UNIVERSIDAD AUTÓNOMA AGRARIA ANTONIO NARRO

SUBDIRECCIÓN DE POSTGRADO

LA JERARQUÍA SOCIAL CAPRINA Y SU RELACIÓN CON LA MORFOLOGÍA CORPORAL Y DE LA UBRE, LA CALIDAD DEL CALOSTRO Y LECHE, Y EL CRECIMIENTO PREDESTETE DE SUS CRIAS

Tesis

Que presenta MA. SILVIA CASTILLO ZUÑIGA

como requisito parcial para obtener el Grado de
DOCTOR EN CIENCIAS EN PRODUCCIÓN AGROPECUARIA

Torreón, Coahuila   Diciembre, 2022

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Torreón, Coahuila

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Elaborada por MA. SILVIA CASTILLO ZUÑIGA 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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Contenido

I. Introducción

Las cabras representan un sector de gran importancia a nivel socioeconómico en muchas áreas rurales marginales del mundo (Navarrete *et al*., 2020). En la zona agroecológica localizada en el semiárido norte de México, se encuentra una de las principales concentraciones caprinas de América, particularmente, la región que comprende la Comarca Lagunera, es considerada el primer lugar en la producción de leche de cabra en nuestro país, generando ingresos bajo un esquema enfocado en la producción ecológica de leche y carne, coadyuvando a la sostenibilidad social, económica y biótica (Navarrete-Molina *et al*., 2019; 2020). Algunos de los pocos investigadores que abordan el tema, como Clark (2017) señalan que la producción de leche caprina no solo se ve influenciada por variables fisiológicas, sino también etológicas, e incluso morfológicas, impactando en la cantidad y calidad del calostro y de la leche.

Al igual que con otras especies, la cabra es altamente sociable, donde el rango social está determinado por una serie de factores que incluyen principalmente por el peso corporal, la edad, el tamaño y/o la altura del cuerpo y la presencia de cuernos (Barroso *et al*., 2000; Pelletier y Festa-Bianchet, 2006; Ungerfeld y Lacuesta, 2010).

Las cabras por su conducta social encuentran estresante la separación del rebaño (Miranda-De la Lama y Mattiello, 2010), debido a su jerarquía social preservada por comportamientos agonísticos y afiliativos, las cabras de alto rango tienen acceso prioritario a los recursos sin necesidad de pelear y por ende las cabras de menor rango son más afectadas por recursos limitados (Barroso *et al*., 2000).

El consumo de alimento de los animales subordinados es generalmente perturbado por los animales dominantes, lo que puede afectar las principales características fisicoquímicas no solo en la producción y riqueza del calostro, sino también de la leche (Isidro-Requejo *et al*., 2019). La finalidad de la caprinocultura en la Comarca Lagunera es practicada en su mayoría para producción de leche, bajo un sistema extensivo, por familias rurales de bajos recursos, presentando un bajo nivel de tecnificación y asesoría, omitiendo aspectos importantes en el manejo del hato (Escareño *et al*., 2011).

Según Anzuino (2016), los trabajos que abordan la importancia de la jerarquía social en la producción y reproducción caprina no son recientes ni abundantes, destacando lo informado por varios autores (Ungerfeld y Lacuesta, 2008; Álvarez *et al*., 2010; Miranda-De la Lama y Mattiello, 2010; Ungerfeld, 2012). Basándonos en dichos hallazgos, planteamos la hipótesis de que en los hatos caprinos el estatus de alto rango social está relacionado con la morfología y algunos indicadores morfométricos de la ubre, así como la calidad tanto del calostro como de la leche. Este estudio tiene como objetivo evaluar el efecto del rango social sobre la morfología y la morfometría de la ubre, calidad fisicoquímica de la leche y calostro, así como su posible interacción en cabras lecheras cruzadas en un ambiente extensivo.

II. Revisión de literatura

2.1 Importancia de la caprinocultura

La importancia de esta especie se sustenta en los incrementos considerables que ha tenido en la producción de leche y carne a través del tiempo a nivel mundial, nacional y regional. La leche de cabra ha estado arraigada en diversas civilizaciones y culturas a nivel mundial (Escareño *et al*., 2011), el área intertropical de Asia y África posee la mayor población humana y caprina (80% del inventario), lo que parece indicar que más humanos consumen productos derivados caprinos que de otros rumiantes (Silanikove *et al*., 2010).

Según la FAO (2022) en el año 2020, de los casi 1,128 millones de cabras en el mundo, el 44% se concentraba en seis países: India (13%), China (12%), Nigeria (7%), Pakistán (7%) y Bangladesh (5%). Así mismo, durante la última década, la producción mundial de leche de cabra (Capra hircus) aumentó un 17%, al pasar de 17.6 Mt en 2010 a casi 20.0 Mt en 2020, en ese contexto, la producción de queso de cabra incremento un 18%, de 460.5 Kt en 2010 a 567.1 Kt en 2019 (FAO, 2022). La leche de cabra podría posicionarse a escala mundial por las propiedades no alergénicas, capacidad digestiva y su contribución a la reducción de la pobreza y la desnutrición a nivel familiar en los pequeños productores y el consumidor final (Haenlein, 2004; Chacón, 2005; Kumar *et al*., 2012; Escareño *et al*., 2013).

En México, para 2020, existían cerca de 9 millones de cabras, principalmente animales cruzados mantenidos bajo ecotipos áridos y semiáridos (SIAP, 2022). A nivel nacional aproximadamente 250.000 familias se dedican a la producción caprina como actividad productiva primaria o complementaria (Aréchiga *et al*., 2008; Orona-Castillo *et al*., 2014). Lo anterior explica el motivo por el cual la producción de leche caprina en México proviene principalmente de fincas de pequeña escala que complementan las principales actividades agropecuarias (Morales-Pablo *et al*., 2012).

La Comarca Lagunera, ubicada en el norte árido de México, cuenta con una de las más numerosas concentraciones caprinas de América, ocupando el primer lugar en la producción de leche de cabra a nivel nacional, lo anterior permite tener ingresos económicos bajo un esquema orientado a la producción ecológica de leche y carne, de forma ecoeficiente, promoviendo la sostenibilidad social, económica y biótica (Ríos-Flores *et al*., 2018; Navarrete-Molina *et al*., 2019a; 2020). Estos son animales sin un fenotipo definido; aunque en la Comarca Lagunera parece haber una influencia significativa de los genotipos lecheros, principalmente de las razas Alpina, Saanen, Nubia y Toggenburg (Iñiguez *et al*., 2013).

2.2 Bienestar en animales de interés zootécnico

El bienestar animal es un tema que preocupa desde hace algunas décadas, debido a que diferentes investigaciones evidencian los efectos en el estado de salud física y mental de los animales, con la producción, la reproducción y la calidad de los productos pecuarios (Muñoz, 2014).

En diversas investigaciones se acepta que los animales pueden sentir una amplia gama de emociones y sensaciones positivas y negativas; como placer, dolor, comodidad, miedo, ansiedad, aburrimiento, frustración (Mellor, 2016). En la actualidad la mayoría de los métodos implementados para evaluar el bienestar animal sólo permiten valorarlo de forma indirecta, algunos de estos indicadores son: condición corporal, salud, presencia de lesiones, el diámetro de la zona de fuga, el comportamiento social, la tendencia agresiva, entre otros. El origen de estos indicadores es principalmente el de determinar el desempeño del sistema de producción (Arraño *et al*., 2007). Además, hoy en día, los consumidores demandan seguridad y calidad en los alimentos que se les oferta, considerando importante el bienestar animal durante la producción (Dalmau *et al*., 2006). Al respecto, en los sistemas de producción caprinos, es posible evaluar el bienestar animal mediante indicadores conductuales (conductas agonistas, de exploración, sociales, etc.) (Otero, 2013).

El interés por mantener condiciones de bienestar animal en los sistemas de producción pecuarios, es motivado, principalmente, por el incremento de la productividad y el ingreso (Muñoz, 2014).

El presente estudio aborda la línea de investigación en el comportamiento de animales de interés zootécnico en virtud de que algunos investigadores entre ellos Barroso *et al*. (2000) identificaron que la mayoría de las investigaciones en ganado caprino se enfocan solamente en las áreas de nutrición, reproducción, producción y enfermedades, sin conocer los mecanismos del comportamiento animal lo cual también es muy importante en el desarrollo de técnicas de manejo eficientes en pro de una producción óptima, sin excluir el bienestar de los animales (cabras).

Día con día se están abordando con mayor frecuencia estudios del bienestar animal y la organización social de los animales de interés zootécnico, debido a la disminución en la productividad y calidad de productos por efectos negativos del ritmo de producción intensivo, o al estrés que genera la pérdida del ambiente de confort (Landaeta-Hernández, 2011).

2.3 Conductas de comportamiento en animales domésticos

Una comprensión del comportamiento del ganado facilitará el manejo, reducirá el estrés y mejorará tanto la seguridad del manejador como el bienestar animal. Se ha demostrado que reducir el estrés en los animales mejora la productividad y previene cambios fisiológicos que podrían confundir los resultados de la investigación (Mellor, 2016).

En animales en cautiverio que viven en ambientes confinados, grandes densidades de animales pueden generar un nivel aún mayor de agresión y perturbación, promoviendo conductas agresivas y lesiones, paralelamente a una reducción en el peso vivo, especialmente en animales de bajo rango jerárquico (Estévez *et al*., 2007; Vas y Andersen, 2015). Tanto en esquemas de producción intensiva como semintensiva, la competencia continua entre los miembros del hato, provoca resultados adversos en la provisión de espacios adecuados para los comederos y en el acceso a la ración alimenticia, donde el comportamiento de los subordinados es a menudo perturbado por los dominantes (Manousidis *et al*., 2016). En los diferentes sistemas de producción pecuaria, día con día se toma en cuenta el propiciar las condiciones necesarias para que las especies domesticas alcance un estado de bienestar (Muñoz, 2014). El interés por esta arista del sistema productivo muestra un desarrollo considerable, reflejado en la rigurosidad jurídica y comercial que actualmente tiene en la expansión internacional del mercado de proteína de origen animal (Henao, 2013).

2.4 Comportamiento conductual en cabras

Las cabras son animales sociales y se estresan ante la separación del rebaño (Miranda-De la Lama y Mattiello, 2010). En las cabras de vida libre, el tamaño del grupo varía según las condiciones ambientales locales y suele ser de 2 a 20 individuos. Se pueden encontrar grupos más grandes de 100 a 150 en campo abierto (Andersen *et al*., 2011).

Las cabras utilizan una amplia gama de señales, olfativas, visuales, vocales, táctiles, para comunicarse unos con otros, la comunicación olfativa es particularmente importante. Son muy vocales, usando una mezcla de resopla, bala y estornuda, y cuando está alarmado, muestra señales visuales como como estampado.

Las cabras forman relaciones a través de una mezcla de comportamientos agonistas (antipáticos) y afiliativos (amistosos). Muestran comportamientos hostiles que pueden ser sin contacto físico, como amenazas y persecuciones, o con contacto físico como mordidas y embestidas, donde el conflicto escala se paran sobre sus patas traseras, bajan la cabeza y apuntar a golpear la cabeza de su oponente. El comportamiento amistoso incluye olfatear, acicalarse unos a otros, acostarse juntos y apoyando la barbilla en el lomo de otra cabra, dicho comportamiento ayuda a formar lazos entre individuos (Miranda-De la Lama y Mattiello, 2010). Incluso hay evidencia de que algunas cabras actúan como mediadores, interviniendo y reparando las relaciones dañadas por el conflicto (Andersen *et al.*, 2011).

Los rebaños son muy invariables una vez establecidos, las cabras de alto rango tienen acceso prioritario a los recursos sin necesidad de pelear. Las cabras de bajo rango reciben en lugar de iniciar cualquier agresión (Barroso *et al.*, 2000). Cuando se les da a elegir, las cabras mantienen un cierto mínimo de distancia de otras cabras, de acuerdo con la calidad y naturaleza de las relaciones entre estas (Aschwanden *et al.*, 2008). Las actividades de los individuos del grupo suelen ser muy sincronizado son alojadas juntas en grupos, a menudo de 80 a 100 individuos (Anzuino *et al.*, 2016), sin embargo, cuando son confinados que tienden a un contacto más cercano puede conducir a encuentros más agresivos debido a una mayor competencia por los recursos. En particular, la comida es un recurso prioritario que debe protegerse estrechamente. Las cabras de menor rango son más afectadas por recursos limitados (Barroso *et al.*, 2000).

Un entorno social estable les brinda condiciones para adaptarse al entorno a través del aprendizaje social y el bienestar, como lo sugiere el bajo umbral para responder a eventos estresantes (Pitcher *et al*., 2017; Napolitano *et al*., 2018; Zobel *et al*., 2018). Aunque existe alguna información sobre el efecto del comportamiento social con respecto a la eficiencia productiva, la importancia de esta relación no ha sido suficientemente explicada en algunas especies animales, especialmente en las cabras. Los herbívoros domésticos bajo esquemas de pastoreo ejercen dominio social, especialmente cuando el pasto está disponible *ad libitum*; si existe una mayor disponibilidad-diversidad de alimentos, el animal dominante tendrá acceso prioritario a los recursos de mejor calidad con respecto a los animales subordinados (Barroso *et al*., 2000; Di Virgilio y Morales, 2016; Hussein *et al*., 2016; Bica *et al*., 2020; Zúñiga-García *et al*., 2020). Dicho dominio en la jerarquía social del rebaño asegura el acceso al mejor alimento disponible, ya sea en praderas o pastos, lo que a su vez tiene un efecto positivo y significativo sobre el peso vivo del animal dominante. Además, un mayor peso vivo se alinea positivamente con un mejor estado metabólico y una mayor capacidad productiva y reproductiva (Zuñiga-García *et al*., 2020).

En la alimentación grupal bajo esquemas de producción intensivos y semi-intensivos, se considera que la competencia continua entre los integrantes del rebaño genera resultados adversos, no solo en cuanto a la provisión de espacio adecuado para los comederos, sino también en cuanto al acceso a la alimentación racionada, pues el comportamiento de ingestión de los subordinados a menudo es perturbado por los dominantes; además, caprinos que ejercen un consumo de dieta altamente selectivo (Manousidis *et al*., 2016; Nevae *et al*., 2018). La hora del día, la temperatura ambiental, la estación del año y otros aspectos relacionados con la jerarquía social afectan el acceso al alimento, la competencia animal y los disturbios sociales (Zobel *et al*., 2018; Hartley *et al*., 2019).

Aunque existe alguna información sobre el efecto del comportamiento social con respecto a la eficiencia productiva, la importancia de esta relación no se ha explicado adecuadamente, especialmente en las cabras (Miranda-De la Lama y Mattiello, 2010).

2.5 Relación entre el comportamiento caprino y el bienestar

La buena salud física y mental son importantes para el bienestar animal, reflejándose en su comportamiento. Comprender las necesidades de comportamiento y evaluar las actividades de comportamiento mostradas puede ayudar a prevenir y resolver problemas de salud en la granja. Los responsables del manejo del ganado deben estar en condiciones de comprender tanto las necesidades de los animales como las necesidades de producción del ganadero observando la explotación como un todo. La base de evidencia para comprender el bienestar de las cabras está creciendo, pero aún es escasa en comparación con otras especies que se crían más comúnmente en el Reino Unido (Dawkins, 2004).

Según Anzuino (2016), los veterinarios comprenden los requerimientos de los animales, así como las demandas productivas de los agricultores, con las capacidades de ver la finca como un todo. Dado que tales veterinarios tienen un papel clave que desempeñar en la evaluación del bienestar e identificar soluciones en las que todos ganan que mejoren o protejan el bienestar de las cabras manteniendo la producción.

2.6. Importancia de las jerarquías en las sociedades animales

Una de las características más destacadas en grupos de animales bajo cualquier tipo de organización social, es el sistema de rango social. Una jerarquía social puede ser definida como “un rango de individuos, en una unidad social, basada en mutuas relaciones de dominancia-subordinación” (Lacuesta, 2008).

Fuera del mundo científico, el efecto del comportamiento social sobre la producción es poco tenido en cuenta, pero la importancia de esta relación ha sido suficientemente demostrada en algunas especies animales encontrando que los animales de bajo estatus pueden sufrir un acceso reducido a recursos como alimentos, lugares de descanso, sombra, apareamiento e inhibición general de la actividad y por el contrario, los animales superiores en un orden de dominancia generalmente tienen acceso prioritario a recursos limitados (Barroso *et al*., 2000). Las investigaciones relacionadas con la organización social tanto en confinamiento como pastoreo restringido y sus efectos en los diferentes parámetros productivos son dramáticamente escasas (Ungerfeld y Lacuesta, 2010 y Ungerfeld, 2012). En sistemas de producción semiextensivos, existen algunos estudios iniciales que evidencian que los animales dominantes permanecen más tiempo en el comedero y son menos molestados que lo subordinados. Los individuos de rango social alto tienen mayor éxito reproductivo que los de rango social bajo (Pelletier y Festa-Bianchet, 1995). Algunas investigaciones han demostrado que el tratamiento con hormonas esteroides modifica las relaciones de dominancia en un grupo, por lo que las relaciones de dominancia social parecieran sustentarse en factores hormonales que afectan a su vez al temperamento (Landaeta-Hernández, 2011).

Para los animales en estado salvaje ser altamente gregario le permite divisar y protegerse de los depredadores con mayor facilidad, preservarse mejor y ubicar los recursos alimenticios, beneficiando a las nuevas generaciones, facilitando la reproducción. Sin embargo, ser una especie altamente gregaria también presentar algunas desventajas; se motiva la competencia por el acceso prioritario a los recursos, incrementando las probabilidades de infección. Los animales domésticos actuales descienden de especies que vivieron en grupos sociales altamente organizados en estado salvaje (Herrera *et al*., 2005).

La domesticación implica cambios anatómicos, en ese sentido Herrera *et al*. (2005), indican que un cerebro más pequeño supone la domesticación, implica que disminuya la reactividad y las reacciones de alarma, haciéndolos socialmente más tolerables que los salvajes. Sin embargo, estas especies domésticas conservan características de sus ancestros salvajes. La domesticación puede modificar la intensidad y la frecuencia en la expresión de los patrones de conductas, sin embargo, las características básicas de estos sones inalterables. Los cerdos domésticos criados en sistemas extensivos tienen una organización social similar a la del cerdo salvaje europeo. En aras de propiciar un sistema de producción sostenible y sustentable en esta especie se deben incluir los procedimientos que promuevan la interacción en pro del conservar el grupo y perpetuar su existencia (Herrera *et al*., 2005).

El comportamiento social y la persistencia del grupo depende de la capacidad de comunicación de los animales entre sí. Durante los últimos 30 años, con la intensificación de la producción animal, la forma de vida de los animales se ha vuelto cada vez menos natural. La investigación se ha dedicado particularmente a los problemas relacionados con la nutrición, la reproducción y las enfermedades. Sin embargo, es importante conocer bien los mecanismos del comportamiento animal para que se puedan desarrollar técnicas de manejo eficientes para una producción óptima y el bienestar de los animales, la jerarquía social permite la coexistencia exitosa en comunidades sociales (Barroso *et al*., 2000).

2.7 Pruebas de comportamiento para establecer el rango de un individuo dentro de un grupo social

Tener el conocimiento sobre los diferentes comportamientos que pueden mostrar los animales, es muy útil en la selección de los ítems que nos permitirán reflejar con objetividad lo que el estudio pretende evaluar. La descripción detallada y completa del comportamiento de una especie en estudio se denomina etograma; este instrumento será muy útil si la descripción del comportamiento en cuestión se basa en los criterios y momentos correctos (Herrera *et al*., 2005).

Algunos investigadores vinculan la dominación social con la agresión. La jerarquía, es establecida por enfrentamientos, como amenazas sumisión o evitación, mediante la cual se intenta describir la posición relativa de un animal con respecto a todos los demás (Barroso *et al*., 2000).

Existen diferentes formas para identificar el orden de dominancia. Algunas toman en cuenta el grado de agresión al momento de competir por el acceso a los recursos. La dominancia, basada en golpeteo con la cabeza, se identifica de forma rápida, para lo cual se debe tener claro que la dominancia es evaluada mediante el registro del número de encuentros agonísticos entre dos animales, y la proporción directa que hay entre los eventos ganados y los perdidos. Un animal dominante es el que gana más del 50 por ciento de las conductas agonísticas. Algunos investigadores señalan que las relaciones de dominancia social se establecen con rapidez, y son afectadas por el área disponible y el contexto social: en explotaciones extensivas, los animales tienen menor contacto y las relaciones se crean lentamente; a mayor distancia social menor agresión; por ejemplo, en los bovinos, un 66 por ciento se establecen en los primeros 10 min después de que los animales se mezclan, y el 84 por ciento de 1 a 2 h (Lacuesta, 2008).

Lacuesta (2008), llevó a cabo un estudio con el registro de las Unidades Comportamentales mediante observaciones preliminares se establecieron las unidades comportamentales (UC) utilizadas para el desplazamiento físico en las Interacciones Agonísticas (IA):

- Cornada: un individuo desplaza al subordinado por medio de la utilizaci6n de sus cuernos con o sin contacto físico con su oponente.
- Mirada: al individuo subordinado se desplaza a partir de que el individuo dominante lo mira.
- Mordida: el individuo dominante desplaza al subordinado con una mordida.
- Cabezazo: desplazamiento de los individuos subordinados al ser golpeados con la cabeza por parte de la dominante.
- Empujón: el individuo dominante desplaza al subordinado al empujarlo con su cuerpo.

Se registraron 4584 IA, con las que se calculó el índice de dominancia individual (ID), de acuerdo con Alvarez *et al*., 2003:

ID= (número de individuos desplazados) / (número de individuos desplazados + número de individuos que la desplazaron).

Este índice vario de 0 a 1, donde al individuo que domino a todos los individuos con los que interactuó obtiene el mayor valor (1), mientras que el que fue dominado por todos los individuos con los que interactu6 obtiene el menor valor (0).

Los individuos fueron clasificados, en tres categorías, de acuerdo a su ID (Barroso *et al*., 2000; Ungerfeld y Correa, 2007):

- Estrato alto (A): 0,66 a 1.0
- Estrato medio (M): 0,33 a 0,66
- Estrato bajo (B): <0,33

2.8 Principales características que presenta una cabra dominante

Existe una clara estructura de dominancia en los rebaños caprinos. El efecto del rango social sobre la productividad puede ser considerable, según la especie y el tipo de sistema de gestión (Barroso *et al*., 2000). En rumiantes silvestres (*Ammotragus lervia sahariensis*) refiriéndonos a las hembras, existe una alta correlación entre el rango social de las mismas y la probabilidad de aparearse can el macho dominante (Lacuesta, 2008). Las hembras de cabras de montaña de alto rango social producen mayor cantidad de crías que las hembras subordinadas a lo largo de su vida reproductiva (Cote y Festa- Bianchet, 2001). Las cabras de alto rango jerárquico ovulan y conciben antes que las de rango más bajo, probablemente debido a una estimulación más intensa de los machos (Alvarez *et al*., 2003). Sin embargo, en cabras domesticas no se observó relación entre el rango social y la tasa de concepción cuando el desafío es producido por la administración de hormonas, como en tratamientos de sincronización de celo e inseminación a tiempo fijo (Ungerfel *et al.,* 2007).

2.9 Morfología de la Cabra y su relación con la jerarquía

Miranda-De la Lama *et al.* (2011), indican como se midieron algunos rasgos morfológicos, las cinco medidas corporales obtenidas fueron: DE: distancia entre ojos; LB: longitud de la barba; BL: longitud del cuerpo; HW: altura a la cruz; CT: circunferencia torácica (fig. 1).

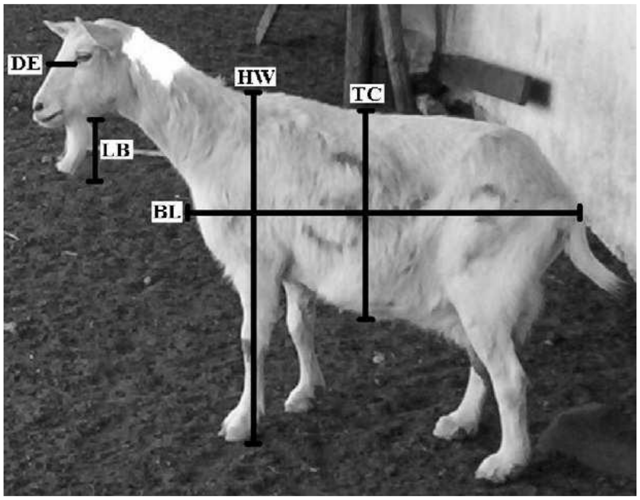

Fig. 1. Variables morfológicas estudiadas y sus puntos de referencia.

En otro estudio realizado por Whannou *et al.* (2022), se evaluó la diversidad morfológica real existente dentro y entre las cabras de las tres zonas de vegetación de Benin. Así mismo, se tomó en cuenta la metodología citada por la (FAO, 2013), para describir las características morfológicas de cada cabra muestreada, en donde se contemplan 26 medidas (fig. 2) tales como: altura de la cruz (WH), altura de la grupa (RH), altura del esternón (SH), altura de la espalda (BH), profundidad del pecho (CD), profundidad de la grupa (RD), ancho del pecho (CW), longitud escápulo-isquiática (SIL), longitud del cuerpo (BL), longitud de la cabeza (HL), anchura de la cabeza (HW), longitud de la oreja (EL), Longitud del cuerno (HoL), diámetro del hocico (MD), longitud del cuello (NL), circunferencia del cuello (NG), longitud de la cola (TL), circunferencia del corazón (HG), circunferencia del pecho (CC), circunferencia abdominal (AG), diámetro bi-costal (BD), ancho de la grupa (RW), longitud de la grupa (RL), circunferencia del hueso de la caña (TC), circunferencia del corvejón (HC) y peso corporal (BW).

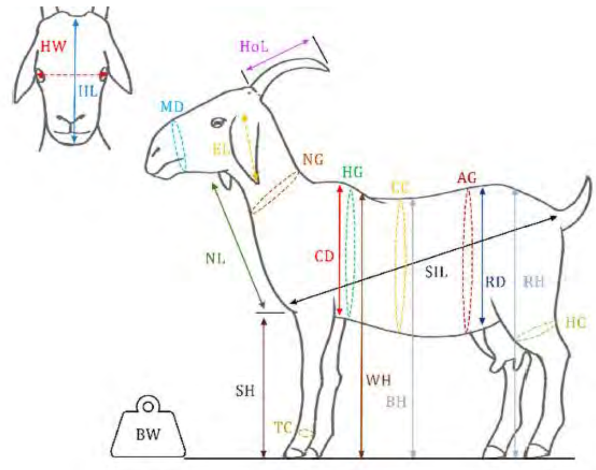

Fig. 2. Ilustración de 26 medidas corporales lineales tomadas en cada cabra muestreada.

2.10 Morfología de la ubre en cabras lecheras

La ubre de la cabra está conformada por dos glándulas mamarias separadas anatómicamente, situada en la región inguinal con una glándula a cada lado de la línea media ventral. La lactogénesis comienza a los 95 y 100 días de iniciada la preñez, con la detección de la lactosa (inicio de la lactogénesis) después de los 100 días, la morfología de la glándula mamaria y la constitución de la ubre son aspectos muy importantes para obtener mayores rendimientos de leche mediante ordeño mecánico en rumiantes, encontrándose diferencias significativas entre razas e incluso entre animales de la misma manada/rebaño (Sanz, 2021).

La glándula mamaria es una sección de los animales (hembras) misma que tiene como función principal producir y ofrecer al recién nacido un fácil acceso a la leche materna, se encuentra suspendida por afuera de la pared del abdomen posterior y no se encuentra unida, soportada o protegida por estructura ósea (Lozano *et al.*, 2021)

2.11 Procesos fisiológicos involucrados en la producción de leche

El período más influyente en el desarrollo de la glándula mamaria, que determina no solo la producción de leche sino la calidad del calostro, está alineado con el peso vivo, condición corporal y metabolitos de la cabra en el último tercio de gestación y primera fase de lactancia (Davis, 2017; Flores-Nájera *et al*., 2021).

El proceso metabólico en la ubre de la cabra es de gran interés pues en la ubre son transformados los materiales recibidos de la sangre en productos muy específicos de secreción: proteínas, grasas, lactosa, sales, vitaminas y fermentos. Se requiere un gran volumen de sangre para suministrar a la glándula mamaria los elementos necesarios en la síntesis de la leche. Estudios previos han revelado que para que se produzca un litro de leche se requieren aproximadamente 500 litros de sangre circulando por la ubre (Bruckmaier, 2005). La liberación de oxitocina promovida por el tacto en la ubre tiene lugar a los 30 segundos, y su concentración aumenta significativamente en el primer minuto de ordeña, por lo que se recomienda ordeñar inmediatamente, para lograr la máxima eficiencia de la oxitocina. Al terminar a ordeña, la actividad glandular se reinicia (Bruckmaier, 2005). Cuando la ordeña se lleva a cabo en condiciones inadecuadas, produciendo estrés, tensión nerviosa, o algún tipo de malestar en los animales, se inhibe la eyección de la leche por activación del sistema nervioso simpático, lo que aumenta la secreción de catecolaminas (adrenalina), cuya función es contraria a la de la oxitocina, por lo que se recomienda mantener un ambiente tranquilo al momento de realizar la ordeña (Buxadé, 1996).

2.12 Fisiología de la lactancia en cabras y su afectación por la jerarquía

Los nutrientes disponibles en la sangre, la circulación de la sangre y la absorción de nutrientes a través la glándula mamaria son factores que afectan directamente la síntesis de leche. Durante la lactancia aumenta la puesta en funcionamiento de grasas, proteínas y glucosa de la zona periférica hacia la glándula mamaria favorecido por un cambio en la distribución sanguínea, la absorción de nutrientes necesarios en la síntesis de la leche (González, 2017). La curva de lactancia en cabras lecheras, se ha estudiado y descrito por investigadores (Ratto y López, 1990), sus hallazgos se resumen en los siguientes aspectos: a) Los niveles más altos producción se alcanzan entre las 8 y 12 semanas (60 a 90 días después del parto). b) A los 14 días de lactancia se alcanza un 80 por ciento del valor máximo de producción. c) A las 21 semanas la producción ha disminuido en 25 y 50 por ciento (240 a 260 días de lactancia). d) La duración de la lactancia oscila entre los 38 a 48 semanas. e) El descenso de la producción es de un siete por ciento mensual.

En los sistemas de producción caprinos lecheros, la curva de lactancia se caracteriza por una fase de incremento y un periodo de producción máxima seguido por una fase de disminución continuo en la producción. Este comportamiento es afectado por variables genéticas y ambientales; el registro del trayecto de la lactancia puede realizarse a base de funciones matemáticas que estiman el nivel de producción a través del tiempo (Ochoa y Restrepo, 1986; Quintero *et al*., 2007). Resultados de Ángel Marín *et al*. (2009) mostraron la siguiente curva de lactancia en cabras:

El pico de producción (típico) en el modelo se alcanzó a los 33.62 ± 1.536 días en cabras de primer parto, 38.98 ± 9.290 días en cabras de segundo parto y 42.17 ± 9.128 días para cabras de 3 o más partos. La producción al pico (ymax) fue de 3.06 ± 0.966, 3.10 ± 0.875 y 3.36 ± 0.691 kg para las cabras de uno, dos y tres o más partos, respectivamente.

Las gráficas de las curvas de lactancia para hembras de primera, segunda y tercera o más lactancias se muestran en la Figura 1, en ellas se observa que las cabras de primera lactancia alcanzaron el pico de producción en menor tiempo (días), y con producción máxima (kg) similar a cabras de segunda lactancia. En cabras de tres o más lactancias se observó una mayor producción y mayor número de días en leche con respecto a las cabras de una y dos lactancias. El período que más influyó en el desarrollo de la glándula mamaria, que determina no solo la producción de leche sino también la calidad del calostro, está alineado con el peso vivo, la condición corporal y el estado metabólico de la cabra en el último tercio de gestación y primera etapa de lactancia (Davis, 2017; Flores-Nájera *et al*., 2021).

La producción de leche caprina involucra diferentes variables, no solo fisiológicas, sino también etológicas, e incluso morfológicas, con respecto a la ubre caprina, las cuales impactan en la cantidad y calidad del calostro y la leche (Clark y Mora-García, 2017).Además, el consumo de alimento de los animales subordinados es generalmente perturbada por los animales dominantes, lo que puede afectar las principales características fisicoquímicas no solo en la producción y riqueza del calostro, sino también de la leche (Isidro-Requejo *et al*., 2019).

2.13 Producción de leche de cabra

Clarck y García-Mora (2017), encontraron que la leche de cabra es de gran importancia en la nutrición humana durante milenios, debido a la mayor similitud de la leche de cabra con la leche humana, así como a la formación de cuajada más suave, la mayor cantidad de pequeños glóbulos de grasa láctea; sin embargo, las deficiencias nutricionales clave limitan su idoneidad para los bebés. Las diferencias de proteínas, grasas y enzimas entre la leche de cabra y de vaca y su efecto sobre las propiedades físicas y sensoriales de la leche de cabra y los productos lácteos son tema actual para diversos investigadores. La leche de cabra es promocionada por su fácil digestibilidad y menores propiedades alergénicas en comparación con la leche de vaca.

Salinas-González *et al.* (2015), determinaron la calidad de la leche de cabras locales de la Comarca Lagunera en México, registraron valores de grasa, proteína, lactosa, sólidos no grasos y sólidos totales en cabras de seis rebaños, con manejo extensivo y alimentadas con plantas nativas, y esporádicamente su dieta se adicionaron esquilmos de cultivos agrícolas y obteniendo los resultados que se muestran en el cuadro 1.

Cuadro 1. Media, desviación estándar e intervalo de confianza de los componentes de la leche.

Variable / Variable	Mean / Media	S. D. / D. E.	Confidence interval / Intervalo de confianza
Fat (%) / Grasa (%)	4.13	0.66	3.89- 4.37
Protein (%) / Proteína (%)	3.32	0.29	3.21-3.42
Lactose (%) / Lactosa (%)	4.95	0.43	4.79-5.10
Non-fat Solids (%) / Sólidos No Grasos (%)	7.41	0.67	7.16-7.65
Total Solids (%) / Sólidos Totales (%)	13.14	0.79	12.76- 13.53
α=0.05			

La producción de leche de cabra varía de un año a otro y es estacional debido a los períodos reproductivos naturales y la disponibilidad de alimento durante la época de lluvias y residuos de alimento de las cosechas (Hoyos y Salinas, 1994; Mellado y Meza-Herrera, 2002; Flores-Najera *et al*., 2010; Rosales-Nieto *et al*., 2011; Delgadillo y Martin, 2015).

Los componentes del patrón de lactancia lo definen el pico de producción es decir la máxima producción de leche durante la lactancia y la persistencia, que indica la capacidad del animal para mantener una producción de leche continua después del pico de lactancia (Salinas y Martínez, 1988; Cannas *et al*., 2002). Es importante conocer la composición de la leche de cabra (grasa [FT], proteína [PR], lactosa [LC], sólidos no grasos [NFS] y sólidos totales [TS]) para identificar estrategias de alimentación y poder tomar decisiones oportunas, sobre todo en las épocas críticas en los sistemas de producción natural de secano (Bedoya *et al*., 2012). La composición de la leche de cabra puede ser afectada por diversos factores: la raza, características individuales, etapa de lactancia, el manejo, el clima, el fotoperíodo, la alimentación, entre otros (Veliz *et al.*, 2009; Maroteau *et al*., 2014; Salinas-González *et al*., 2016). Los productores de leche caprina desconocen las características fisicoquímicas de la leche que producen y cómo este producto puede verse afectado por cambios en el manejo del rebaño. Conocer los parámetros fisicoquímicos de la leche permite tener una mejor relación proveedor-industria láctea y beneficiarse de ventanas de oportunidad en los mercados que transforman la leche en queso o dulces para untar a base de leche (Salinas *et al*., 2011).

2.14 Importancia del calostro en la supervivencia de la cría

El calostro de cabra tiene mayor valor nutritivo e inmunológico elevado, incluso es mayor que el de bovinos, su importancia radica en que provee a los cabritos de inmunoglobulinas que proporcionan la inmunidad pasiva que necesitan para los 2 primeros meses de vida, los anticuerpos (moléculas grandes de proteína) penetran en la pared intestinal y de esta corriente sanguínea del cabrito, proceso que declina en un plazo de 1 hora después del nacimiento y disminuye drásticamente después de las 12 horas, terminándose en las primeras 24 horas, dicha transferencia inmunológica de la madre a la cría es alta en ganado caprino, principalmente porque las cabras tienen buena habilidad materna y los cabritos son muy hábiles para amamantarse en las primeras horas después del parto, que es cuando se presenta la mayor producción y absorción inmunológica (Villarreal *et al*., 2005).

El calostro ha sido muy estudiado por diversos investigadores y han encontrado que es la principal fuente de nutrición en rumiantes neonatos, cuya función biológica fundamental es la transferencia de inmunoglobulinas de la madre a su recién nacido, proporcionándole protección contra patógenos y otros desafíos ambientales posparto, debido a que el calostro está constituido por grasa, lactosa, vitaminas y minerales, así como una mezcla compleja de proteínas que participan activamente para fortalecer el sistema inmunológico. (E Hernandez-Castellano et al., 2014)

2.15 Factores que afectan en el reconocimiento madre-cría

Al nacer la cría depende totalmente de la madre para su alimentación, por lo que una expresión adecuada de la conducta materna es de gran importancia para su desarrollo y crecimiento (Nowak y Poindron, 2006). La conducta materna es la expresión de diversos patrones conductuales encaminados a incrementar la viabilidad del recién nacido, determinante en la adecuada nutrición y cuido de su progenie, dicha conducta es influenciada por la combinación de factores neuronales, humorales y sensoriales (González-Mariscal y Poindron, 2002).

En cualquier especie las hembras muestran comportamientos muy específicos en la conducta materna, por ejemplo, las ovejas, reducen su conducta gregaria y se aíslan del grupo antes del parto, aislarse del rebaño le facilita el reconocimiento y establecer el vínculo exclusivo con su cría (Poindron y Romeyer, 1997). En el nacimiento y durante el posparto, el reconocimiento entre la oveja y la cría sucede mediante señales olfativas, auditivas y visuales (Martínez, 2011).

La conducta de aislamiento es diferente entre razas y es una alteración transitoria al carácter altamente gregario de esta especie (Dumont y Boissy, 2000). La madre aprende a reconocer a su cría por su olor en las primeras dos a cuatro horas después de que nace, procurando el cuidado y amamantamiento exclusivo de su cría (Véliz-Deras *et al*., 2020). En ovejas, aunque un poco más tarde que la activación del olfato se activa el oído y la vista en el reconocimiento a distancia intervienen el oído y la vista (Ferreira *et al*., 2000). Las crías muestran preferencias hacia su madre a partir de las primeras 12 horas después de nacer, aunque al principio por algunos momentos intenten amamantarse de otras ovejas. Sin embargo, es hasta las 48 horas después del nacimiento que la capacidad para reconocer su madre es total, dicha capacidad generalmente se puede ver afectada por su capacidad para discriminar entre un conjunto de señales de aceptación que muestra la madre propia y señales de rechazo que muestra la madre ajena (Terrazas *et al*., 2002).

El reconocimiento madre-cría es crucial para la supervivencia de la descendencia. A largas distancias, este reconocimiento se basa principalmente en vocalizaciones. Debido a los cambios en la estructura de las vocalizaciones relacionados con la maduración, los padres tienen que aprender versiones de llamadas sucesivas producidas por sus hijos a lo largo de la ontogenia para mantener el reconocimiento (Briefer *et al*., 2012). Estudiar el vínculo entre las señales vocales y la ecología de las especies puede ayudar a comprender cómo evoluciona la comunicación animal. Cada vez hay más pruebas de un vínculo entre las limitaciones ecológicas (por ejemplo, el tamaño del grupo) y el grado de individualidad de las señales vocales (codificación de la identidad individual) y los procesos de reconocimiento vocal (Briefer y McElligott, 2011).

En la interacción madre-cría con ovinos se establece un vínculo fuerte y selectivo inmediatamente después del parto, mediante señales olfativas, auditivas y visuales, si la oveja acepta su cría como propia, le permite la ingesta de calostro, en caso contrario rechaza a la cría con comportamientos agresivos, durante la lactancia los cuidados de la madre evolucionan hasta el destete, etapa en que la cría es capaz de consumir alimento diferente a la leche materna. En la mayoría de los sistemas de producción ovina esta etapa se finaliza antes mediante un destete artificial generando estrés y afectando su comportamiento y fisiología (Nowak y Walker, 1999).

En la Comarca Lagunera el sistema de producción ovina (crianza) que predomina es la explotación extensiva, el cual depende del pastoreo en campo abierto, caracterizado por una gran disminución en la producción de forraje en el invierno, época de gestación en este sistema, lo cual afecta su alimentación en la etapa de preñez sufriendo una restricción nutricional reflejado en la pérdida de peso y condición corporal, afectando de forma negativa también el peso y las reservas energéticas de sus crías al nacimiento, así como el establecimiento del vínculo entre la oveja y su cría (Meza *et al*., 2014).

Cuando el establecimiento del vínculo madre-cría no es el óptimo, los índices de mortalidad posnatal de corderos se elevan, y disminuye la eficiencia reproductiva. Con la disminución en la producción de leche, se pone en riesgo el desarrollo de los corderos, y la evolución del vínculo madre-cría. Después del parto se establece un vínculo fuerte y selectivo entre la oveja y su cría (Poindron y Le Neindre, 1980). Al finalizar la expulsión del feto, la oveja tiende a ser atraída fuertemente hacia el líquido amniótico que recubre a la cría, llevando a cabo su acicalamiento durante los primeros 20 o 30 minutos, iniciando por la cabeza y continua por otras partes del cuerpo, emitiendo balidos bajos (Poindron y Le Neindre, 1980). Otros autores señalan que la oveja reconoce a su cría entre los

30 y 120 min establecido el contacto madre-cría y al momento de concluir el periodo de reconocimiento, la madre rechaza agresivamente a las crías ajenas (Poindron *et al*., 2007).

Los criterios que se toman en cuenta para identificar si la madre aceptó a una cría como propia es el que lleve a cabo los comportamientos propios de acicalamiento, la emisión de balidos bajos y manteniendo la posición de pie y orientada de forma paralela al cordero mientras este intenta mamar (Poindron y Le Neindre, 1980). Algunos de los comportamientos de la cría, como son las emisiones de balidos aumentan la probabilidad de sobrevivir, debido a que sus validos estimulan las vocalizaciones de la madre, ayudando a que se establezca y fortalezca el vínculo cría-madre (Nowak, 1999). Generalmente, la mayoría de los corderos se logran pararse a los 20 y 60 min después del nacimiento y se amamantan a los 20 y 95 min después de que nacen, es de gran importancia que la cría logre pararse lo antes posible y coordine sus acciones con la madre, pues será guiado por ella hacia la ubre para que pueda hacer la ingesta del calostro adecuada (Nowak, 1999). Tomando en cuenta la época en la que nacen las crías (invierno), se requiere elevar los niveles de energía y calor de la madre para mantener la temperatura corporal de los corderos, entre más tiempo dure la succión e ingesta del calostro por parte de la cría desde que nace, más pronto será reconocido por su madre (Nowak, 2006).

De 1 a 2 h después del parto, cuando hay cercanía entre la cría y la madre, el olfato adquiere una gran importancia en la formación de la memoria de la madre hacia su cría, sin embargo, a la distancia el sentido del oído y la vista se anteponen al del olfato (Ferreira *et al*., 2000).

Desde el nacimiento de la cría surge una interacción y un reconocimiento mutuo de la cría con la madre, permitiendo el establecimiento adecuado del vínculo entre ellos, contribuyendo a incrementar la tasa de supervivencia de la cría. Una conducta propia que se observa en la interacción madre-cría durante la lactancia es que la madre acepta que la cría tenga acceso a la ubre que se amamante en el tiempo y la veces que lo desee; mostrando rechazo a corderos ajenos (Poindron y Le Neindre, 1980).

III. Artículos

agriculture

MDPI

Article

Interactions between Social Hierarchy and Some Udder Morphometric Traits upon Colostrum and Milk Physicochemical Characteristics in Crossbred Dairy Goats

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Abstract: The possible relationship between udder morphometric variables (UMVs), chemical quality (CHQ) of both colostrum (CA), and milk (MK), as affected by goat's social rank (SR) (i.e., low-LSR, or high-HSR), was assessed. In late June, goats (Alpine–Saanen–Nubian x Criollo; $n = 38$; 25° N) were estrus-synchronized and subjected to a fixed-time artificial insemination protocol. Thereafter, in October, while a behavioral study was performed in confirmed-pregnant goats to define the SR classes ($n = 15$), live weight (LW), body condition (BCS), and serum glucose (GLUC) were registered on the last day of the behavioral study. The expected kidding date was 25 November. Both the UMVs (i.e., seven dates) and the CHQ (i.e., either one for CA and three times for MK) were collected across time (T). The UMVs involved udder perimeter (UDPER, cm), udder diameter (UDDIA, cm), left-teat (LTPER, cm) and right-teat perimeter (RTPER, cm), left-teat (LTLT, cm) and right-teat length (RTLT, cm), left-teat diameter (LTDIA, cm) and right-teat diameter (RTDIA, cm), and medium suspensory ligament (MSL, cm). The registered CHQ variables for both CA and MK were fat (FAT), protein (PRO), lactose (LAC), nonfat solids (NFS), freezing point (FP), and total solids (TS). The possible effect of SR, T, and the SR × T interaction upon the described response variables was tested. While LW favored the HSR goats (54.6 vs. 48.2 ± 1.7 kg; $p < 0.05$), neither BCS nor GLUC differed ($p > 0.05$) between SR. An SR × T interaction affected ($p < 0.05$) most UMVs (i.e., UDPER, MSL, LTLT, RTLT, LTDIA, and RTDI). UMV differences were associated with both changes across time and between SR. Whereas RTLT, LTDIA, RTDIA, and MSL showed their highest values one week prior to kidding, the largest UDPER values ($p < 0.05$) occurred within the week of kidding. Additionally, HSR goats showed increased values regarding UDPER, MSL, and LTLT. No differences ($p < 0.05$) between SR occurred regarding the CA-CHQ (i.e., FAT, PRO, LAC, NFS, FP, and TS). Still, an SR x T interaction affected ($p < 0.05$) the MK content of FAT, PRO, and NFS; while the largest values ($p < 0.05$) occurred on Day 7 postpartum, the other MK constituents decreased as the lactation advanced. Further, the HSR goats showed an enlarged MK-CHQ (i.e., FAT, PRO, and NFS). HSR goats merged some central behaviors such as aggressiveness, assertiveness, and supremacy to have primacy to feed access, augmenting their LW. Whereas said bodyweight advantage was not reflected upon in CA-CHQ, HSR goats augmented some morphological udder values (i.e., UDPER, MSL, and LTLT) and produced the best MK-CHQ (i.e., > FAT, > PRO, and > NFS) during early lactation. Therefore, both social rank (i.e., HSR goats), as well as the temporal transition stage from the last third of pregnancy to the first phase of lactation (i.e., time), operated as important modulators upon both udder architecture and milk quality in crossbred dairy goats under a dry-semiarid production system.

Keywords: goats; udder development; colostrum and milk quality; social dominance; live weight

1. Introduction

Goats have a multifaceted social arrangement, with a social hierarchy preserved by agonistic and affiliative behaviors; they are social and gregarious animals. A steady social milieu provides them with conditions to adapt to the environment by means of social learning and well-being, as suggested by the low threshold to respond to stressful events [1–3]. Although there is some information regarding the effect of social behavior with respect to productive efficiency, the significance of this relationship has not been appropriately explained, especially in goats [4]. Indeed, studies addressing the importance of social hierarchy in goat production and reproduction are neither recent nor abundant, highlighting what was formerly reported [5–7]. Domestic herbivores under grazing schemes exert social dominance, especially when grass is available ad libitum [8,9]. If there is greater feed availability and diversity, the dominant animal will have priority access to the best quality resources with respect to subordinate animals [10–12]. Said dominance in the herd's social hierarchy ensures access to the best available feed, either in grasslands or pastures, which in turn has a positive and significant effect on the live weight of the dominant animal. Moreover, a higher live weight is positively aligned with better metabolic status and greater productive and reproductive capacity [13].

In confined animals living in restrained environments, large animal densities can generate an even higher level of hostility and greater disturbance, promoting aggressive behavior and injuries, parallel to a reduction in the live weight, especially in animals of low hierarchical rank [14,15]. Even in group feeding under intensive and semi-intensive production schemes, it is considered that continuous competition among the members of the herd causes adverse results, not only regarding the provision of adequate space for feeders, but also regarding access to the ration feeding, because the ingestion behavior of the subordinates is habitually disturbed by the dominants; on top of that, goats exert a highly selective diet intake [16,17]. In addition, feed consumption is affected by other factors such as time of day, environmental temperature, season of the year, and other issues involved in the social hierarchy, affecting access to feed while generating animal rivalry and social disturbance [3,18].

Goat milk has been rooted in various civilizations and cultures worldwide [19]. During the last decade, world production of goat milk (*Capra hircus*) has increased by 12%, from 17.6 Mt in 2010 to almost 20.0 Mt in 2019, and the manufacture of goat cheese has increased by 18%, from 460.5 Kt in 2010 to 567.1 Kt in 2019 [20]. Mexico has close to 9 million goats, mainly crossbred animals and primarily under arid and semiarid ecotypes; in 2020, goat production generated almost 40,000 tons of meat and 167,000 tons of milk [21,22]. The Comarca Lagunera, an agroecological area situated in the arid lands of northern Mexico, has one of the main goat concentrations in the Americas, reaching first place in the production of goat milk at the national level, generating significant economic income mainly based on organic milk and meat production, the latter backing the social, economic, and biotic sustainability of producers [21–23]. Goat milk production involves different variables, not only physiological, but also ethological, and even morphological, with respect to the goat udder, which impact the quantity and quality of colostrum and milk [24]. In this regard, the most influential period in the development of the mammary gland, which determines not only the milk yield but the quality of the colostrum milk, is aligned to the live weight, body condition, and metabolic status of the goat in the last third of gestation and first stage of lactation [25,26]. Additionally, the feed consumption of subordinate animals is generally disturbed by dominant animals, which can affect the main physicochemical characteristics not only in the production and richness of colostrum, but also of milk [27]. Building on said findings, we hypothesized that in goats, a high social rank status leads to priority feed access, increasing both live weight and, in turn, udder morphometric values, affecting the quality of both colostrum and milk. Hence, this study aims to test such a hypothesis in crossbred dairy goats under a subtropical dry-hot environment.

2. Material and Methods

2.1. General

All the exerted experimental procedures, methods, and handling of the animals used in this study fulfilled the guidelines for ethical use, care, and animal welfare in research at both international [28] and national [29] levels, with reference Institutional Approval Number UAAAN-UL-20-3059.

2.2. Location, Environment, and General Management during the Reproductive Transition Pretrial Period

The study was performed in northern Mexico (Durango; 25°46′ N and 103°21′ W), under dry-hot semiarid subtropical conditions, at 1100 m above sea level, with a mean annual rainfall of 266 mm (range: 163 to 504 mm; June–September). The variations of the photoperiod in the region are 13:41 h during the summer solstice and 10:19 h during the winter solstice [30]. Adult goats of the crossbred dairy type (Alpine–Saanen–Nubian × Criollo, n = 38; 2–3 lactations) were considered during the pretrial phase (i.e., transition from anestrous to reproductive season; June–July). Both environmental conditions and general female management prior to the experimental period were homogeneous with those previously described, although our study was performed during the transition from anestrous to reproductive season (i.e., mid-June) [12,31].

Briefly, once the goats' anestrus status was confirmed in mid-June by means of two transrectal ultrasound scans, using a 7.5 MHz human prostate transducer (Aloka 500, MHz linear array; Corometrics Medical Systems, Inc., Wallingford, CT, USA), goats were subjected to an estrus induction protocol; upon estrus confirmation, all goats (n = 38) were subjected to a fixed-time artificial insemination (FTAI) procedure by the end of June, as previously outlined [31]. Thereafter, all the FTAI goats, and goats up to the first 4 months of pregnancy, were managed under the rangeland-based grazing system, predominant in the Comarca Lagunera [31]. Concisely, the rangeland has native vegetation typical of arid-land ecotypes such as *Cenchrus ciliare*, *Cynodon dactylon*, *Bouteloua* spp., *Sorghum halepense*, *Atriplex canescens*, sprouts and fruits from *Prosopis glandulosa*, and *Acacia farnesiana*; grazing was exerted from 10:00 to 18:00 h.

In general, the amount of range vegetation available is around 2000 kg dry matter ha^{-1}, with browse (60%) and forage herbs (40%) providing the main rangeland available feed biomass. Goats were daily directed to different grazing–browsing sites through feeding paths of approximately 6 to 8 km; thus, location-linked grazing restrictions can be considered minor. Additionally, goats were subcutaneously dewormed (Ivermectin 1%, Baymec, Bayer, Mexico City, Mexico) and also received doses of vitamin A (500,000 IU), D3 (75,000 IU), and E (50 mg) (Vigantol: ADE + Selenium, 250 mL, Zapopan, Jalisco, Mexico) one month prior to the FTAI protocol. Additionally, water, shades, and mineral salts (17% P, 3% Mg, 5% Ca, and 75% NaCl) were freely accessible during the experimental period [32].

2.3. Experimental Period: Defining the Social Rank among Female Goats

From the original 38 pregnant FATI goats, a total of 15 goats (51.4 ± 1.7 kg, body weight and 2.27 ± 0.13 units, body condition score) were considered to perform a 7-day behavioral study to define the social rank, either low (LSR) or high (HSR). This study was conducted during late October (i.e., 20–26 October), around 30 d prior to the expected average kidding date (i.e., 25 November). The behavioral test (n = 15) was carried out at feeding time (08:00, 13:00, and 17:00 h; 60 min each; 180 min day^{-1}, during 7 days) for a total of 1260 min (i.e., 21 h), as previously described [12]. The main behavioral goat-to-goat exerted interactions were recorded: hitting, threats, pushing, chasing, escaping, and evasion. Of note, the outlined agonistic contacts between two goats, either an instigator or a victim, exerting either physical contact or not, which eventually resulted in the physical displacement of an animal by the other, were considered ad hoc signs of the aggressive nature and social status of the assessed goats. Subsequently, with the information obtained from such behavioral interactions, that is, the result of winning or losing, a success index (SI) was individually obtained by using the formula:

$$SI = \text{number of won events}/(\text{number of won events} + \text{number of lost events}) \quad (1)$$

Based on the attained SI, the tested goats ($n = 15$) were classified into two social ranks: low-ranking goats (LSR; SI from 0 to 0.49; $n = 7$) and high-ranking goats (HSR; SI from 0.5 to 1; $n = 8$). Once the social rank based on the success index was defined, the variables live weight (LW, kg), body condition (BCS, units), and serum glucose (mg mL^{-1}) of the social-ranked goats were quantified on the last day of the behavioral test (i.e., 26 October). A blood sample was collected by jugular venipuncture to quantify serum glucose concentrations (AccuCheck Sensor Comfort, Roche, Mexico) with a reliability of 95%. A timeline of actions of the main activities carried out during the experimental period is shown in Figure 1.

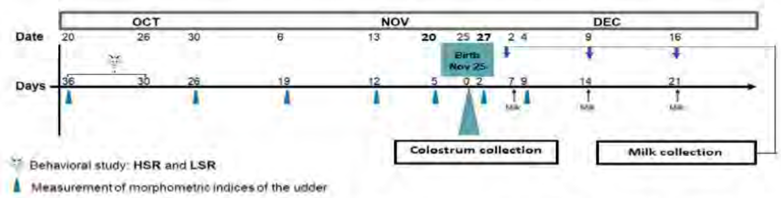

Figure 1. Timeline of actions along with the experimental period. A behavioral study was conducted in all the experimental units ($n = 15$) to determine the goat social rank, either high (HSR) or low (LSR). The behavior test was carried out at feeding time (08:00, 13:00, and 17:00) for a period of 60 min (i.e., 180 min total d^{-1} during 7 days). At the time of parturition and before kid suckling, a sample of 20 mL of colostrum was individually collected per goat from both udders; samples were pooled to generate a homogeneous mixture; the same process was performed during the milk postpartum sampling.

2.4. Measurement of Udder Morphometric Variables According to the Social Rank Status

2.4.1. Udder Morphometric Quantification

The morphological measurements of the udder were also quantified by a single trained technician using a Vernier (i.e., 30 cm) and tape measure (i.e., 100 cm). The udder of the experimental pregnant goats ($n = 15$), derived from the FTAI procedure, was measured weekly from Day 36 prepartum to Day 7 postpartum: 20 and 23 October; 6, 13, 20, and 27 November; and 4 December. The morphometric variables of the udder considered were: udder perimeter (UDPER, cm), udder diameter (UDDIA, cm), left-teat perimeter (LTPER, cm), right-teat perimeter (RTPER, cm), left-teat length (LTLT, cm), right-teat length (RTLT, cm), left-teat length diameter (LTDIA, cm), right-teat diameter (RTDIA, cm), and medium suspensory ligament (MSL, cm) according to the social rank (i.e., LSR and HSR) and time (i.e., 7 times); (Figure 2).

2.4.2. Colostrum and Milk Physicochemical Quantifications

At the time of parturition and before kid suckling, each goat was hand-milked, and a sample of 20 mL of colostrum was individually collected from both udders; samples from each goat were pooled to form a homogeneous mixture. Subsequently, colostrum samples were kept at 4 °C to later perform the chemical composition analyses. The response variables of the goat colostrum constituents were: fat (FATCA, %), protein (PROCA, %), lactose (LACCA), %), nonfat solids (NFSCA, %), freezing point (FPCA, units), and total solids (TSCA, %). Subsequently, the same procedure was carried out to evaluate the milk by chemical quality; the response variables registered to evaluate the goat milk constituents were: fat (FATMK, %), protein (PROMK, %), lactose (LACMK), %), nonfat solids (NFSMK, %), freezing point (FPMK, units), and total solids (TSMK, %) according to the social rank (i.e., LSR and HSR) and time (i.e., 3 times). Colostrum and milk component content was determined using a LactiCheck (LC-01 RR, Page and Pedersen International, Ltd., Hopkinton, MA, USA), after calibration for goat milk, as outlined by the manufacturer.

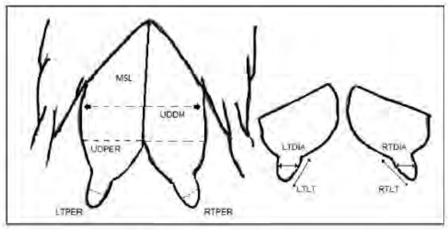

Figure 2. Morphological udder response variables considered: udder perimeter (UDPER, cm), udder diameter (UDDIA, cm), left-teat perimeter (LTPER, cm), right-teat perimeter (RTPER, cm), left-teat length (LTLT, cm), right-teat length (RTLT, cm), left-teat length diameter (LTDIA, cm), right-teat diameter (RTDIA, cm), and medium suspensory ligament (MSL, cm) registered from crossbred dairy goats (Alpine–Saanen–Nubian x Criollo; $n = 15$) in Northern Mexico (25° N).

2.5. Statistical Analyses

A split-plot ANOVA for repeated measures across time was used to evaluate the udder morphological variables: udder perimeter (UDPER, cm), udder diameter (UDDIA, cm), left-teat perimeter (LTPER, cm), right-teat perimeter (RTPER, cm), left-teat length (LTLT, cm), right-teat length (RTLT, cm), left-teat length diameter (LTDIA, cm), right-teat diameter (RTDIA, cm), and medium suspensory ligament (MSL, cm). Likewise, a split-plot ANOVA was also developed to evaluate the milk components, fat (FAT,%), protein (PROT,%), lactose (LAC,%), nonfat solids (NFS,%), freezing point (FP, °C), and total solids (TS,%), as affected by social rank (i.e., LSR and HSR). In both split-plot analyses, the goat was the experimental unit; the fixed effects of social rank (i.e., LSR, HSR) and sampling day (Time) were assessed using a MIXED model for repeated measures across time, with time as the repeated measure and the social-ranked goat as the repeated subject, regarded as a random error term. Additionally, a simple one-way ANOVA was developed in order to evaluate the components of colostrum, fat (FAT, %), protein (PRO, %), lactose (LAC, %), nonfat solids (NFS%), freezing point (FP, °C), and total solids (TS,%), according to social rank (i.e., LSR or HSR) in crossbred dairy goats (Alpine–Saanen–Nubian x Criollo; $n = 15$). Since no differences occurred between social rank regarding litter size (i.e., prolificacy), this variable was not considered in the final statistical models. Least-square means and standard errors for each class of social rank status, sampling time, and their interaction were computed; multiple mean comparisons were solved by means of Fisher's least significant differences. All statistical analyses were done using the procedures of SAS statistical package version 9.2; a significant difference between means was set at $p < 0.05$.

3. Results

The relationships between live weight (LW), body condition (BCS), and serum glucose (GLUC) according to social rank in crossbred dairy goats are shown in Table 1. The response variable LW was the only one that differed ($p < 0.05$) between social ranks, with an absolute difference of 6.4 kg favoring the HSR group. This difference between groups with respect to the LW was not reflected ($p > 0.05$) with respect to the variables BCS (2.27 ± 0.13 units) and GLUC (40.03 ± 2.26 mg mL^{-1}).

Table 1. Least-square means ± standard error for live weight (LW, kg), body condition score (BCS, units), and serum glucose concentration (GLUC, mg mL^{-1}) according to either low or high social rank (i.e., LSR and HSR) in crossbred (Alpine–Saanen–Nubian × Criollo; n = 15) dairy goats in northern Mexico (25° N) [1,2].

	Social Rank		
	LSR [1]	HSR [1]	p-Value
LW (kg)	48.20 ± 1.80 ^{b}	54.60 ± 1.63 ^{a}	0.017
BCS (units)	2.27 ± 0.14 ^{a}	2.27 ± 0.12 ^{a}	0.979
GLUC (mg mL^{-1})	40.88 ± 2.37 ^{a}	39.18 ± 2.15 ^{a}	0.601

^{a,b} Least-square means without a common superscript within response variable (i.e., lines), differ ($p < 0.05$). [1] In October, a behavioral study was carried out to define the social ranks, either low (LSR), or high (HSR) social rank. [2] Most conservative standard error is presented.

3.1. Effect of Social Rank and Time upon Udder Morphometric Components in Crossbred Dairy Goats

The dependent variables of the goat udder morphometric, components considering udder perimeter (UDPER, cm), udder diameter (UDDIA, cm), left-teat perimeter (LTPER, cm), right-teat perimeter (RTPER, cm), left-teat length (LTLT, cm), right-teat length (RTLT, cm), left-teat length diameter (LTDIA, cm), right-teat diameter (RTDIA, cm), medium suspensory ligament (MSL, cm) according to the social rank (i.e., LSR and HSR), and time (i.e., seven times), are shown in Table 2. No differences ($p > 0.05$) between social ranks occurred for any of the udder morphometric components response variables. However, the response variables UDPER, LTLT, RTLT, LTDIA, RTDIA, and MSL differed ($p < 0.05$) across time. Interestingly, when comparing the initial (October 20) and the final (December 04) values for UDDIA and MSL, an increased value ($p < 0.05$) for both variables occurred on the last date of the experimental period. The opposite scenario occurred with respect to the response variables LTLT, RTLT, LTDIA, and RTDIA, whose values decreased ($p < 0.05$) by the end of the measurement period.

Table 2. Least-square means ± s.e. for goat udder morphometric components considering udder perimeter (UDPER, cm), udder diameter (UDDIA, cm), left-teat perimeter (LTPER, cm), right-teat perimeter (RTPER, cm), left-teat length (LTLT, cm), right-teat length (RTLT, cm), left-teat length diameter (LTDIA, cm), right-teat diameter (RTDIA, cm), and medium suspensory ligament (MSL, cm) as affected by either social rank (i.e., LSR and HSR) and time (i.e., 7 times) in crossbred (Alpine–Saanen–Nubian × Criollo; n = 15) dairy goats in northern Mexico (25° N) [1,2].

Variables (cm)	Social Rank (SR)		Time (T)								p-Value	
	LSR	HSR	20 Oct	30 Oct	6 Nov	13 Nov	20 Nov	27 Nov	4 Dec	s.e. [2]	SR	T
UDPER	37.7 ^{ab}	38.5 ^{ab}	27.9 ^{c}	35.3 ^{b}	39.5 ^{ab}	41.8 ^{ab}	39.9 ^{ab}	43.6 ^{a}	38.8 ^{ab}	**2.4**	**0.68**	**0.04**
UDDIA	9.5 ^{a}	10.8 ^{a}	9.7 ^{a}	14.1 ^{a}	9.8 ^{a}	9.6 ^{a}	9.2 ^{a}	10.0 ^{a}	8.6 ^{a}	**1.8**	**0.34**	**0.42**
LTPER	7.5 ^{a}	7.6 ^{a}	8.0 ^{a}	7.5 ^{a}	7.8 ^{a}	7.3 ^{a}	8.7 ^{a}	6.8 ^{a}	6.7 ^{a}	**1.2**	**0.89**	**0.86**
RTPER	7.6 ^{a}	7.6 ^{a}	8.2 ^{a}	7.2 ^{a}	8.3 ^{a}	7.4 ^{a}	8.7 ^{a}	6.9 ^{a}	6.3 ^{a}	**1.2**	**0.97**	**0.89**
LTLT	5.6 ^{ab}	5.7 ^{ab}	5.7 ^{ab}	7.4 ^{a}	5.8 ^{ab}	5.9 ^{ab}	6.3 ^{ab}	4.4 ^{b}	4.1 ^{b}	**0.8**	**0.83**	**0.04**
RTLT	5.8 ^{abc}	5.7 ^{abc}	5.7 ^{ab}	6.9 ^{a}	6.5 ^{ab}	6.6 ^{ab}	6.4 ^{abc}	4.3 ^{bc}	3.9 ^{c}	**0.8**	**0.98**	**0.04**
LTDIA	2.0 ^{ab}	2.0 ^{ab}	2.2 ^{ab}	3.0 ^{a}	1.9 ^{bc}	1.8 ^{bc}	2.5 ^{ab}	1.6 ^{bc}	1.1 ^{c}	**0.3**	**0.85**	**0.04**
RTDIA	2.0 ^{ab}	2.0 ^{ab}	2.4 ^{ab}	2.9 ^{a}	2.1 ^{ab}	1.8 ^{bc}	2.5 ^{ab}	1.6 ^{bc}	1.1 ^{c}	**0.3**	**0.99**	**0.04**
MSL	19.5 ^{abc}	20.1 ^{abc}	17.2 ^{bc}	16.6 ^{c}	21.8 ^{ab}	23.0 ^{a}	20.8 ^{abc}	20.1 ^{abc}	19.3 ^{abc}	**1.7**	**0.64**	**0.03**

^{a,b,c} Least-square means without a common superscript within response variable differ ($p < 0.05$). [1] In October, a behavioral study was carried out to define the social ranks, either low (LSR) or high (HSR) social rank. [2] Most conservative standard error is presented.

3.2. Effect of the Interaction Social Rank × Time upon Udder Morphometric Components in Crossbred Dairy Goats

A social rank × time interaction affected ($p < 0.05$) the morphometric variables UDPER, LTLT, RTLT, LTDIA, RTDIA, and MSL; yet, the other udder values were not affected (i.e., UDDIA, LTPER, and RTPER). Most of the observed social rank × time were interaction effects were related to the large response variable differences were observed across time ($p < 0.05$). Indeed, while the variables RTLT, LTDIA, RTDIA, and MSL showed their highest values the week before kidding, the variables UDPER and MSL showed a continuous and ascending increase from the first measurement (i.e., 20 October), achieving the highest values one week prior to kidding (i.e., MSL), as well as within the week of kidding (i.e., UDPER). However, for the variables UDPER (T6), MSL (T6 and T7), and LTLT (T2 and T5), increased values occurred in the HSR group (Table 3).

Table 3. Least-square means ± s.e. for the interaction social rank (i.e., LSR and HSR) and time (i.e., 7 times) for goat udder morphometric components considering udder perimeter (UDPER, cm), udder diameter (UDDIA, cm), left-teat perimeter (LTPER, cm), right-teat perimeter (RTPER, cm), left-teat length (LTLT, cm), right-teat length (RTLT, cm), left-teat length diameter (LTDIA, cm), right-teat diameter (RTDIA, cm), and medium suspensory ligament (MSL, cm) in crossbred (Alpine–Saanen–Nubian × Criollo; $n = 15$) dairy goats in northern Mexico (25° N) [1,2].

Variables (cm)	20 Oct		30 Oct		6 Nov		13 Nov		20 Nov		27 Nov		4 Dec			p-Value
	LSR	HSR	LSR	HSR	LSR	HSR	LSR	HSR	LSR	HSR	LSR	HSR	LRS	HSR	s.e. [2]	SR × T
UDPER	27.7 ^{d}	28.1 ^{d}	34.3 ^{c}	36.1 ^{bc}	39.2 $^{a–c}$	39.8 $^{a–c}$	41.7 ^{ab}	41.9 ^{ab}	39.7 $^{a–c}$	41.5 $^{a–c}$	41.3 ^{b}	45.5 ^{a}	39.5 $^{a–c}$	43.2 $^{a–c}$	**2.2**	**0.001**
UDDIA	9.4 ^{a}	10.2 ^{a}	9.4 ^{a}	9.4 ^{a}	9.8 ^{a}	9.8 ^{a}	10.0 ^{a}	9.5 ^{a}	9.3 ^{a}	9.1 ^{a}	9.7 ^{a}	10.4 ^{a}	8.6 ^{a}	8.8 ^{a}	**0.6**	**0.614**
LTPER	8.1 ^{ab}	8.0 ^{ab}	7.0 ^{b}	7.9 ^{ab}	7.9 ^{ab}	7.8 ^{ab}	7.0 ^{b}	7.6 ^{ab}	7.9 ^{ab}	9.4 ^{a}	7.2 ^{ab}	6.4 ^{b}	7.3 ^{ab}	6.2 ^{b}	**0.8**	**0.411**
RTPER	8.4 ^{ab}	8.1 ^{ab}	6.9 $^{a–c}$	7.4 $^{a–c}$	8.0 $^{a–c}$	8.6 ^{ab}	6.8 $^{a–c}$	7.9 $^{a–c}$	8.3 ^{ab}	9.1 ^{a}	7.5 $^{a–c}$	6.5 ^{bc}	7.2 $^{a–c}$	5.6 ^{c}	**0.9**	**0.248**
LTLT	5.7 $^{b–e}$	5.8 $^{b–d}$	6.8 ^{b}	8.0 ^{a}	5.8 $^{b–d}$	5.7 $^{b–d}$	5.9 ^{bc}	5.9 ^{bc}	5.7 $^{b–e}$	6.9 ^{a}	5.1 $^{b–e}$	3.9 ^{e}	4.2 $^{c–e}$	4.0 ^{de}	**0.6**	**0.001**
RTLT	5.8 $^{a–c}$	5.6 $^{a–d}$	6.7 ^{a}	7.0 ^{a}	6.5 ^{ab}	6.4 ^{ab}	6.8 ^{a}	6.5 ^{ab}	5.6 $^{b–d}$	7.0 ^{a}	4.7 $^{a–d}$	3.9 ^{d}	4.1 ^{cd}	3.8 ^{d}	**0.7**	**0.001**
LTDIA	2.2 ^{bc}	2.2 ^{bc}	3.1 ^{a}	2.9 ^{a}	1.8 $^{b–d}$	1.9 ^{bcd}	1.5 $^{c–e}$	1.9 $^{b–d}$	2.5 ^{ab}	2.5 ^{ab}	1.7 ^{cd}	1.6 $^{c–e}$	1.0 ^{e}	1.2 ^{de}	**0.2**	**0.001**
RTDIA	2.4 $^{b–d}$	2.4 $^{b–d}$	3.1 ^{a}	2.8 ^{ab}	1.9 $^{c–f}$	2.2 $^{b–e}$	1.6 $^{e–g}$	2.0 $^{c–f}$	2.5 ^{abc}	2.4 $^{a–c}$	1.7 $^{d–g}$	1.5 ^{fg}	1.1 ^{g}	1.1 ^{g}	**0.2**	**0.001**
MSL	17.1 $^{e–g}$	17.3 $^{d–g}$	16.7 ^{fg}	16.5 ^{g}	21.0 $^{a–d}$	22.5 ^{ab}	23.5 ^{a}	22.7 ^{ab}	20.3 $^{a–f}$	21.2 $^{a–c}$	18.4 $^{c–e}$	20.8 ^{ab}	18.3 $^{c–g}$	20.7 ^{ab}	**1.3**	**0.005**

[a,b,c,d,e,f,g] Least-square means without a common superscript within response variable differ ($p < 0.05$). [1] In October, a behavioral study was carried out to define the social ranks, either low (LSR) or high (HSR) social rank. [2] Most conservative standard error is presented.

3.3. *Effect of Social Rank upon Colostrum Quality Composition in Crossbred Dairy Goats*

The dependent variables of the goat colostrum constituents, fat, protein, lactose, nonfat solids, freezing point, and total solids, as affected by the social rank (i.e., LSR and HSR), are shown in Table 4. No differences ($p > 0.05$) between social ranks (i.e., LSR and HSR) were observed with respect to the quality of the colostrum. Therefore, these results suggest that variables LW, BCS, or even GLUC are not directly related to the components that define the quality of colostrum (Table 4).

Table 4. Least-square means ± standard error for goat colostrum constituents, fat (FATCA, %), protein (PROCA, %), lactose (LATCA), %), nonfat solids (NFSCA, %), freezing point (FPCA, units), and total solids (TSCA, %) according to the social rank (i.e., LSR and HSR) in crossbred (Alpine–Saanen–Nubian × Criollo; $n = 15$) dairy goats managed under semi-intensive conditions in northern Mexico (25° N) [1,2,3].

Variables, (%)	Social Rank		
	LSR	HSR	p-Value
FATCA	7.2 ± 2.2	7.6 ± 2.0	0.892
PROCA	10.6 ± 1.7	10.0 ± 1.6	0.804
LACCA	3.3 ± 0.3	2.6 ± 0.3	0.184
NFSCA	12.0 ± 2.4	15.6 ± 2.2	0.300
FPCA	0.3 ± 0.0	0.3 ± 0.0	0.284
TSCA	23.1 ± 3.0	22.3 ± 2.7	0.838

[1] No differences for any of the response variables occurred between LSR and HSR; most conservative standard error is presented. [2] In October, a behavioral study was carried out to define the social ranks, either low (LSR) or high (HSR) social rank. [3] Most conservative standard error is presented.

3.4. Effect of Social Rank and Time upon Milk Quality Composition in Crossbred Dairy Goats

The milk constituents quantified in this study, that is fat, protein, lactose, nonfat solids, freezing point, and total solids according to the social rank (i.e., LSR and HSR) and time (i.e., three times), in crossbred dairy goats are shown in Table 5. No effect of the social rank ($p > 0.05$) was observed with respect to MK-CHQ shown in all the analyzed components. Regarding the time factor, however, only the PROMK and NFSMK variables showed the highest values ($p < 0.05$) at Time 1 and later showed a reduction as the lactation stage advanced.

Table 5. Least-square means ± standard error for goat milk constituents, fat (FATMK, %), protein (PROMK, %), lactose (LACMK), %), nonfat solids (NFSMK, %), freezing point (FPMK, units), and total solids (TSMK, %) according to the social rank (i.e., LSR and HSR) and time (i.e., 3 times) in crossbred (Alpine–Saanen–Nubian × Criollo; n = 15) dairy goats in northern Mexico (25° N) [1,2].

Variables	Social Rank		Time			*p*-Value
	LSR	HSR	1	2	3	
FATMK, %	3.5 ± 0.5^{a}	4.2 ± 0.5^{a}	4.6 ± 0.6^{a}	3.2 ± 0.6^{a}	3.8 ± 0.7^{a}	0.380
PROMK, %	3.2 ± 0.1^{ab}	3.4 ± 0.1^{a}	3.8 ± 0.2^{a}	3.3 ± 0.2^{ab}	2.7 ± 0.2^{b}	0.470
LACMK, %	4.1 ± 0.1^{a}	4.2 ± 0.1^{a}	4.3 ± 0.1^{a}	4.0 ± 0.1^{a}	4.2 ± 0.1^{a}	0.491
NFSMK, %	7.8 ± 0.3^{ab}	8.3 ± 0.3^{a}	8.8 ± 0.3^{a}	8.1 ± 0.3^{ab}	7.3 ± 0.4^{b}	0.324
FPMK, °C	0.4 ± 0.0^{a}	0.4 ± 0.0^{a}	0.4 ± 0.01^{a}	0.4 ± 0.01^{a}	0.4 ± 0.02^{a}	0.742
TSMK, %	11.9 ± 0.7^{a}	12.8 ± 0.8^{a}	13.6 ± 0.9^{a}	11.7 ± 0.9^{a}	11.7 ± 1.0^{a}	0.461

[a,b] Least-square means without a common superscript within response variable differ ($p < 0.05$). [1] In October, a behavioral study was carried out to define the social ranks, either low (LSR) or high (HSR) social rank. [2] Most conservative standard error is presented.

3.5. Effect of the Interaction Social Rank × Time upon Udder the Milk Components in Crossbred Dairy Goats

An SR × T occurred regarding FATMK, PROMK, and NFSMK (Table 6). Although LACMK, FPMK, and TSMK were not influenced ($p > 0.05$) by the SR × T interaction, larger FATMK, PROMK, and NFSMK values occurred at T2 in the HSR group. Regarding the variables LACMK, NFSMK, and TSMK, the highest values also occurred in T1. The FPMK variable was affected ($p > 0.05$) neither by social rank, nor by sampling time (Table 6).

Table 6. Least-square means ± standard error for the interaction social rank (i.e., LSR and HSR) and time (i.e., 3 times) regarding the goat milk constituents for fat (FATMK, %), protein (PROMK, %), lactose (LACMK), %), nonfat solids (NFSMK, %), freezing point (FPMK, units), and total solids (TSMK, %) according to the social rank (i.e., LSR and HSR) and time (i.e., 3 times) in crossbred (Alpine–Saanen–Nubian × Criollo; n = 15) dairy goats in northern Mexico (25° N) [1,2].

Variables	Time 1		Time 2		Time 3		*p*-Value
	LSR	HSR	LSR	HSR	LSR	HSR	
FATMK (%)	4.6 ± 0.6^{ab}	4.7 ± 0.6^{a}	2.7 ± 0.4^{b}	3.7 ± 0.4^{a}	3.3 ± 0.6^{ab}	4.4 ± 0.7^{ab}	0.049
PROMK (%)	3.8 ± 0.2^{a}	3.8 ± 0.2^{a}	3.1 ± 0.2^{bc}	3.5 ± 0.1^{a}	2.6 ± 0.1^{c}	2.9 ± 0.1^{b}	0.002
LACMK (%)	4.5 ± 0.2^{a}	4.2 ± 0.2^{ab}	3.7 ± 0.2^{b}	4.3 ± 0.2^{a}	4.2 ± 0.2^{ab}	4.2 ± 0.2^{ab}	0.165
NFSMK (%)	9.0 ± 0.4^{a}	8.7 ± 0.4^{ab}	7.5 ± 0.4^{cd}	8.6 ± 0.4^{ab}	7.1 ± 0.3^{d}	7.7 ± 03^{bc}	0.013
FPMK (°C)	0.4 ± 0.0^{a}	0.4 ± 0.0^{a}	0.4 ± 0.0^{a}	0.4 ± 0.01^{a}	0.4 ± 0.0^{a}	0.4 ± 0.0^{a}	0.941
TSMK (%)	13.7 ± 0.9^{a}	13.6 ± 0.8^{ab}	11.0 ± 0.9^{b}	12.4 ± 0.8^{ab}	11.0 ± 0.9^{b}	12.3 ± 1.0^{ab}	0.106

[a,b,c] Least-square means without a common superscript within response variable differ ($p < 0.05$). [1] In October, a behavioral study was carried out to define the social ranks, either low (LSR) or high (HSR) social rank. [2] Most conservative standard error is presented.

4. Discussion

Our working hypothesis stated that a high social rank status leads to priority feed access, increasing live weight aligned with augmented udder morphometric values; thereafter, increased quality of both colostrum and milk would be expected in high-social-ranked crossbred dairy goats. According to our general results, such a working hypothesis cannot be rejected. In fact, both the social rank, mainly the high-social-ranked goats, as well as time of sampling, considered the temporal stage of the last third of pregnancy and its transition to the first phase of lactation, operated as key modulators upon both udder architecture, as well as milk quality, with no effect of social rank upon colostrum quality in crossbred dairy goats managed under semi-extensive, dry-semiarid conditions (≈260 mm rainfall yearly). Our research outcomes endorse that high-social-ranked goats merged some essential behaviors such as aggressiveness, assertiveness, and supremacy to have primacy to feed access, augmenting live weight. Even though such an increased body weight advantage was not reflected upon in an enlarged colostrum quality, there were witnessed increases in both udder morphometric size (i.e., UDPER, MSL, and LTLT) and milk quality (i.e., fat, protein, and nonfat solids) in the HSR goats.

Goats are a gregarious species with complex social interactions between dominant and subordinate animals. High-ranking animals generally exert priority access to more and better available resources, which favor productive performance [8,12,33–37]. This high hierarchy is positively correlated to privileged access to food, which generally translates into greater increases in live weight in the dominant groups (i.e., HSR) [12]. In addition to a higher LW and BCS and even metabolic state, a high social rank generates greater reproductive and productive success [12,13,37–41]. Our main research outcomes are aligned with such aforementioned findings.

In goats, a positive relationship has been described between udder morphological measurements and milk production [42]. When evaluating the relationship between udder characteristics and milk production in goats, a positive association was observed; then, such findings were also positively aligned with increases in LW and BCS across time [43,44]. These results are consistent with our study since the udder variables UDPER, MSL, LTLT, RTLT, LTDIA, and RTDIA showed increased values when comparing the initial values with respect to those obtained at the end of the experimental period. Therefore, the transition from the third trimester of gestation to the early stage of lactation positively affected some of the main components of the architecture of both the udder and the nipple. Other studies have reported positive associations between udder morphometry with respect to milk quality and yield, not only in goats, but also in cattle and sheep [45–49]. Although increases in udder morphometry components (i.e., UDPER, MSL, and LTLT) and some quality milk constituents (i.e., FAT, PRO, and NFS) occurred in the HSR in our study, such a scenario was not observed when the colostrum quality was evaluated; in fact, no differences occurred between social ranks.

Studies aimed at understanding the modulation of the colostrum quality components are of fundamental relevance due to the central role that colostrum exerts upon both peri- and postnatal kid survival and also upon the sustainability of the production system itself [50]. As in other mammals, kids are born with low levels of immunoglobulins [51,52] and, therefore, depend on an adequate intake of colostrum to obtain passive immunity that guarantees a competent future health status [53,54]. Additionally, a higher protein concentration of colostrum, mainly immunoglobulins, promotes faster colonization of the intestine by anaerobic bacteria. Moreover, a density >1.070 g/cm^3 enhanced the growth of *Lactobacilli* and *Bifidobacterium* spp., which reduced hostile microflora, such as *Coliforms* or *Enterococci*, improving in parallel the daily weight gains of the newborn [55]. In this context, although a higher social rank generates a greater live weight in goats, which should be positively aligned with the viability of the kids as they have better access to better-quality colostrum [56–59], such a physiologic scenario was not observed in our study.

For millennia, goat milk has been a central issue of human nutrition in different cultures and civilizations, due to its great similarity to human milk [24]. Goat milk is composed of 85.5% water and 14.5% of total solids, which are made up of fat, protein, carbohydrates, and minerals; said composition largely evidences the high quality of goat milk [27,60]. The production and quality of milk are influenced not only by intrinsic factors (i.e., genetic background, production level, lactation stage, physiological state), but also by extrinsic factors as well (i.e., year, season of the year, feed quality). Certainly, both in extensive and semi-extensive systems, the season of the year defines the availability of pasture and directly affects milk composition [61].

Other extrinsic factors include temperature, herd management, milking system, feeding, health status, and duration of the dry period, among others [62,63]. However, limited information has been generated regarding the interplay between social behavior and milk production; most studies have been focused on disentangling the social interaction with respect to animal growth and reproductive performance [8,12,33–35,37,40]. Nonetheless, milk quality can also be modulated by the social array or production system; when compared to housed cows, grazing cows interacted more socially, increased affiliative interactions, and produced higher-quality milk (i.e., > fat%, > urea, mg mL^{-1}, and < somatic cells and bacterial count, log10 mL^{-1}) [64]. In line with such findings, in our study, the HSR goats demonstrated increased milk quality, with augmented fat, protein, and nonfat solids percentages during early lactation regarding the LSR goats ($p < 0.05$). A possible physiometabolic scenario explaining such outcomes is that the higher LW observed in the HSR goats could have granted better performance when competing against the LSR goats regarding the feed intake while partitioning nutrients are partitioned, privileging milk quality, especially its fat, protein, and nonfat solids content. According to our literature search, this study seems to be the first report assessing the main interactions between social hierarchy, live weight, metabolic status, udder architecture, and milk quality in goats.

5. Conclusions

Although we still have a disconnected understanding about the interplay that goat social rank, live weight, and some udder morphometric traits exert upon colostrum and milk quality, our results endorse that high-social-ranked goats merged some central behaviors such as aggressiveness, assertiveness, and supremacy to have primacy to feed access, augmenting their live weight. Whereas said body weight advantage was not reflected upon in colostrum quality, the high-social-ranked goats improved some morphological udder values (i.e., UDPER, MSL, and LTLT), and produced milk with increased quality, specifically with augmented fat, protein, and nonfat solids content at specific points during the early stages of lactation. Therefore, our results confirmed our working hypothesis in that both the social rank, mainly the high-social-ranked goats, as well as the temporal stage of the last third of pregnancy and the first phase of lactation (i.e., time), operated as important modulators upon both udder architecture, as well as milk quality, in crossbred dairy goats managed under a semi-extensive, dry-semiarid production system, the latter scenario being fundamental for the sustainability of marginal goat production systems, the producer and his family.

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animals

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Original article

Maternal social hierarchy, morphometric traits, live weight and metabolic status as related to the offspring preweaning growth in crossbred dairy goats

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Simple Summary: This study aimed to define the possible maternal social rank (SR) effect, either low (LSR) or high (HSR), by quantifying diverse morphophysiological maternal markers upon the birth-to-weaning growth dynamics of their kids. The maternal-SR was defined through a behavioral study conducted 30 days prior to the expected kidding date. The behavioral study was conducted during the feeding time (i.e., 08:00, 13:00 & 17:00; 60 min test-1, 180 min d-1). Our research outcomes suggest that HSR-goats articulated physiological and morphometric responses to achieve better and greater access to food, increasing prepartum and postpartum live weight & zoometric values, however, these advantages were not reflected in a higher level of productivity neither regarding litter size nor about the kid or total offspring growth during the birth-to-weaning period. The last seems to be a very interesting physio-ethological strategy to assure the survival of their kids, irrespectively of social rank, in crossbred dairy goats managed under dry-semi-arid marginal production systems.

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Abstract: We evaluated the possible effect of maternal social rank with respect to different morpho-physiological maternal indicators such live weight (LW, kg), body condition score (BCS, units), thoracic diameter (TD, cm), thoracic perimeter (TP, cm), and serum glucose content (GLUC, mg dL-1), upon the kid´s live weights (LWK, kg) during the birth-to-weaning period. To define the SR, a behavioral study was conducted on pregnant goats (Alpine-Saanen-Nubian x Criollo; n=15, 2-3 yr. old) 30 days prior to the expected kidding date to determine the SR, either high (HSR) or low (LSR) managed under semi-extensive conditions. The behavioral study was conducted during the feeding time (i.e., 08:00, 13:00 & 17:00; 60 min test-1, 180 min d-1). Goats were managed under semi-extensive conditions in the norther-arid Mexico (25° N). The HSR-goats showed higher values ($p < 0.05$) regarding prepartum, parturition and postpartum weights and zoometric values, however, no differences ($p > 0.05$) between HSR and LSR goats occurred neither with respect to the maternal serum glucose values nor regarding to litter size, individual kid´s weights or litter weights at weaning. Such research outcomes are interesting in that, it seems that, despite the corporal, morphological and metabolic increases observed in the HSR goats, such physiological and ethological advantages were not diverted toward better litter size or preweaning growth rates; both social ranked goats assured the survival of their kids. The last seems to be a very interesting physio-ethological strategy in crossbred dairy goats managed under dry-semi-arid marginal production systems.

Keywords: goats; social hierarchy; maternal status; preweaning growth

1. Introduction

The goat (*Capra hircus* L.) is a highly gregarious species that lives in very stable social groups based on a linear social hierarchy of relationships among its members [1-4]. Despite the scientific attention that this social hierarchy has received, its importance and dimension have not been fully explained; to know such information could be a key component for the welfare and management of animals in the various production schemes [5,6]. This social hierarchy is a common characteristic in most domestic herbivores, especially in grazing systems, where food is available *ad libitum*. In general, the dominant animal will have privileged access to better quality resources compared to subordinate animals, regardless of whether there is greater food availability-diversity [7-11].

Goat production can be modulated by different variables, not only physiological, but also ethological, and even morphological [12]. In this sense, the food consumption of subordinate animals is generally disturbed by dominant animals, which in turn can affect the physiological and morphological characteristics, not only of the mother, but also of her offspring [13]. Considering the importance of goat production, especially as a productive strategy to mitigate the effects caused by climate change, goats emerge as a recurring theme on the public agenda and scientific literature [14-16]. Based on the previous information, we hypothesize that female goats with a high social hierarchy have better physiological and morphometric values compared to subordinate goats, which translates into a better nutritional environment that generates higher birth weights of the offspring from this social rank. Therefore, we aimed to identify the possible effect of maternal social rank with respect to various morpho-physiological indicators such as live weight, body condition, thoracic diameter, thoracic perimeter, and serum glucose content, in order to evaluate the possible maternal effect of such variables with respect to the preweaning growth rate dynamics of their offspring; this was the scientific question of the study.

2. Materials and Methods

2.1 Ethical note

In the present investigation, the animal management was in accordance with the technical specifications for the production, care and use of laboratory animals [17]. Moreover, all the experimental units considered in this research, as well as the experimental procedures, methods and management, were developed considering the requirements issued for good ethical use, care and animal welfare both at international [18] and national [19] levels, and with institutional approval registered under the reference: UAAAN-UL-18-3059.

2.2 Location of the study area, animals and management

The present study was carried out between October-December in northern Mexico, in the Comarca Lagunera (25° 51′ N, 103° 16′ W, 1190 m) located in the subtropics with a dry-hot semi-arid climate and average annual rainfall of 266 mm (range: 163 to 504 mm; Jun to Sep) [20]. In this region, the photoperiod during the summer solstice is 13:41 h, and 10:19 h for the winter solstice. Crossbred dairy adult goats (Alpine-Saanen-Nubian x Criollo; n=15, under semi-intensive conditions and 2-3 yr. old) were assigned to two groups based on their social rank (HSR; n=8 and LSR; n=7). The onset of the study was 1-month prior kidding, with Nov-25 as expected kidding date. All goats were housed in a 150 m^2 (10 x 15

m) pen for one month prior to kidding. The goats were fed alfalfa hay with free access three times a day (08:00, 13:00 and 17:00); water and mineral salts were also provided in the same way, considering the NRC requirements [21].

2.2 Behavioral study to define the maternal social rank

All goats under study (n=15) were subjected to a behavioral test (i.e., Oct-20), 36 days prior to the average kidding date, in order to define the social hierarchy among the goats. The behavior test was performed at feeding time (i.e., 08:00, 13:00 and 17:00) for a period of 60 min (180 min day^{-1}), for 7 days (Figure 1). The main behavioral interactions exerted and documented among goats were: hitting, threatening, pushing, chasing, fleeing and evading. In this regard, the observed agonistic interactions between two individuals involve an instigator and a victim, whether or not the physical contact occurred, but considered the physical displacement of an animal. With the information obtained from the agonistic interactions, that is, the result of winning or losing, a success rate index (SI) was calculated considering the following formula:

$$SI = \text{number of cases won} / (\text{number of cases won} + \text{number of cases lost})$$

Considering the recommendations reported [15], the goats were individually classified into two social ranks: seven low-rank goats (LSR; IE 0 to 0.49) and eight high-rank goats (HSR; IE 0.5 to 1).

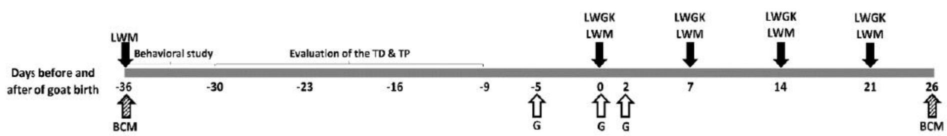

Figure 1. Schematic representation of the study protocol, indicating the main actions carried out throughout the research period. A behavioral study was conducted to determine the social rank of the 15 pregnant goats, either high (HSR) or low (LSR). The behavioral study was carried out at feeding time (08:00, 13:00, and 17:00) for a period of 60 minutes (180 minutes per day). Subsequently, regarding the dam, the response variables live weight (LWM, kg); body condition (BCM, units); thoracic diameter (TD, cm); thoracic perimeter (TP, cm), and serum glucose content (GLU, mg dL-1), were evaluated. Regarding kids, live weight at birth (LWK, kg) and litter size were registered under semi-extensive management conditions, in northern Mexico (25° N).

2.3 Quantification of the response variables according to maternal social rank

To determine live weight, an electronic scale with a capacity of 250 kg and a precision of 50 g (Torrey 110v/220v, Digital Industrial Scale, Jalisco, Mexico) was used. The live weight of the 15 pregnant goats was recorded 36 d before kidding, and later on the kidding day as well as on days 7, 14 and 21 postpartum. Goats were weighed in the morning prior to feeding. Body condition score (BCS) was considered an indicator of the level of body reserves present in an animal, and therefore an indirect marker of the metabolic status. The BCS indicates the amount of lipid (i.e., fat) and protein (i.e., muscle) reserves that are available to the animal for maintenance, reproduction, and production. The BCS is an important record for producers to optimize production (i.e., meat and/or milk), as well as to define strategies for feeding, reproduction and animal welfare. BCS quantification considered the technique of palpation of the lumbar region [22], quantifying the level of muscle and fat tissue in the animal, using a scale from 1 to 4 (i.e., 1 =skinny; 4=fat); this activity was carried out by specialized technicians.

Regarding the morphometric variables, the thoracic diameter and perimeter were recorded; these variables were registered during four consecutive weeks, starting 30 days before kidding. The thoracic diameter was measured with an adjustable zoonometer and the thoracic perimeter with a calibrated tape measure [23]. The thoracic diameter (TD, cm) was determined by measuring from the dorsal point to the lower sternal region and the thoracic perimeter (TP, cm) was determined by measuring from the lowest dorsal point of the interscapular region towards the lower sternal region to return to the starting point (Fig. 2).

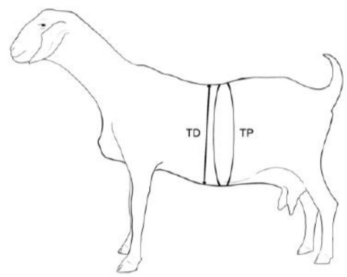

Figure 2. Morphological variables evaluated and their body reference points: Thoracic perimeter (TP, cm) and thoracic diameter (TD, cm) from crossbred dairy goats (Alpine–Saanen–Nubian x Criollo; n = 15) in Northern Mexico (25° N).

2.5. Maternal serum glucose levels, and recording of the pre-weaning growth of the offspring

A blood sample was collected by jugular venipuncture to quantify serum glucose concentrations (AccuCheck Sensor Comfort, Roche, Mexico) with a reliability of 95%. This variable was registered five days before kidding, the day of kidding, and two days post-kidding. Regarding the offspring, the birth weight was registered after delivery, once the mother finished cleaning it, and before ingesting the colostrum. Live weight of the offspring was also registered at 7, 14 and 21 days after kidding. The weight of the kids was recorded in the afternoon, avoiding that the kids had been suckled for a period of 10 h; a scale with a capacity of 10 kg and a precision of 25 g was used.

2.6. Statistical analyses

The mixed model procedure (i.e., PROC MIXED) was used, analyzing repeated measures across-time to evaluate the variables live weight of the mother (LWM, kg) and kid (LWGK, kg), body condition (BCS, units), the morphological variables of the mother included thoracic diameter (TD, cm) and thoracic perimeter (TP, cm), as well as serum glucose (GLU, mg dL^{-1}). In all analyzes, either the doe or the kid was the experimental unit, the fixed effects of social rank (i.e., LSR & HSR) and sampling day (i.e., time) were evaluated for repeated measures across time; time was considered as a repeated measure while the doe classified by her social rank was considered the repeated subject. In addition, a one-way-ANOVA was developed to evaluate the aforementioned variables, according to social rank (i.e., LSR & HSR) in crossbred dairy goats (Alpine-Saanen-Nubian x Criollo; n = 15).

Since no differences occurred between social rank regarding litter size (i.e., prolificacy), this variable was not considered in the final statistical models. Least squares means and standard errors for each social rank class, sampling time, and the combination of these two factors were calculated and used to determine multiple comparisons of means via the LSD-Fisher test. All statistical analyzes were performed using the procedures of the statistical package SAS version 9.2; a significant difference between means was set at $p < 0.05$.

3. Results

3.1. Social rank, time and doe´s live weight: simple effects

The social rank (i.e., LSR & HSR) and time (i.e., 5 dates) fixed effects upon the response variables live weight of the mother (LWM) are shown in Table 1. The LSR group presented the lowest value ($p < 0.05$), with an average of 49.27 kg with respect to the average observed in the HSR group (i.e., 57.39 kg). When performing an analysis of the trends of the LWM across time, a recovery of the live weight was observed in the third postpartum week with respect to the average weight that the goats showed at the beginning of the 3/3 of gestation.

Table 1. Least-square means ± s. e. for live weight of does (LWM, kg) as affected by either social rank (i.e., LSR and HSR) and time (i.e., 5 dates) in crossbred (Alpine–Saanen–Nubian *x* Criollo; n = 15) dairy goats in northern Mexico (25° N)

Variable	Social Rank			Days regarding kidding date [1]					
	LSR	HSR	s. e.	- 36	0	+ 07	+ 14	+ 21	s. e. [3]
LWM (kg)	49.3[b] [2]	55.7[a]	1.8	52.6[ab]	58.8[a]	51.5[ab]	50.2[ab]	49.1[b]	2.9

[1] Expected kidding date, 25 November.
[2] [ab] Least-square means without a common superscript within response variable, differ ($p < 0.05$).
[3] Most conservative standard error is presented

3.2. Social rank, time, and doe´s live weight across time: interaction effects

The LWM variable was affected ($p < 0.05$) by the effect between social rank (i.e., LSR & HSR) by time (i.e., five dates) interaction; the values obtained are presented in Table 2. When comparing the minimum and maximum values of the LWM recorded along with the experimental period, the highest values either at the beginning ($p < 0.05$; 37.90 vs. 42.90 kg) or at the end of the experiment (i.e., 61.80 vs. 73.40 kg) favored the HSR group. The percentage differences represented 11.3% and 14.4% at the beginning and end of the experiment, always favoring to the HSR group.

Table 2. Least-square means ± s. e. of the dam´s live weight (LWM, kg) according to the interaction social rank (i.e., LSR & HSR) and time (i.e., 5 dates) in crossbred (Alpine–Saanen–Nubian X Criollo; n = 15) dairy goats in northern Mexico (25° N)

Variable	Days regarding kidding date [1]										s.e.[3]
	-36		0		07		14		21		
	LSR	HSR	LSR	HSR	LSR	HSR	LSR	HSR	LSR	HSR	
LWM (kg)	49.5[cdef] [2]	55.8[b]	55.7[b]	62.0[a]	48.5[def]	54.6[bc]	47.3[ef]	53.2[bcd]	45.3[f]	52.9[bcde]	2.0

[1] Expected kidding date, November 25.

[2] ^{abcdef} Least-square means without a common superscript within response variable, differ ($p < 0.05$).
[3] Most conservative standard error is presented

3.3. Social rank, time, and dam´s body condition score across time: interaction effects

The response variable maternal BCS favored the HSR group ($p < 0.05$) compared to the LSR, either at the onset or the end of the experimental period; moreover, a social rank x time interaction effect was observed (Table 3). The difference observed between the average of the initial and final BCS, in numerical terms, was 0.57 units for the LSR (2.29, initial & 1.71 final), while corresponding values of 0.69 were observed in the HSR-group, with ranges of 2.44, initial and 1.75 final, favoring to the HSR group. When analyzing the simple effects of social rank and time on the BCS, no differences occurred between social ranks, although differences did occur with respect to the initial and final BCS; an average reduction of 2.3 vs. 1.8 units occurred, which denoted a drop close to 30% between said times ($p < 0.05$).

Table 3. Least-square means ± s. e. for the dam´s body condition score (BCS, units) according to the initial and final dates according to social rank (i.e., LSR and HSR) in crossbred (Alpine–Saanen–Nubian X Criollo; n = 15) dairy goats in northern Mexico (25° N) [1]

Variable	Initial [2]		Final [3]	
	LSR	HSR	LSR	HSR
BCS (units)	2.2±0.14^{a} [4]	2.4±0.13^{a}	1.8±0.14^{b}	1.8±0.13^{b}

[1] Expected kidding date, November 25
[2] Initial: 36 days prior kidding
[3] Final: 25 days post-kidding
[4] ^{a,b} Least-square means without a common superscript within response, differ ($p < 0.005$).

3.4. Social rank, time, and dam´s morphometry: simple effects

The morphometric maternal variables evaluated considered the thoracic diameter (TD, cm) and the thoracic perimeter (TP, cm). Table 4 shows the values observed for these morphometric variables considering the simple effects of social rank (i.e., LSR and HSR), and time (i.e., four times). While the quantification of the morphometric variables favored the HSR-goats, it was observed that as the kidding date approached, these morphometric variables showed an increase in their quantitative values.

Table 4. Least-square means ± s. e. for dam´s thoracic diameter (TD, cm) and thoracic perimeter (TP, cm), according to social rank (i.e., LSR and HSR) and time (i.e., 4 dates) in crossbred (Alpine–Saanen–Nubian X Criollo; n = 15) dairy goats in northern Mexico (25° N) [1]

Variable	Social Rank			Days regarding kidding date				
	LSR	HSR	s. e.	- 30	- 23	- 16	- 09	s. e. [3]
TD (cm)	33.9^{b} [2]	35.7^{a}	0.6	31.6^{b}	34.9^{a}	36.0^{a}	36.8^{a}	0.8
TP (cm)	108.4^{a}	112.6^{a}	1.4	107.2^{b}	109.0^{ab}	112.1^{ab}	114.4^{a}	2.3

[1] Expected kidding date, November 25.
[2] [abcdef] Least-square means without a common superscript within response variable, differ ($p < 0.05$).
[3] Most conservative standard error is presented

3.5. Social rank, time and dam´s morphometry across time: interaction effects

Once the simple effects on the morphometric variables were analyzed, a second analysis confirmed an interaction effect of social rank (i.e., LSR & HSR) by time (i.e., four dates). In general, the performance of these morphometric variables favored ($p < 0.05$) to the HSR group (Table 5). This interaction presented a positive trend in both social hierarchies, however, the values over time proportionally favored to the females of the HSR-group.

Table 5. Least-square means ± s. e. for the interaction social rank (i.e., LSR and HSR) and time (i.e., 4 dates) for the thoracic diameter (TD, cm) and thoracic perimeter (TP, cm) of the mother in crossbred (Alpine–Saanen–Nubian X Criollo; n = 15) dairy goats in northern Mexico (25° N).

Variable	Days regarding kidding date [1] - 30		- 23		- 16		- 09		s. e. [3]
	LSR	HSR	LSR	HSR	LSR	HSR	LSR	HSR	
TD (cm)	30.8^{e,2}	32.3^{de}	33.8^{cd}	35.9^{ab}	35.1^{c}	36.9^{ab}	35.1^{c}	36.9^{ab}	0.6
TP (cm)	105.1^{e}	109.0^{cd}	106.7^{de}	111.2^{bc}	109.5^{bc}	114.3^{ab}	109.5^{cde}	114.3^{ab}	1.7

[1] Expected kidding date, November 25.
[2] [abcdef] Least-square means without a common superscript within response variable, differ ($p < 0.05$).
[3] Most conservative standard error is presented

3.6. Social rank, time and dam´s serum glucose concentration across time: interaction effects

An interaction effect ($p < 0.01$) of social rank (i.e., LSR & HSR) by time (i.e., 3 dates) occurred with respect to the variable maternal serum glucose (Table 6). In fact, throughout the experimental period, increases in prepartum, partum, and postpartum glucose levels of 157% and 224% were observed for the LSR & HSR, respectively. However, these levels normalized on subsequent days, considering the mother's initial and final blood glucose readings, where the percentage increase was 9% and 11% for the LSR and HSR groups, respectively.

Table 6. Least-square means ± s. e. for doe´s serum glucose levels (GLU, mg dL^{-1}) as affected by the social rank (i.e., LSR and HSR) by time (i.e., 3 dates) interaction in crossbred (Alpine–Saanen–Nubian *x* Criollo; n = 15) dairy goats in northern Mexico (25° N).

Variable	Days regarding kidding date [1] - 05		0		+ 02		s. e. [3]
	LSR	HSR	LSR	HSR	LSR	HSR	
GLU (mg dL^{-1})	39.4^{b,2}	37.1^{b}	101.5^{a}	116.0^{a}	43.1^{b}	41.5^{b}	3.3

[1] Expected kidding date, November 25.
[2] [ab] Least-square means without a common superscript within response variable, differ ($p < 0.05$).
[3] Most conservative standard error is presented

3.7. Maternal social rank, time, and kid´s pre-weaning live weight across time: interaction effects

Regarding the kid´s live weight, this was affected by the interaction social rank *x* time, ($p < 0.05$; Table 7). While pre-weaning weights did not differ ($p > 0.05$) between kids from the LSR & HSR groups on days 0, 7 and 14 with respect to birth, on d21 live weight favored to the LSR-kids. Interestingly, however, it was observed that 66.6% of the total pups were male, and the rest (i.e. 33.33%) were female pups, while male pups were 3% heavier at birth than female pups. In this regard, while the female kids of the LSR group were 208 g heavier than those of the HSR group, this trend was also observed in male kids, since the males of the LSR group were 221 g heavier than those of the HSR group.

Table 7. Least-square means ± s. e. for the pre-weaning live weight of kids as (LWGK, kg) as affected by the interaction social rank of their mothers (i.e., LSR and HSR) and time (i.e., 3 dates) in crossbred (Alpine–Saanen–Nubian X Criollo; n = 15) dairy goats in northern Mexico (25° N).

	Days regarding kidding date [1]								s. e.[3]
Variable	0		07		14		21		
	LSR	HSR	LSR	HSR	LSR	HSR	LSR	HSR	
LWGK (kg)	3.5^{e}	3.3^{e}	4.8^{d}	4.5^{d}	6.1^{c}	5.7^{c}	7.6^{a}	6.8^{b}	0.2

[1] Expected kidding date, November 25.
[2] [abcde] Least-square means without a common superscript within response variable, differ ($p < 0.05$).
[3] Most conservative standard error is presented

4. Discussion

The hypothesis raised at the beginning of our research proposed that a high maternal social rank generates higher physio-morphometric values in the mother, which in turn promotes higher birth weights and augmented pre-weaning growth of the offspring from the HSR-goats. Our results suggest that HSR-goats articulated physiological and morphometric responses to achieve better and greater access to food, increasing live weight values, but these physio-ethological advantages were not assumed with respect to the pre-weaning growth of their offspring. Our results are in agreement with other reports, which indicate that goats are a gregarious species that present interactions between dominant and subordinate animals, which translates into complex social interactions. In general, the high-ranked animals show a better productive and reproductive performance, derived from exercising priority access to more and better resources [4,10,11,24-33].

Certainly, social hierarchies determine unequal access to different resources; goats belong to this group of animals, which naturally have a complex social structure, determined by a social hierarchy preserved by agonistic and affiliative behaviors. In goats and sheep, a stable social environment provides them with the ideal conditions to adapt to stressful environments, through social learning [1-3]. However, the information reported on the importance of social hierarchy is not sufficient, abundant or recent [34-36]. For example, social behaviors of licking and grooming described in herbivores contribute to individual recognition, improve the maintenance of social relations and favor group cohesion, generating positive affective states [37]. On the other hand, the inclusion of individuals unknown to the group alters the social structure of the herd, and may alter an already established hierarchical social structure [38,39].

Even under intensive and semi-intensive production schemes, social hierarchy is present, generating continuous competition among the members of the herd and on many occasions causes adverse results, mainly related to the spatial distribution of the feeders and therefore access to quantity and quality of food, where low social ranks are habitually disturbed by high social ranks animals. Likewise, if we consider the high food selectivity shown by the goat, this feeding behavior favors the fact that goats with a high social hierarchy may exert an enhanced diet intake with higher chemical quality than low social ranks peers [40,41]. In addition to social rank, food consumption is also affected by other factors such as the season of the year, environmental temperature, time of day, among other factors [3,42]. In goats, a positive relationship between morphological values and production levels has been reported, while these morphological and productive values were positively related to other variables such as LW and BCS, over time [4,43-45]. In our study, the LWM and BCS variables showed higher values at the start of the experiment compared to the final values (Tables 1, 2 & 3). This could be related to the fact that our research period included parturition, a point at which, naturally, dams lose important energy reserves to ensure the production of colostrum and milk to feed the newborn.

The TD and TP variables showed values with a positive relationship in the social rank by time interaction and expressed significantly higher values at the end of the experiment compared to the initial values (Tables 4 & 5). Also, a negative relationship was observed between social rank and the amount of serum glucose, that is, goats with LSR showed slightly higher amounts glucose, with the exception of the kidding day, which is not consistent with that reported in other investigations [11,46]. In this context, such a high glucose level on the partum day in the HSR group could be related to a better LWM and BCS, a scenario previously reported [4,28,29]. Around parturition, a higher social rank generates an increased LWM, which has been related to a greater and better access to colostrum by the offspring delivered by HSR-goats [3,47-53]. Interestingly, this scenario was not consistent with the results obtained in this study, which suggests that goats, regardless of social rank, ensure optimal colostrum production and that the possible effect of social rank is not evident in the process of colostrogenesis but in the process of galactopoiesis; future research should address this hypothesis.

5. Conclusions

According to our results, even when goats with high social rank showed higher values in prepartum, partum, and postpartum weights and morphometric values, no differences occurred neither with respect to the maternal serum glucose values nor with respect to litter size, individual weights of kids, or total litter weights from the kidding-to-weaning period between high and low social rank goats. Our results suggest that although the HSR-goats articulated physiological and morphometric responses to achieve better and greater access to food, increasing prepartum and postpartum live weight & zoometric values, such advantages were not reflected in a higher level of productivity neither regarding litter size nor about the kid or total offspring weights during the birth-to-weaning period. Such research outcomes are interesting in that, it seems that, despite the corporal, morphological and metabolic increases observed in the HSR goats, such physiological and ethological advantages were not diverted toward better litter size or preweaning growth rates; thus, both social ranked goats assured the survival of their kids. The last seems to be a very interesting physio-ethological strategy in crossbred dairy goats managed under dry-semi-arid marginal production systems.

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Methodology, Ma. Silvia Castillo-Zuñiga, Cesar A. Meza-Herrera, Guadalupe Calderón-Leyva, Francisco G. Véliz-Deras, Oscar Angel-Garcia and J. A. Bustamante-Andrade; Project administration, J. A. Bustamante-Andrade, Ramón Delgado-Gonzalez and Viridiana Contreras-Villarreal; Resources, C. Navarrete-Molina, Francisco G. Véliz-Deras, Oscar Angel-Garcia, Ramón Delgado-Gonzalez and Viridiana Contreras-Villarreal; Supervision, Cesar A. Meza-Herrera; Writing – original draft, Ma. Silvia Castillo-Zuñiga; Writing – review & editing, Cesar A. Meza-Herrera.All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement: In the present investigation, the animal management was in accordance with the technical specifications for the production, care and use of laboratory animals. Moreover, all the experimental units considered in this research, as well as the experimental procedures, methods and management, were developed considering the requirements issued for good ethical use, care and animal welfare both at international and national levels, and with institutional approval registered under the reference: UAAAN-UL-18-3059.

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IV. Conclusiones generales

Nuestros resultados confirmaron nuestra hipótesis de trabajo ya que las cabras de alto rango social, mostraron los valores más altos en los indicadores morfométricos en el último tercio de preñez y en la primera fase de lactancia, así mismo, el rango social está relacionado con la morfometría de la ubre y con la calidad de la leche. Sin embargo, no hubo diferencias ni con respecto a los valores de glucosa sérica materna ni con respecto al tamaño de la camada, pesos individuales de los cabritos, o pesos de camada del período parto-destete entre grupos de alto y bajo rango social.

Nuestros resultados sugieren que, aunque las cabras HSR articularon respuestas fisiológicas y morfométricas para lograr un mejor y mayor acceso al alimento, aumentando el peso vivo preparto y posparto y los valores morfométricos, sin embargo, estas ventajas no se reflejaron en un mayor nivel de productividad ni en cuanto al tamaño de la camada, ni sobre el peso total de los cabritos o crías durante el período del nacimiento al destete. Tales resultados de investigación son interesantes porque parece que, a pesar de los aumentos corporales, morfológicos y metabólicos observados en las cabras de alto rango social, tales ventajas fisiológicas y etológicas no se desviaron hacia un mejor tamaño de camada o tasas de crecimiento antes del destete; así, ambas cabras de rango social aseguran la supervivencia de sus cabritos. Esta última parece ser una estrategia fisio-etológica muy interesante en cabras lecheras mestizas manejadas bajo sistemas de producción marginales secos-semiáridos, siendo este un escenario fundamental para la sustentabilidad de los sistemas productivos caprinos marginales, del productor y su familia.

V. Literatura Citada

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