywords: social rank; anestrus ewe; sexual behavior

1. Introduction

The ram effect induces estrus in non-cycling ewes [1] and increases luteinizing hormone (LH) secretion advancing the LH surge in cycling ewes [2]. Nevertheless, the response of ewes to the introduction of rams can fluctuate due to several factors, such as the quality of the stimulus from the male, the intensity of the smell, vocalizations, and the male sexual behavior [3,4]. In addition, the response may also differ due to other factors related to ewes, such as body energy reserves and hierarchy [5,6].

In most ungulates, male reproductive success increases with increasing social rank [7]. Social status refers to the relative position of an individual animal within a dominant hierarchy established in a group [8,9]. In sheep, hierarchy is established at a young age (i.e., lambs), and it determines the behavioral and morphological development of rams [10]. Hierarchical links among rams determine unequal access to food and ewes in estrus; higher-ranked rams have more mounts and offspring than lower-ranked rams [11,12]. On the other hand, high social-ranked ewes subjected to the “male effect” ovulate and get pregnant earlier than ewes with low social status [13]. Dominant ewes, in addition to having a larger body weight or body energy reserves, have a greater interaction time (i.e., stimulus) which seems to make them more sensitive to socio-sexual cues emitted by rams. Such

physiological and behavioral scenarios favor sexual bio-stimulation, which triggers an early reproductive activity [13,14].

During the reproductive season, high-ranked rams present higher blood testosterone concentrations, a greater volume of ejaculate, and higher sperm concentrations than subordinate rams [15]. Besides, dominant rams have more successful copulations than low social-ranked rams. Moreover, high-ranked rams restrict the reproductive activity of lower-ranked rams [15]. In general, individuals of high social rank have greater reproductive success than those of lower social ranks [5,15,16]. In addition, the highest number of mounts occurs during the day than at night, with peaks of behaviors between 08:00 to 14:00 and 18:00 to 20:00 h [17], being of interest to analyze the sexual behaviors presented during the twilight hours, when many ungulate species are more active [18].

Thus, when rams and ewes interact freely, dominant rams perform a greater number of copulations. However, it has been recently proposed that when the activity of both dominant and subordinate rams is restricted (i.e., distributed in different pens), estrus ewes tend to be mounted and impregnated by rams of lower socio-sexual hierarchy [11]. Based on the above findings, we hypothesize that, in absence of high-ranking rams, low-ranking rams show a high quality of sexual behaviors that stimulate estrus response and a high pregnancy rate in anestrus ewes. This study had two objectives; to compare estrus response and pregnancy rate of anovulatory well-fed Dorper ewes joined to either low social or high social-ranked rams, and also to determine various sexual behavior responses of low social and high social-ranked rams.

2. Materials and Methods

2.1. General

The procedures used for this study were approved by the Autonomous Agrarian University Antonio Narro Ethics Committee (38111-425501002-2870).

2.2. Location and Environmental Conditions

The study was carried out during the natural anestrus season (March–May) in the semi-desert of northern Mexico (25°32'40" N, 103°26'33" W). The area is characterized by an arid climate, with an annual average temperature of 23.1 °C and an average annual rainfall of 230 mm. The relative humidity ranges from 26 to 61%; the photoperiod ranges from 13 h 41 min during the spring solstice (June) to 10 h 19 min during the winter solstice (December).

2.3. Experimental Animals and Their Management

Dorper adult rams were included in the study ($n = 36$, 3-yr-old, average live weight (LW) 77.4 ± 3.3 kg, and body condition score (BCS) of 3.9 ± 0.1 units), the BCS was determined by a well-trained technician using a 1–5 scale with 0.5 increments with 1 being emaciated and 5 being extremely fat [19], along with multiparous Dorper ewes ($n = 76$, 2–3 lambings, LW = 40.2 ± 3.3 kg, and BCS = 2.5 ± 0.4 units). All animals were fed twice a day (10:00 and 18:00 h) with a mixed ration (17% CP and 1.5 Mcal ME/kg DM), having free access to mineral salts and water. All animals received fat-soluble vitamins and were dewormed three weeks before the study. The main management practices and experimental activities are shown in Figure 1.

2.4. Determination of Socio-Sexual Ram Hierarchy (Ram Sexual Index)

A competition test was performed for the evaluation of the social rank (ESR) during two days ($n = 36$). These tests were performed using estrogenized ewes ($n = 10$, treated with 2 mg of estradiol cypionate every 48 h for 7 d) as the stimulus. Ram dyads were exposed to an ewe for 5 min in individual 2.5×2.5 m pens to elicit competitions. New pairs of rams were formed until each ram competed against the remaining rams recording agonistic behaviors such as aggression (AG); headbutting (HB); knocking (KN); blocking (BL); thrusting (TU); and avoidance (AD), also sexual behaviors such as approaches (AP);

flehmen (FL); mounting (MO); sniffing (SN); and disinterested behaviors such as peripheral activity (PE) and eating (EA) were recorded.

The rams' social rank was determined calculating the success index (SI) formula [13,20], where the performance of each individual is calculated considering all the dyads contested, thus determining three social ranks in the evaluated rams: low (LSR; SI = 0 to 0.33); medium (MSR; SI = 0.34 to 0.66); and high (HSR; SI = 0.67 to 1.0):

$$\text{Success index} = \frac{\text{won events}}{\text{won events} + \text{lost events}}$$

An event was considered as "won" when the male was able to displace the contestant and as "lost" when the male was displaced.

2.5. The "Male Effect": Sexual Behavior of Rams

Once the socio-sexual rank was determined, two experimental groups were formed based on such test: randomly selecting 4 low hierarchy rams (LHR; 0.283 ± 0.03) and 4 high hierarchy rams (HHR; 0.576 ± 0.06), then, their ability to induce the reproductive response of anovulatory ewes through the "male effect" was assessed. The timeline of actions is depicted in Figure 1.

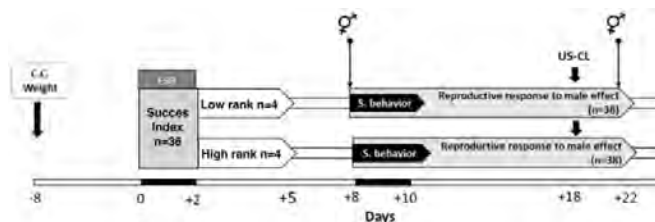


Figure 1. Timeline of actions. The social rank evaluation (ESR) was carried out for two days. During the test of sexual behavior (S. behavior), low (LHR) and high (HHR) hierarchy rams were exposed to anovulatory ewes for two consecutive days/two hours. Morphometric characterization is described in the text, BCS = body condition score, Weight = live weight. The reproductive response of ewes was recorded with either LHR or HHR twice a day (08:00 and 18:00 h). An ultrasound scanning for corpora lutea detection (US-CL) was performed 10 d after the introduction of rams.

Response variables indicative of appetitive sexual behavior (ASB) were: flehmen; anogenital sniffing; approaches; pawing; vocalization; penis extrusion. Consummatory sexual behavior (CSB) included mount attempts and successful mounts. Indicators of sexual inactivity (ISR) were isolation-standing; isolation-lying down; attempt to escape; aggressions; evasions; and external distractions [21].

2.6. The "Male Effect": Response of the Anovulatory Ewes Exposed to High and Low Hierarchy Rams

To quantify the possible reproductive response of anovulatory Dorper ewes ($n = 76$; homogeneous regarding age, BW and BCS) to the socio-sexual cues exerted by the LHR and HHR, ewes were divided into two groups: LHRe ($n = 38$; four groups of ewes exposed to one LHR each) and HHRe ($n = 38$; four groups of ewes exposed to one HHR). Rams within rank groups were randomly assigned to each experimental group, placed in pens 100 mts apart and rotated between groups every 12 h, before behavioral and estrus evaluations. Before breeding, ewes underwent two ultrasound scans (d -15 and d -7) to determine the absence of corpora lutea to confirm anestrus. In addition, ewes of both groups received an intramuscular dose of 25 mg progesterone 24 h before exposure to rams in order to prevent short estrus cycles [22]. Then, on d 0, the first day of the male-to-female interaction and up to 15 days later, the rams remained with the ewes.

Ewes in estrus were recorded during ram exposure to detect the onset of estrus; evaluations were made every 12 h for 15 d, twice a day (07:00 and 19:00) for 15 min each time. Then, the rams were removed from the ewes' pen. The latency to estrus was the interval between the first contact with rams and estrus activity. Ewe immobilization was considered a sign of receptivity to rams [23]. The percentage of ovulating ewes was determined as ewes ovulating/ewes exposed, considering the presence of corpora lutea [24] during the ten days after the introduction of rams. Ovaries were scanned with a transrectal ultrasound (Aloka SSD 500, Tokyo, Japan) connected to a 7.5-MHz linear probe. The same equipment was used for pregnancy diagnosis at 45 d after the introduction of rams. Ultrasound scanning was performed by the same skilled operator.

2.7. Statistical Analyses

Rams within each socio-sexual rank and ewes exposed to rams were the experimental units. Since the percentages of aggressive behaviors, sexual behaviors, disinterested behaviors and sexual-success index had non-normal distribution according to the PROC UNIVARIATE procedure of SAS (SAS Institute, Cary, NC, USA), these data were subjected to logarithmic transformation ($\log(X + 1)$); later on, data were analyzed using the PROC GLM procedure of SAS to assess the effects of hierarchical status (low or high) upon such variables. The PROC GENMOD procedure of SAS was used to determine the effect of ram social rank (two levels), time of day (a.m. and p.m.), and totals per day on appetitive and consummatory behaviors. The distribution of counting variables (i.e., estrus induction, inter-estrus interval, estrus duration, ovulation percentage, gestation, and ovulation rate) among main effects were compared using the SAS CATMOD procedure to determine the possible effect of hierarchical status (low or high) on the reproductive response of ewes in anestrus. This procedure was used for evaluating the social rank effect upon the reproductive performance of anestrus ewes (i.e., estrus induction; estrus interval; estrus duration; ovulation percentage; gestation; and ovulation rate). Differences were considered significant at $p < 0.05$. Values are presented as means \pm standard deviations.

3. Results

3.1. Evaluation of Social Rank

Table 1 presents the variables for determining the social rank index of rams in the present study. HHR showed a higher ($p < 0.05$) proportion of animals showing threatening, knocking, and blocking behaviors than LHR regarding aggressive behaviors. Table 2 presents sexual behaviors shown by LHR and HHR towards ewes during the competition test, HHR had the highest number of mounting and sniffing behaviors ($p < 0.05$).

Table 1. Confrontational behaviors of well-fed adult Dorper rams recorded during the competition test used to measure the Success Index.

	Low Rank ($n = 14$)	High Rank ($n = 6$)
Confrontational behaviors		
Aggressions (AG; %-n)	1.5 (4/253) ^b	4.7 (17/355) ^a
Headbutting (HB; %-n)	16.2 (41/253) ^a	21.1 (43/355) ^a
Knocking (KN; %-n)	22.1 (56/253) ^b	15.2 (54/355) ^a
Blocking (BL; %-n)	39.1 (99/253) ^b	53.1 (185/355) ^a
Thrusting (TU; %-n)	19.7 (50/253) ^a	15.2 (54/355) ^a
Avoidance (AD; %-n)	1.1 (3/253) ^a	0.5 (2/355) ^a
Rank index		
Events won (%)	28.2 (95/336) ^b	57.6(83/144) ^a
Events lost (%)	71.7 (241/336) ^a	42.3 (61/144) ^a
Success index	0.283 \pm 0.03 ^b	0.576 \pm 0.06 ^a

^{a,b} Values in the same column with different superscript differ ($p < 0.05$).

Table 2. Sexual and non-sexual behaviors of LHR and HHR shown in the competition tests during the non-breeding season.

	Low Rank (<i>n</i> = 14)	High Rank (<i>n</i> = 6)
Sexual behaviors		
Approaches (AP; %- <i>n</i>)	26.3 (159/604) ^a	23.0 (108/469) ^a
Flehmen (FL; %- <i>n</i>)	6.7 (41/604) ^a	4.6 (22/469) ^a
Mounting (MO; %- <i>n</i>)	19.0 (115/604) ^b	28.5 (134/469) ^a
Sniffing (SN; %- <i>n</i>)	47.8 (289/604) ^a	43.7 (205/469) ^b
No sexual behaviors		
Peripheral behavior (PE; %- <i>n</i>)	78.1 (111/142) ^a	70.0 (28/40) ^a
Eating (EA; %- <i>n</i>)	21.8 (31/142) ^a	30.0 (12/40) ^a

^{a,b} Values in the same column with different superscript differ ($p < 0.05$).

3.2. Sexual Behaviors of LHR and HHR during the “Male Effect”

The general result of the appetitive sexual behavior, consummatory sexual behavior and sexual inactivity, aggressions, and escapes of the rams (low and high social rank) are shown in Table 3. In general, in the appetitive behavior, there was a more significant number in the HHR vs. LHR (3576 ± 0.7 vs. 3054 ± 0.7 , respectively; $p < 0.05$). There were more of these behaviors during the morning regardless of social rank ($p < 0.05$). The number of consummatory sexual behaviors was greater in HHR than in LHR rams ($p < 0.05$). Finally, the SRI did not differ between HHR and LHR ($p > 0.05$).

Table 3. Appetitive and consummatory sexual behaviors and sexual inactivity, aggressions, and escape behaviors of adult low or high hierarchy Dorper rams (ASB; *n* = 8) during the morning or afternoon during the non-breeding season.

	Low Rank (<i>n</i> = 4)	High Rank (<i>n</i> = 4)
Appetitive sexual behavior (ASB; <i>n</i>)		
Morning	1747 \pm 1.2 ^{aB}	2107 \pm 1.2 ^{aA}
Afternoon	1347 \pm 1.2 ^{bB}	1599 \pm 1.2 ^{bA}
Whole day	3094 \pm 0.7 ^B	3706 \pm 0.7 ^A
%	45.5	54.5
Consummatory sexual behavior (CSB; <i>n</i>)		
Morning	90 \pm 0.1 ^{aB}	298 \pm 0.5 ^{aA}
Afternoon	120 \pm 0.3 ^{aB}	201 \pm 0.5 ^{bA}
Whole day	210 \pm 0.1 ^B	499 \pm 0.3 ^A
%	33.3	66.6
Indicators for sexual inactivity, aggressions, and escapes (SRI; <i>n</i>)		
Morning	193 \pm 0.1 ^{aA}	205 \pm 0.5 ^{aA}
Afternoon	240 \pm 0.2 ^{aA}	201 \pm 0.5 ^{bA}
Whole day	433 \pm 0.1 ^A	499 \pm 0.3 ^A
%	53	47

^{A,B} Values in the same row, with different superscript differ ($p < 0.05$), ^{a,b} Values in the same column, with different superscript differ ($p < 0.05$).

Appetitive sexual behaviors of the rams (low or high rank) are shown in Table 4. The percentages of behaviors were higher in the HHR ($p < 0.05$), except for approaches where the LHR was higher ($p < 0.05$). Therefore, it is believed that, regardless of social rank, there is a behavioral distribution of the flehmen. That is, ASU and ASF behaviors have priority relative to WSF, regardless of rams' social rank. Regarding the number of 'sniffings' (AGS), HHR and LHR did not differ ($p > 0.05$). However, in terms of vocalizations, approaches, pawing, and penis extrusion, the HHR showed a greater number ($p < 0.05$) of these behaviors than LHR.

Table 4. Appetitive sexual behavior of adult Dorper rams (ASB) classified as low (LHR) or high hierarchy rams (HHR) during the morning and afternoon.

Appetitive Sexual Behavior (ASB; n)	LHR	HHR	Flehmen	
			LHR	HHR
Approaches			After directly smelling the female	
Morning	258 ± 3.8 ^{aA}	213 ± 2.3 ^{aA}	80 ± 0.9 ^{aA}	92 ± 0.8 ^{aA}
Afternoon	194 ± 2.0 ^{bA}	145 ± 2.0 ^{bA}	67 ± 0.7 ^{aA}	41 ± 0.4 ^{bA}
Whole day	452 ± 2.1 ^A	358 ± 1.5 ^B	147 ± 0.5 ^A	133 ± 0.5 ^A
%	62	44.8	42.6	44
Pawing			Without smelling the female	
Morning	143 ± 1.6 ^{aB}	256 ± 3.7 ^{aA}	12 ± 0.3 ^{aA}	22 ± 0.3 ^{aA}
Afternoon	133 ± 1.6 ^{aB}	185 ± 2.4 ^{bA}	22 ± 0.3 ^{aA}	20 ± 0.4 ^{aA}
Whole day	276 ± 1.1 ^B	441 ± 2.2 ^A	34 ± 0.2 ^A	42 ± 0.2 ^A
%	38	55.2	9.8	13.9
Penis extrusion			After smelling the ewe's urine	
Morning	24 ± 0.4 ^{aB}	92 ± 1.6 ^{aA}	84 ± 0.7 ^{aA}	66 ± 0.9 ^{aA}
Afternoon	16 ± 0.3 ^{aB}	38 ± 0.5 ^{bA}	80 ± 0.8 ^{aA}	61 ± 0.6 ^{aA}
Whole day	40 ± 0.3 ^B	130 ± 0.5 ^A	164 ± 0.5 ^A	127 ± 0.6 ^A
%	24	76	47.5	42
Total	40 ± 0.2 ^B	130 ± 0.8 ^A	345 ± 0.3 ^A	302 ± 0.2 ^A
Vocalizations			Sniffing	
Low			Anogenital	
Morning	46 ± 0.8 ^{aB}	128 ± 3.1 ^{aA}	818 ± 5.1 ^{aA}	913 ± 5.1 ^{aA}
Afternoon	50 ± 0.7 ^{aA}	61 ± 0.9 ^{bA}	596 ± 3.5 ^{bA}	633 ± 3.2 ^{bA}
Whole day	96 ± 0.5 ^B	189 ± 1.6 ^A	1414 ± 3.2 ^A	1546 ± 3.1 ^A
%	66.6	53.3	76.9	72.8
High			Body	
Morning	21 ± 0.4 ^{aB}	84 ± 1.5 ^{aA}	261 ± 2.8 ^{aA}	241 ± 2.2 ^{bA}
Afternoon	27 ± 0.7 ^{aB}	81 ± 1.8 ^{aA}	162 ± 1.8 ^{bB}	334 ± 3.0 ^{aA}
Whole day	48 ± 0.4 ^B	165 ± 1.2 ^A	423 ± 0.7 ^B	575 ± 1.9 ^A
%	33.3	46.6	23	27.1
Total	144 ± 0.3 ^B	354 ± 1.0 ^A	1837 ± 2.2 ^B	2121 ± 2.2 ^A

^{A,B} Values in the same row, with different superscript, differ ($p < 0.05$), ^{a,b} Values in the same column, with different superscript differ ($p < 0.05$).

The appetitive behaviors are shown in Table 5. There was a significant difference between mounts with unsheathing, mounts with penetration, and unsheathing, HHR displayed greater appetitive behaviors than LHR ($p < 0.05$). Finally, Table 6 shows the behaviors related to sexual disinterest, aggression, and escape. There was no difference in the number of behaviors between the two social ranks ($p < 0.05$).

Table 5. Consummatory sexual behavior in Dorper rams (CSB; $n = 8$) of low (LHR) or high social hierarchy (HHR) during the morning and afternoon, during the non-breeding season.

Consummatory Sexual Behavior	LHR	HHR	Mounting with penetration	
			LHR	HHR
Mounting attempts			Mounting with penetration	
Morning	37 ± 0.6 ^{bB}	86 ± 1.7 ^{aA}	24 ± 0.5 ^{aA}	42 ± 0.6 ^{aA}
Afternoon	73 ± 1.3 ^{aA}	67 ± 1.5 ^{aA}	11 ± 0.2 ^{aB}	31 ± 0.5 ^{aA}
Whole day	110 ± 0.7 ^a	153 ± 0.9 ^a	35 ± 0.3 ^b	73 ± 0.4 ^a
%	52.3	41.4	16.6	19.8

Table 5. Cont.

Consummatory Sexual Behavior	LHR	HHR	LHR	HHR
	Mounting with penis unsheathed		Mounting with ejaculation	
Morning	19 ± 0.3 ^{ab}	65 ± 1.4 ^{aA}	10 ± 0.2 ^{aA}	13 ± 0.5 ^{aA}
Afternoon	23 ± 0.5 ^{aA}	43 ± 0.7 ^{aA}	13 ± 0.3 ^{aA}	22 ± 0.5 ^{aA}
Whole day	42 ± 0.3 ^b	108 ± 0.8 ^a	23 ± 0.2 ^a	35 ± 0.3 ^a
%	20	29.2	11	9.5

^{a,b} Values in the same line, with different superscript, differ ($p < 0.05$); ^{A,B} Values in the same column, with different superscript, differ ($p < 0.05$).

Table 6. Sexual inactivity, aggressions, and escapes (SRI; $n = 8$) of low (LHR) or high social ranking (HHR) Dorper rams during the morning and afternoon under natural photoperiod, when joined to anovulatory ewes.

Indicators for Sexual Rest, Aggressions and Escapes (SRI; n)	LHR	HHR	LHR	HHR
	Aggressions		Isolation	
			Standing isolation	
Morning	33 ± 0.3 ^{aA}	22 ± 0.1 ^{aA}	40 ± 0.3 ^{bA}	63 ± 0.7 ^{aA}
Afternoon	25 ± 0.2 ^{aA}	12 ± 0.4 ^{aA}	70 ± 0.8 ^{aA}	52 ± 0.7 ^{aA}
Whole day	58 ± 0.2 ^A	34 ± 0.5 ^A	110 ± 0.5 ^A	115 ± 0.3 ^A
%	63	37	62.5	73.2
	Scape attempts		Isolation lying down	
Morning	3 ± 0.0 ^{aA}	1 ± 0.0 ^{aA}	33 ± 0.3 ^{aA}	17 ± 0.2 ^{aA}
Afternoon	5 ± 0.1 ^{aA}	7 ± 0.1 ^{aA}	25 ± 0.2 ^{aA}	25 ± 0.4 ^{aA}
Whole day	8 ± 0.5 ^A	8 ± 0.1 ^A	58 ± 0.2 ^A	42 ± 0.2 ^A
%	50	50	33	26.7
	Evasions		Total	
Morning	84 ± 0.8 ^{aA}	102 ± 1.1 ^{aA}	73 ± 0.2 ^A	95 ± 0.2 ^A
Afternoon	115 ± 1.0 ^{aA}	89 ± 1.0 ^{aA}		
Whole day	199 ± 0.6 ^A	191 ± 0.7 ^A		
%	45	55		

^{a,b} Values in the same line, with different superscripts, differ ($p < 0.05$), ^{A,B} Values in the same column, with different superscripts, differ ($p < 0.05$).

3.3. Reproductive Response of Ewes Exposed to LHR and HHR

The reproductive response of anovulatory ewes exposed to LHR or HHR is shown in Table 7 and Figure 2. The estrus response was similar in both groups of ewes ($p > 0.05$); likewise, the ovarian response was similar ($p > 0.05$) between groups. However, a shorter interval to estrus was observed in ewes exposed to HHR than LHR ($p < 0.05$). This difference is observed in Figure 2, where the cumulative percentage of ewes that showed estrus was higher in ewes exposed to HHR after 96 h of joining than ewes in contact with LHR.

Table 7. Reproductive response of anovulatory ewes (LHR_e and HHR_e) exposed to low (LHR) or high (HHR) hierarchy rams under natural photoperiod during the anestrus season.

	LHR _e	HHR _e
Estrus induction rate (%), n	81 (30/37)	89.4 (34/38)
Estrus interval (h)	121 ± 10.9	88.6 ± 8.8
Estrus duration (h)	25.6 ± 2.2	28.2 ± 1.9
Ovulation rate (%), n	73 (27/37)	89.4 (34/38)
Pregnancy rate (%), n	64.4 (24/37)	84.2 (32/38)
Ovulation rate (n)	1.22 ± 0.0	1.44 ± 0.0

For all variables no differences ($p > 0.05$) were detected when comparing high vs. low-ranked rams.

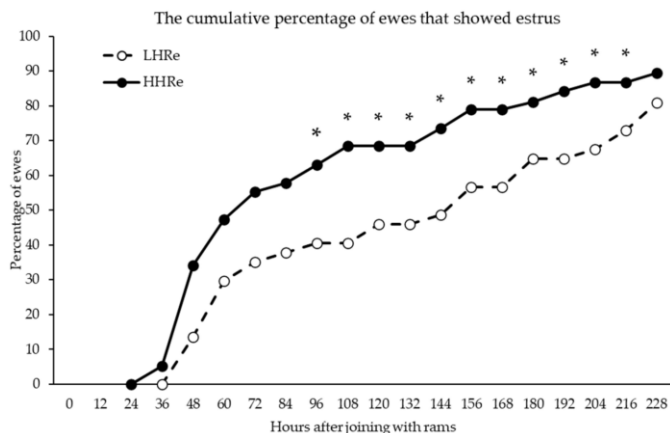


Figure 2. Cumulative percentage of ewes that showed estrus (%; $n = 75$) exposed to low ranked-rams (LHR) and high ranked-rams (HHR) under natural photoperiod. * Statistical differences between groups ($p < 0.05$).

4. Discussion

During the success index test, more AG and MO behaviors were observed in HHR than LHR. When comparing these results with the CSB and SRI tests they were similar. These two variables are tangible indicators for both tests. By performing the social rank test, the MO and AG of rams could be determined without the need to run an additional CSB and SRI test. An index of 0.57 is high enough to classify rams as high-ranking animals, which differs from the values of Alvarez et al. [13], who established a high social status above an index of 0.66. However, the present study agrees with the aforementioned author, in that values below 0.33 are low indexes.

HHR had more than 65% consummatory behaviors, which indicates that ewes exposed to HHR had a higher quality–quantity socio-sexual stimulation, generating a rapid response of ewes to these rams. This response partially agrees with previous results where Dorper rams given exogenous testosterone, and presumably with stronger sexual stimuli toward ewes, markedly increased ewes in estrus, the interval from joining to onset of estrus, duration of estrus, and ewes ovulating [25].

An interesting finding was that flehmen behavior is similar in ASF and ASU, which are greater than WSF behaviors regardless of social rank. This can be attributed to the fact that for ASU and ASF, there was physical contact with the ewes, which may stimulate the expression of flehmen because sheep urine is a source of chemical information that conveys sexual receptivity clues to rams [26]. Flehmen behavior is associated with incentives of pheromones from the urine, wherein by the act of smelling the perianal region or urine, the flehmen response is triggered [27]. In addition to confirming the ewe's sexual responsiveness, this behavior enhances the male's libido to perform other sexual activities during courtship and copulation [28].

A greater number of ASB behaviors were observed during the morning regardless of social rank, and a greater number of CSB behaviors only in the HHR. These findings are in line with previous studies where Hair rams were more sexually active during daytime [29]. This is probably due to a variation in testosterone production as this hormone exhibits a circadian rhythm. For example, Bremner et al. [30] mention that young men show a circadian rhythm in serum testosterone, with levels higher around 08:00 h and lower levels in the late afternoon, which would explain this difference in rams in the present study. High hierarchy rams have higher plasma testosterone concentrations [31], which is responsible for rams'

sexual drive and smell, essential to generate a more potent stimulus to induce estrus in anestrus ewes [32].

Rams with stronger sexual behavior stimulate more anestrus ewes to become in estrus, accelerating this response [21]. On the other hand, HHR during the reproductive season present higher blood testosterone concentrations than subordinate mates [15]. Thus, in sheep, dominant rams have more successful mounts than LHR [33]. Usually, estrus females will mate with the dominant males but subordinate males are not excluded from reproduction [34]; however, it has been suggested that ewes express greater interest or spend more time near to LHR when the HHR rams' behavior is restricted, because HHR tend to show more aggressive behaviors [11].

The sexual response of ewes to the introduction of rams was similar in both groups, indicating that stimulus from HHR and LHR was adequate to induce sexual activity in anestrus ewes. Indeed, more than 80% of ewes in both groups showed estrus during the first 10 days of stimulus. In addition, estrus of those ewes exposed to the ram stimulus was accompanied by ovulation, with more than 60% of ewes becoming pregnant. Nonetheless, there was a strong tendency towards a higher response from females exposed to HHR, this could be explained by the higher amount of CSB showed by this group. The CSB are more important for inducing estrus and ovulation in ewes due to a faster increase in LH and FSH, which in order elicits faster follicular waves that, in line, increases ovulation rate and enhances embryo survival [17,35]. In this regard, it is important to note that the Dorper breed has a mild sexual seasonality. Therefore, at any time of the year, rams of this breed have an adequate sexual behavior for inducing ovulation in anestrus ewes [36]. In fact, in sheep breeds with low reproductive seasonality, the male effect is efficient at any time of the year, as long as ewes are not cycling [37,38], as was the case of ewes in the present study.

The level of sexual behavior expressed by LHR was probably because these animals have always been in an intensive system where they do not experience undernutrition, which can significantly influence weight gain. Indeed, nutrition plays an essential role in the secretion of reproductive hormones; for example, when feeding is increased, plasma leptin concentrations increase, and these are correlated with an increase in the frequency of LH pulses [39]. However, although the sexual response was adequate in both groups of ewes, it is important to note that sheep exposed to low-ranking rams had a slower sexual response. A suboptimal quality could generate this delay in the estrus response in the sexual stimulation of the rams. However, it is worth mentioning that LHR rams have been more effective than HHR rams when mating ewes in estrus without competition [40].

5. Conclusions

Low-ranked rams did not differ from high-ranked rams to stimulate sexual activity in non-estrous ewes; however, ewes exposed to low-ranked rams showed a slower sexual response. Likewise, low-ranked rams were equally effective in inducing ovulation and impregnating ewes as high-ranked rams did. Regardless of socio-sexual hierarchy, appetitive behavior was greater in the mornings than in the afternoon.

Author Contributions: Conceptualization, C.A.M.-H. and F.G.V.-D.; Data curation, Formal analysis, C.A.M.-H.; Funding acquisition, F.G.V.-D. and V.C.-V.; Investigation, F.G.V.-D., M.M., V.C.-V., O.Á.-G., J.R.A. and A.G.-T.; Methodology, F.G.V.-D., M.M., V.C.-V., G.A.-R. and A.G.-T.; Project administration, V.C.-V. and J.R.A.; Resources, G.A.-R.; Validation, M.M.; Writing—review and editing, M.M. and C.A.M.-H. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the Institutional Ethics Committee of the Universidad Autónoma Agraria Antonio Narro (protocol code 38111-425501002-2870; 16 June 2020).

Informed Consent Statement: Not applicable.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

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Artículo 2

Title Page (WITH Author Information)

Effect of social ram hierarchy upon scrotal circumference, semen quality and copulation performance under arid land conditions

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Abstract. Social hierarchies among animal species are based on the animal's dominance-aggressiveness level aligned with the subordination of their mates. Social order is mostly defined by the animal size, live weight, or age. This study aimed to evaluate the association among odor score (OS), horn presence (HP), horn size (HS), and body temperature on social rank hierarchy, scrotal circumference (SC), semen quality (SQ), and sexual drive (SD). Adult Dorper rams (n=24) with similar live weight (LW), body condition score (BCS), and age (AG) were subjected to a behavioral test to define a success index (SI) based on male-to-male interactions. OS was highest ($P<0.05$) for rams with high social rank (HSR; 2.5 ± 0.4) and lowest for rams with low social status (LSR; 0.75 ± 0.01). Scrotal circumference was highest ($P<0.05$) for HSR rams (40.0 ± 3.5) and lowest for rams with medium social rank (MSR; 29.3 ± 1.20). Sperm cell concentration/mL was highest ($P<0.05$) for HSR rams (3848 ± 187) and lowest for LSR (2660 ± 463). 80% of the HSR rams had horns, while 33.3 of the LSR rams were hornless. The percentage of rejection to mount an estrous ewe was 77.7 for LSR and 20% for HSR and MSR rams ($P<0.05$). To conclude, the HSR rams presented the highest successful copulation, the highest scrotal circumference, and the highest sperm cell concentration compared to rams with lesser social rank scores.

Keywords: socio-sexual cues; sexual odor, horn presence; sexual behavior; seasonal reproduction

Author Contributions:

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Conflicts of Interest. The authors declare no conflict of interest.

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1. Introduction

Various sensory systems, such as chemical, visual, auditory, postural, or a combination of these cues, have evolved among animal species to communicate and to define social and sexual rank among animals (Fernald and Maruska, 2012; Fox et al. 2019). Regarding social dominance, animals exert such behavior to establish an intrasexual competition for mates. In arid zones, the amount of feed resources tends to be limited and must be shared in some way among all members of the flock (Fernald and Maruska, 2012, Broom, 2002). Social rank is established through contests; such hierarchy is positively correlated with body size and body weight (Fernald and Maruska, 2012; Pelletier and Festa-Bianchet, 2006; Orihuela, 2014; Zuñiga-Garcia et al., 2020a, 2020b). These diverse social hierarchies occur among different animal species and production systems, based on the animal's dominance-aggressiveness levels aligned with the level of subordination of others, which generates heterogeneous reproductive outcomes (Zuñiga-Garcia et al., 2020a, 2020b; Ceacero et al., 2012; Pelletier and Festa-Bianchet, 2006). Indeed, the greater sexual behaviors (DeYoung et al., 2006; Perkins and Fitzgerald, 1994) and reproductive outcomes (Ungerfeld and Lacuesta, 2010) are positively associated with higher-sexually ranked animals. Moreover, chemical cues such as odor (Boehm et al., 2005; Russell and Fernald, 2014), which emanate from the head, neck, and shoulders of males in a testosterone-dependent fashion (Keller and Levy, 2012), modulate reproduction by altering both physiology and behavior of receptive females (Petruilis, 2013).

Also, in sheep, a positive interaction exists among serum testosterone concentration and follicular stimulating hormone, testicular size, and horn growth (Lincoln, 1998). Further, both length and diameter of horns are linked with spermatogenic output in wildlife animals (Santiago-Moreno et al., 2007), while horned males have shown better reproductive outcomes (Rekik et al., 2012). Based on such findings, we hypothesized that Dorper rams with similar body weight, BCS and age, both odor intensity, and horn presence-size, would increase socio-sexual status and testicular size, semen quality, and copulation success. This study aimed to disentangle such queries.

2. Material and Methods

2.1. General

All the experimental procedures, handling, and maintenance of the animals used in this study were based on the guidelines for ethical use, care, and welfare of animals in research at international (FASS, 2010) and national (NAM, 2010), with institutional approval reference number UAAAN / UL / 1330-8241-2868.

2.2. Location and environmental conditions

The study was carried out during the anestrus season (March-May) in northern Mexico (25° 51' N, 103° 14' W, 1,115 meters above sea level). The area is characterized by a dry and hot climate, with an average annual temperature of 23.1° C. The mean annual rainfall is 210 mm, the relative humidity oscillates from 12 to 61%, and the variations of light are from 13 h 41 min during the spring solstice (June) to 10 h 19 min in the winter solstice (December).

2.3. Experimental Animals and their Management

Dorper rams (n=24) and ewes (n=10) were selected; animals of both sexes had an average age of 3 years (range 2 to 4 years). Animals were fed twice a day (1000 and 1800 h) with a mixed ration (forage-silage-grains; 2.9 Mcal ME/kg DM and 17% CP). Besides, the experimental units had free access to mineral salts and water. They were vaccinated and dewormed against the main pathogenic agents in the region, three weeks before the start of the study, following routine herd management. The primary management practices and experimental activities are shown in Figure 1.

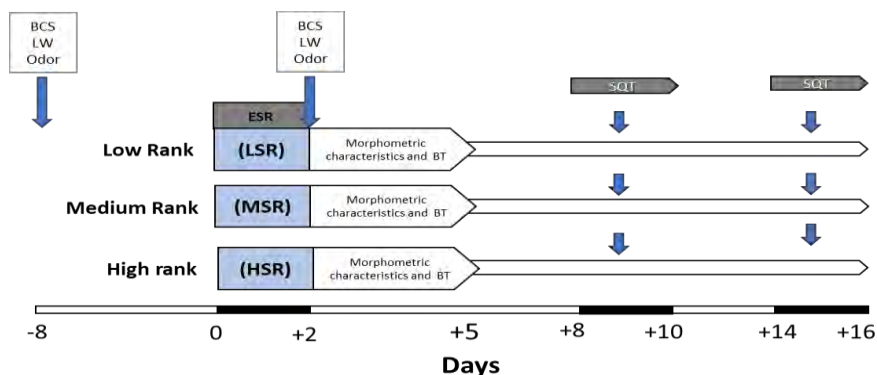


Figure 1. Experimental procedures depicting the timeline of actions. The evaluation of the social rank in Dorper rams (n= 24) was carried out during the non-breeding season (March-May) in northern Mexico (25° N) for two days (ESR). The morphometric characteristics were evaluated for five consecutive days. SQT = Seminal quality tests (dark gray bar). LSR = low social rank, MSR = medium social rank and HSR = high social rank.

2.4. Evaluation of the social rank of Dorper rams: Behavioral tests

During the first phase of the study, the social rank and morphometric characteristics of Dorper rams were determined; also, the live weight and BCS (scale 0 to 5, where 0 = emaciated and 5 = very fat) (Phythian et al., 2012) were recorded. Social rank of rams was assessed using ten estrogenized ewes. Rams were exposed to ewes in individual 2.5 x 2.5 m pens. In each behavioral evaluation, two males were exposed to each female for 30 min to evaluate the sexual behavior of rams. New pairs of rams were formed until each ram competed against the remaining nine rams. The social rank of rams was determined with the success index (SI) described previously (Alvarez et al., 2003; Barroso et al., 2000). The following male-to-male behaviors were considered: bumps, threats, shoves, chases, escapes, and evasions. A ram-to-ewe interaction was considered when a ram displayed dominant behaviors towards the other ram that declined the interaction (subordinated male). To define the success rate, the behavioral characteristics linked to success from the ram-to-ram competitions were considered; in sheep, the opportunity for male reproduction is primarily determined through paired-male rounds (Pelletier and Festa-Bianchet, 2006). The observations of the behavioral study (i.e., agonistic interactions) were made by a single person, and the information was recorded in a digital format. Then, the SI for each ram was quantified. SI was generated by dividing the number of events won by the number of lost events, thus determining three social ranks in the evaluated rams: low (LSR; SI= 0 to 0.33), medium (MSR; SI=0.34 to 0.66), and high (HSR; SI=0.67 to 1.0) as previously described (Hass and Jenni, 1991).

2.5. Skull-horn-body morphometric characteristics

The skull-horn morphometry characterization test of the rams (n=24) included 9 LSR, 10 MSR, and 5 HSR, quantifying the presence of horns (POH; %), distance between horns (DBH; cm), length of horns (LH; cm), size (SH, cm) and width (WH, CM) of the head. Besides, height to withers (HW, cm), thoracic circumference (TC), thoracic diameter (TD, cm), and scrotal circumference (SC, cm) were also recorded.

2.6. Evaluation of seminal characteristics, scrotal circumference, & odor score

Semen was collected with an artificial vagina for sheep (Artificial Vagina for Small Ruminants, IMV Technologies, L'Aigle, France) at 38° C, using one ewe in estrus to induce the mount of rams. The semen collected was deposited in graduated tubes, which were immediately immersed in a container with water at 38° C and transported to the laboratory during the next 10 min after collection. Volume (mL) of ejaculate was directly quantified in the conical collection tube, with optically visible 0.1 mL intervals. The sperm cell concentration was assessed using a photometric analysis (Spermacue®, 12300/0500 Minitub, Landshut, Germany) as previously described (Olivera-Muzante et al., 2011), using undiluted semen, and expressed in 10⁶ cells mL⁻¹. Mass motility (%) was assessed using an arbitrary scale from 1 to 5; where 1 = 25% and 5 = 100% motile sperm (Mahsud et al., 2013). Sperm motility was determined by contrast microscopy, 400X phase, using

a preheated platform (37° C). Seminal pH was evaluated with a paper strip, adding 4 to 6 drops of semen to each strip, and the pH was subsequently determined according to the scale provided by the manufacturer. Scrotal circumference was measured with a flexible tape, and the odor score was determined by smelling the dorsum of the neck 10–15 cm behind the base of the horns and recording a score of 0 (neutral odor indistinguishable from ewes) to 3 (strong smell of rams) (Walkden-Brown et al., 1997). To avoid bias, a single experienced technician recorded the odor each ram. Given that rams were not well-trained to the use of the artificial vagina, only 14 rams could ejaculate due to fear of some rams to the artificial vagina operator: LSR = 2, MSR = 8, and HSR = 4.

2.7. Statistical analyses

For LW, age, BCS, horn dimensions, head measurements, and other body measurements, a completely randomized design using the GLM procedure of SAS (SAS Institute, Cary, NC, USA) was performed, with three social ranks and five to ten replicates per group. Rams within social rank were the experimental units. Means of treatments were compared for differences using the Fisher's MEANS TREATMENT/LSD option of SAS. Besides, pH, ejaculate volume, and sperm concentration mL⁻¹ were analyzed using the GLM procedure of SAS. The significant differences between group means were compared using the PDIF procedure of SAS. The data of microscopic characteristics of sperm cells were subjected to an ANOVA using the MIXED procedure of SAS for repeated measures across time. The sexual behavior variables had non-normal distribution according to the UNIVARIATE procedure of SAS. Therefore, these data were subjected to logarithmic transformation [$\log(X + 1)$]. The transformed data were analyzed using the PROC GLM procedure of SAS to assess the effects of hierarchical status. Significant differences among groups were compared using the MEANS TREATMENT/LSD option of SAS. The GENMOD procedure of SAS was used to assess the effect of social rank (3 levels) on the percentage of mounts and rejection to mount estrous ewes. Group means were compared using the LSMEANS/PDIFF option of SAS. For all statistical analyses, differences were considered significant at $P < 0.05$.

3. Results

3.1. Classification of the social rank and success index in Dorper rams

The proportion of rams in the different social ranks and the success index after win and lost events within rams, is presented in Table 1. MSR rams showed a higher proportion of animals, followed by LSR and HSR. HSR rams showed a greater ($P < 0.05$) number of won events than the other rams. Likewise, HSR rams showed the lowest ($P < 0.05$) lost events compared with MSR and LSR rams. However, SI did not differ ($P > 0.05$) among groups of rams.

3.2. Odor score, and skull-horn-body morphometric characteristics

Bodyweight and BCS, odor score, and some horn, skull, and body morphometric characteristics across experimental groups are shown in Table 2. While the greatest ($P < 0.05$) OS and SC were observed in the HSR-males, the lowest ($P < 0.05$) value for POH occurred in the LSR-rams. The greater odor score ($P < 0.05$) occurred in the HSR and MSR rams, vs. the LSR-group, with respective values of 2.5 ± 0.4 , 1.9 ± 0.2 , and 0.75 ± 0.1 units. Besides, whereas 77.7 % of the LSR-rams were hornless, 80% of the

HSR-group were horned, with intermediate values (50 %) in the MSR rams. Moreover, the HSR-group showed the greatest scrotal circumference (40.0 ± 3.5 cm; $P < 0.05$), followed by the MSR-rams (29.3 ± 1.2 cm) and the lowest ($P < 0.05$) value occurring in the LSR-group. No differences ($P > 0.05$) were observed regarding live weight (LW), body condition (CC), distance between horns (DBH), length of horns (LH), size of the head (SH), width of the head (WH), height at the withers (HW), thoracic circumference (TC), as well as thoracic diameter (TD, cm).

Table 1. Least-square means \pm standard error for of success index, wins and losses events according to social rank (independent variable) in Dorper rams managed under intensive conditions in northern Mexico in the non-breeding season.

	LSR	MSR	HSR
Rank (%; n)	37.5% (9/24) ^a	41.6% (10/24) ^a	20.8% (5/24) ^a
Won events (%; n)	22.2% (48/216) ^b	43.3% (104/240) ^b	60.8% (73/120) ^a
Lost events (%; n)	77.7% (168/216) ^a	56.6% (136/240) ^a	39.1% (47/120) ^b
Success index (SI)	0.22 ± 0.02^a	0.42 ± 0.01^a	0.60 ± 0.07^b

¹ Social ranks: low (LSR), medium (MSR), or high (HSR).

^{a,b,c} Least-square-means without a common superscript within variables in rows differ ($p < 0.05$).

Table 2. Least-square means \pm standard error for age, liveweight, body condition score, odor score, horns, and head traits, body measurements, and scrotal circumference according to social rank (i.e., LSR, MSR and HSR), in Dorper rams ($n = 24$) managed under intensive conditions in Northern Mexico (March, 25° N)¹

	Social rank of rams		
	LSW (n=9)	MSR (n=10)	HSR (n=5)
Age (yr)	3.17 ± 0.1^a	3.20 ± 0.1^a	3.70 ± 0.1^a
Liveweight (kg)	78.3 ± 3.7^a	75.6 ± 5.4^a	79.0 ± 4.4^a
Body condition (units)	3.89 ± 0.4^a	3.90 ± 0.1^a	3.90 ± 0.1^a
Odor score (units)	0.75 ± 0.01^b	1.9 ± 0.2^a	2.5 ± 0.4^a
Presence horns (%)	(3/9) 33.33 ^b	(5/10) 50.0 ^{ab}	(4/5) 80 ^a
Distance horns (cm)	6.94 ± 0.6^a	7.98 ± 0.5^a	7.60 ± 0.4^a
Length of horns (cm)	85.1 ± 2.6^a	84.3 ± 3.3^a	90.7 ± 4.7^a
Head size (cm)	28.1 ± 0.3^a	28.7 ± 0.8^a	28.5 ± 0.5^a
Hight withers (cm)	10.1 ± 0.2^a	10.5 ± 0.5^a	10.0 ± 0.2^a
Head width (cm)	65.9 ± 1.5^a	67.4 ± 1.7^a	70.6 ± 1.9^a

Toracic circumference (cm)	105.2±1.8 ^a	107.8±2.8 ^a	105.8±4.6 ^a
Toracic diameter (cm)	39.2±2.5 ^a	43.4±3.4 ^a	45.5±3.7 ^a
Scrotal circumference (cm)	30.4±1.1 ^b	29.3±1.2 ^b	40.0±3.5 ^a

LSR= low social rank, MSR= medium social rank, HSR= high social rank.

^{a,b}Least-square-means without a common superscript within variables differ ($p < 0.05$).

3.3. Consummatory sexual behavior and semen characteristics

Both mounts with ejaculation and seminal characteristics according to social rank are presented in Table 3. As for the number of mounts with ejaculate, while the HSR and MSR-rams showed the greatest response (80%), the LSR-rams exhibited the lowest performance (22%). Besides, the largest ($P < 0.05$) rejection to ejaculate values were displayed by the LSR-group. On the other hand, no differences for the other seminal characteristics occurred among social ranks; volume, motility, pH, and color ($P > 0.05$). Nonetheless, both the HSR and MSR-rams showed the best performance regarding the sperm concentration with respect to the LSR-rams ($P < 0.05$).

Table 3. Least-square means \pm standard error regarding percentage of mounts, percentage of rejections, and semen characteristics according to social rank of Dorper rams ($n = 24$) under intensive conditions in northern Mexico in the non-breeding season

	Social Rank		
	LSR (n=9)	MSR (n=10)	HSR (n=5)
Mounts (%)	22.2% (2/9) ^b	80 % (8/10) ^a	80 % (4/5) ^a
Rejections (%)	77.7% (5/7) ^a	20 % (2/10) ^b	20 % (1/5) ^b
Ejavulates Volume (mL)	0.9±0.2 ^a	1.0±0.1 ^a	0.9±0.1 ^a
Concentration (x10⁶)	2660±463 ^b	3687±101 ^a	3848±187 ^a
Motility (%)	1.8±0.7 ^a	2.3±0.3 ^a	2.8±0.4 ^a
pH (1-14)	7.7±0.2 ^a	7.6±0.1 ^a	7.4±0.1 ^a
Color (1-4)	1.8±0.6 ^a	2.5±0.2 ^a	2.6±0.2 ^a

LSR= low social rank, MSR= medium social rank, HSR= high social rank.

^{a,b}Least-square-means without a common superscript within variables in rows differ ($p < 0.05$).

4. Discussion

Our working hypothesis stated that in Dorper rams with similar body weight, BCS and age, odor intensity, horn size, and presence of horns would increase socio-sexual status and testicular size, semen quality, and successful copulation. Our results support this hypothesis. Dominance hierarchies are omnipresent in animal social systems; they are essential to define social behaviors and to shape social relations (Fernald and Maruska, 2012). Certainly, hierarchies define social and sexual status, which are ubiquitous in the animal kingdom, and are communicated among animals via sensory systems (i.e.,

chemical, visual, auditory, or a combination of signal cues). This has evolved in diverse animal species assisting them to establish reproductive status. In our study, MSR rams were the most abundant, followed by the LSR and the HSR rams. Greater body weights, body sizes, or age have been closely related to socio-sexual status in both males and females (Pelletier and Festa-Bianchet, 2006; Orihuela, 2014; Zuñiga-Garcia et al., 2020a, 2020b). The most significant morphometric predictors of social rank in ungulates are body weight, muscle mass, and age (Pelletier and Festa-Bianchet, 2006; Fournier and Festa-Bianchet, 1995; Côte, 2000). Even under wild conditions, social rank has been highly associated with age in bighorn sheep populations (Pelletier and Festa-Bianchet, 2006; Hass and Jenni, 1991). Yet, in the present study Dorper rams with similar body LW, size, BCS and age, a socio-sexual hierarchy was clearly established, indicating that other signaling cues play a role in the establishment of socio-sexual ranks in rams.

Chemosignals, such as odor, are able to exert major effects upon the physiology and behavior of diverse mammals. Physical, visual, auditory, and olfactory cues are differently amalgamated among individuals, leading to ritualized clashes or coercions, which are fundamental to decrease the unsafe fights (Boehm et al., 2005; Russell and Fernald, 2014). LSR-rams had the lowest odor score and had a low scrotal circumference, which was reflected in the lowest sperm cell concentration per mL and a high proportion of rejection to mount estrus ewes. This trend could be associated with lower blood testosterone levels because of the positive relationship between male odor score and serum testosterone concentrations in small ruminants (Cruz-Castrejon et al., 2007; De-Santiago et al., 2018). Additionally, there is a significative association between testosterone levels and social dominance in individual ungulates (Pelletier and Festa-Bianchet, 2006). A positive feedback loops exist between GnRH neurons and neurons, influencing both odor and pheromone processing (Boehm et al., 2005). In a previous study of our group, serum testosterone concentrations were positively related to successful copulation (Calderón-Leyva et al., 2018). Rams with low libido (i.e., LSR-males) showed fewer mounts with ejaculation and displayed many rejections to mount estrous ewes. In the present study, the greater mounts with ejaculation occurred in the MSR and HSR rams.

Moreover, a positive relationship was observed among sperm concentration, testicular size, and social rank; the highest the social rank, the largest the testis size, and the greatest the semen concentration. In seasonal breeder mammals, androgens exert a crucial role in the modulation of aggressiveness, with a seasonal shift of androgen concentration between the breeding and non-breeding seasons, thru the involvement of other environmental (i.e., photoperiod) and endocrine cues (i.e., thyroid hormones and steroids) (Hood and Amir, 2018). In the present study, a set of signaling cues may have affected not only the establishment of the highest social hierarchy but also possibly activated accelerated spermatogenesis, generating, in turn, an increased spermatoc output, positively linked to odor score. A key player triggering such a response could be the serum testosterone concentration (Keller and Levy, 2012; Recabarren et al., 2017), as this hormone is highly correlated with scrotal circumference as well as ejaculatory volume in bulls (Sajjad et al., 2007). Testosterone is also correlated with aggression (Muller and Wrangham, 2004), male social dominance (Koren et al., 2002; Muller and Wrangham, 2004), and courtship (Ungerfeld et al., 2019). The last physiological and behavioral scenario requires further experimental substantiation.

There are other individual characteristics in males that can give competitive advantages when establishing social hierarchies (Pelletier and Festa-Bianchet, 2006). Early studies

demonstrated that larger body size, testicular dimensions, augmented odor scores, and blood androgen concentrations were linked to large horn development, which greatly enhances male competitiveness, sexual maturity, physical growth, social hierarchies, and reproductive success (Lincoln, 1998; Santiago-Moreno et al., 2007; Rekik et al., 2012; Coltman et al., 2002; Eberhard, 2006). In the Dorper breed, horns may be present, but selection for hornless animals may improve management (Milne, 2000). When evaluating blood testosterone levels in hornless and horned Dorper rams under extensive conditions, hornless rams exhibited the highest values (Fourie et al., 2005). Also, a positive correlation exists among body measurements and scrotal circumference (Akpa et al., 2021). Such differences in scrotal circumference may arise between production systems since nutritional status positively affected scrotal circumference (Murray et al., 1991). Moreover, the size of antlers and horns plays a vital role in establishing social hierarchies (Coltman et al., 2002; Hass, 1991); in the present study, rams with the smaller horns concentrated in the LSR-group. Yet, since the percentage of horned rams was similar in both the MSR and HSR, brain mechanisms that shape socio-sexual supremacy could be implicated in intermale aggression to establish social rank (Stagkourakis et al., 2018). Besides, the LSR group of rams had the highest proportion of hornless rams and horns with less thickness. Both horn presence and horn length have been positively related to testicular size. This scenario may be related to higher sexual and reproductive success (Preston et al., 2003). Indeed, while horn quality was firstly associated with sperm motility in wild sheep (Santiago-Moreno et al., 2007), improved reproductive outcomes also arose in horned bucks (Rekik et al., 2012). Interestingly, highly expressed genes for horn development were greatly co-expressed in bone, nerve tissue, and testis growth (Wang et al., 2019).

Along with the presence and size of horns, another fundamental trait for establishing social dominance is aggressiveness, a behavior with a relatively similar neurophysiological circuitry and function among vertebrates, where testosterone is the main trigger (Giammanco et al., 2005; Shargal et al., 2008). From our perspective, it is suggested a genomic approach to help to understand our main findings; activation of specific genes that promote intensity of sexual behavior. In this respect, aggressiveness is a fundamental issue to quantify the SI when defining social status.

5. Conclusions

While size and thickness of horns play an essential role in establishing social hierarchies, chemosignals, such as odor, are also crucial cues modulating sexual behavior. This study demonstrates that social rank in Dorper rams is a complex trait influenced by factors other than horns or horn characteristics. Rank was a strong determinant of copulatory capacity, scrotal circumference, and semen quality for mature Dorper rams, so sexual selection should favor high social rank rams.

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