Nutritional and management strategies for sheep and goats

by

Skyler Seth Scotten

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Dr. Cassandra Jones

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Abstract

Three studies were conducted to evaluate methods to improve small ruminant nutritional and management strategies. In Exp. 1, the effects of substituting grain sorghum in place of corn was evaluated in growing lamb diets. A total of 72 Rambouillet wethers (initially 33.9 ± 3.10 kg BW) were utilized in a completely randomized design and allotted to 1 of 4 dietary treatments over 35 d. Each pen contained 3 sheep and there were 6 pens per treatment. Dietary treatments included a corn-based control (42% corn/0% sorghum) or 10%, 20%, or 30% of sorghum replacing corn. All diets included titanium dioxide as an indigestible marker, and fecal samples were collected every 6 hr over a 3-day period at the end of the experiment for determination of total tract nutrient digestibility. There was no evidence ($P > 0.05$) that the inclusion of sorghum impacted any measured growth performance criteria. However, the higher price of sorghum at the time of the experiment led to lambs fed diets with 30% sorghum having a greater ($P = 0.017$) feed cost/lamb than the diets with lower concentrations of sorghum. Lambs fed increasing levels of sorghum had linearly improved ($P < 0.05$) apparent total tract digestibility of dry matter and organic matter, but there was no evidence of diet impacting the nutrient digestibility of crude protein, fiber, or ether extract. In conclusion, at least 20% sorghum can be used in place of corn without impacting feed cost or nutrient digestibility. Up to 30% sorghum can be fed to lambs without altering growth to target specialized markets, but with potential impacts to feed cost and dry matter digestibility. Next, in Exp. 2, the impact of varying oral anthelmintic treatments was evaluated on fecal egg count and growth performance of growing Spanish goats. A total of seventy-two intact male goats (Spanish, 25.17 ± 3.0 kg) were obtained from the same commercial grazing operation. Goats were weighed upon arrival and allocated to elevated pens

in an indoor facility to balance body weight. Pens were randomly assigned one of four oral anthelmintic treatments in a completely randomized design, which were administered according to manufacturers' recommendations on d 0. Anthelmintic treatment included: Control (no treatment administered); 2) moxidectin (0.40 mg/kg; Elanco Animal Health, Greenfield, IN); 3) fenbendazole (10.00 mg/kg; Merck Animal Health, Rahway, NJ); or 4) albendazole (20.00 mg/kg; Zoetis Animal Health, Parsippany, NH). There were 3 goats/pen and 6 pens/treatment. Feces were collected weekly, along with animal weights and feed disappearance to calculate reduction in fecal egg count from d 0, average daily gain, average daily feed intake, and feed efficiency. Data were analyzed using the GLIMMIX procedure of SAS v.9.4 (SAS Inst., Cary, NC). There was no evidence ($P > 0.05$) that treatment impacted any measured response criteria. Compared to the control, the addition of an anthelmintic, regardless of type, reduced ($P < 0.05$) Eimeria eggs on d 7 and total eggs on d 28. The results of this study showed limited efficacy of anthelmintics in Spanish goats; which is contrary to other studies. These results may have been impacted by all animals being housed in elevated pens with no exposure to dirt or feces. Additional research is therefore warranted to compare anthelmintic efficacy in more commercially relevant environments.

Finally, in Exp. 3, the effect of increasing levels of crude protein (CP) by substituting SBM place of corn was evaluated in growing Easycare lambs. A total of 77 Easycare (Dorper × Katahdin × Romanov) lambs were fed one of three dietary treatments in a Latin square design with 7 replicate pens per treatment during three 28-d phases. Dietary treatments included a control (7.7% SBM/89.5% corn) or the control with 11.7% or 15.7% SBM at the expense of corn. At the end of each phase, fecal samples were collected from six lambs per pen and analyzed to determine nutrient digestibility. After phase 1, five male lambs per treatment with

the weight closest to the median were slaughtered and carcass data collected. Lamb ADG was impacted ($P = 0.0004$) by a sex × SBM interaction, with wethers being fed 7.7% SBM having reduced ($P < 0.05$) ADG compared to all ewes or wethers being fed 11.7 or 15.7% SBM diets. Increasing levels of SBM linearly increased lamb BW and ADG but did not impact any other growth performance variable. Increasing levels of SBM also increased ($P < 0.05$) apparent total tract digestibility of dry matter, organic matter, crude protein, and ether extract, but not ($P > 0.05$) crude fiber. Finally, there was no evidence ($P > 0.05$) that dietary treatment impacted carcass characteristics. These results suggest that growing easy care castrated males benefit from adding at least 4% SBM in place of corn to increase dietary CP, and that additional research is warranted to evaluate longer-term impacts on cost and carcass composition. Collectively, these three experiments have increased our scientific understanding in small ruminant nutrition and management and have provided a basis from which to form better science-based recommendations for producers.

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Dedication

This thesis is dedicated to my son, Clancy. I know my time away from home hasn't been easy on you but hope you realize I'm doing this for the both of us and our future. I love you with all that I have.

Chapter 1 - KSU Show Goat Guide

Welcome

Welcome to the Kansas State University Show Goat Guide! The content you find in this guide should help you navigate your way through the essentials of showing meat goats. We hope the material provided is educational for beginning showman, as well as experienced showmen. This gives an overview of selecting, feeding, daily care, and how to show your project. Remember this is an educational experience that can teach you lifelong skills along the way.

Before learning about selection, it is essential that you understand the parts of a goat. The diagram below shows the primary parts of a market goat or breeding doe that you will often hear judges talk about while describing their class. It is also important to understand the parts to communicate effectively with breeders, veterinarians, other youth, and those involved in your meat goat project.

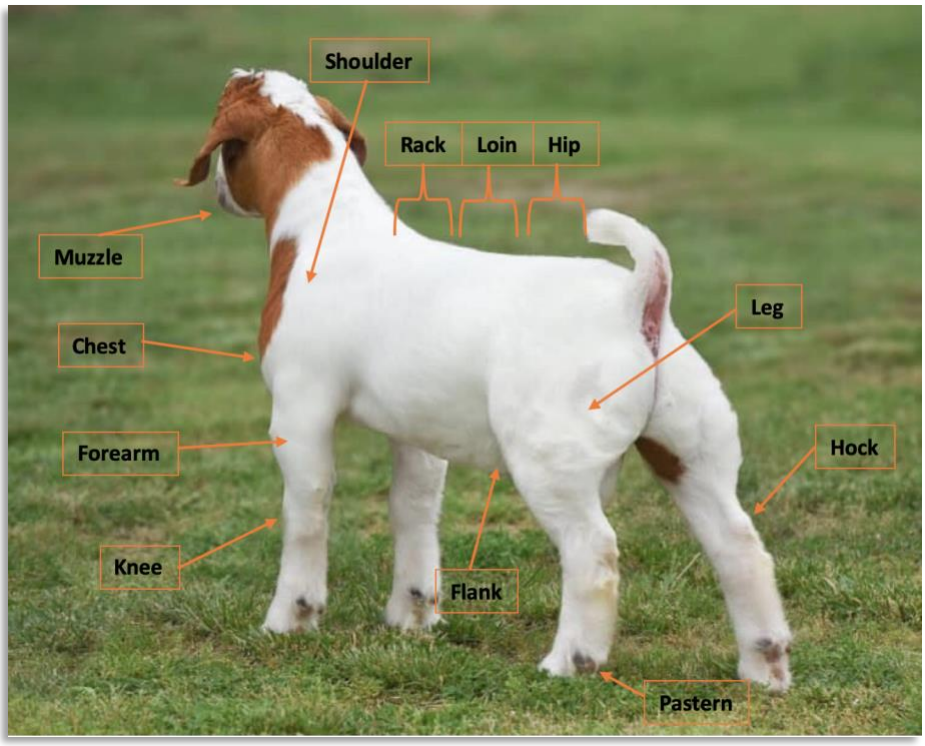

Figure 1.1. Parts of a show goat

Selection

Goat selection may be challenging to those who show other species of livestock, as they may have not been familiar with the species growing up. However, the same basic selection principles apply! When purchasing your project, keep the following things in mind to help find the best show goat for your budget: maturity, genetics, skeletal width, muscle, structural correctness, balance, pattern, and performance. If you aren't comfortable with selecting your own projects, reach out to someone who is familiar with goats. Agriculture teachers, FFA advisors, 4-H leaders, extension agents and breeders are always a helpful resource during this process and would be glad to assist you in selecting the right project for you. To help select the right goat, you should start by asking yourself a few questions:

- What is your optimal show?
    - Do you plan to participate in the county fair, state shows, jackpot circuits, or the national level?
    - Do you need a goat to target for multiple shows?

- Decide on the date of the show that you plan to attend, or the event you want your goat to be in optimal weight/appearance.
    - Here are some things to consider:
        - Where am I going to get it?
        - What size of goat is the best fit for the showman, especially for a beginner?

- Most shows require that you own your project by a certain deadline, typically a few months before the show.

    - This information can be found in the rules/regulations of the show. Usually, it's listed as the "ownership deadline" or the nomination/validation deadline is used.
        - County Fair – check with your local extension office.
        - Kansas State Fair Grand Drive & KJLS – June 15
    - Most local and online sales occur well before the required date of ownership. Be sure to communicate this date with the breeder of your animal to arrange an appropriate pickup time.

- When selecting a goat, finding a project with the appropriate age and size is essential.
    - If you are targeting a county fair, you will want to select a goat that has plenty of size and maturity to ensure it meets the minimum weight requirements for your show.
    - If you plan to find a goat for your state fair or national show, size may not play as big of a factor in your selection process. Comparative to other species, maturity is usually seen as a positive in goats rather than a negative.
    - Don't worry about if they are too old, find the goat that is the best fit for you!
    - Refer to the table 1 for a guide in selecting the appropriately aged project.

Table 1.1. Ideal age of a goat for its target show date.

Target Show Date	Ideal Age of Goat
July-August (most Kansas county fairs)	Early November to Mid-January
September-November (Kansas State Fair, Kansas Junior Livestock Show, and most national livestock shows)	Early November to Late March

Maturity

Goat maturity and end point composition are usually controlled by the amount of feed a goat eats. Ideal fat to lean ratios should peak whenever you reach your target show, so selecting a goat that is proper age is essential. Ultimately, all goats will have a difference in maturity pattern, as not one animal is identical to the other. It is up to you to decide what goat best fits your budget and what animals are best suited for the show(s) that you plan to go to.

- Early Maturing Goats
    - Earlier maturing goats can be shown at lighter weights while being compositionally correct.
        - Their endpoint weight usually ranges from 75-90 pounds.
    - These goats are generally shorter in stature as well as having less length to their face, ears, and body.

- Later Maturing Goats

- Some goats are genetically bred to be later maturing, and they will need to be fed to heavier weights to reach their ideal composition.
    - Their endpoint weight usually ranges from 90-110 pounds.
- Later maturing goats have more length to their ears, neck, body, and legs.
- They tend to require more feed to put on external cover.

Maturity pattern is not a placing factor in the judge's mind. However, it is important to understand how fast your goat will grow and what its ideal size and endpoint weight may be. Early maturing and late maturing goats can find success in the showring, but the timing of your target show and availability of prospects from breeders are things you must take into account.

Below are two photos of wethers with differing maturity patterns. The top photo shows a goat with an early maturity pattern, with the bottom photo showing a later maturity curve. These wethers were both pictured at 3 months of age. The goat on the top is smaller in stature, while the goat on the bottom has more length and size.

Figure 1.2. Example of an early maturing goat

Figure 1.3. Example of a late maturing goat

Genetics

Genetics are important in the process of project selection. It is essential to find a breeder who you trust and is honest in selling goats with the genetic confirmation to get better over time.

- If goats do not have the genetic ability to get better, they WON'T!
    - Always ask the breeder what the genetics are on the prospect you are considering purchasing.
- If you are unsure about the genetic background of goats, ask agriculture teachers, FFA advisors, 4-H leaders, extension agents or anyone familiar with show goats for assistance.
- Successful genetic lines are important in the fact they are proven to work. Buying something that has proven to work in the past can help with what you expect that animal to do moving forward.

Skeletal Width/Muscle

Muscularity and skeletal width go hand in hand, without a wide base, it is hard to build muscle on a narrow foundation.

- Indicators of genuine base width:
    - Width through chest
    - Width from behind indicates genuine base width
- Muscle in market goats and does is evaluated down their top and from behind.

Figure 1.4. Composition of a show goat

    - Shape of their rib, shape of their rack, width/squareness of their loin, shape to leg.
- Judges put a major emphasis on handling quality and freshness, so keeping your goat compositionally correct is essential. This includes:
    - Firm and square rack shape
    - Width to loin
    - Leg shape
    - Hide/hair quality

Structural Correctness

Structural correctness refers to how an animal's skeleton and joints work and are put together. You've might have heard that structure is studied from the ground up. So, what exactly does that mean?

- Feet and legs should all point the same direction.
- The knee should have a slight slope backwards with a correct angle to the pastern.
- The rear hocks should be square; they should not twist in or bow out.
- Goats should have a near 90-degree angle in the way their neck comes into their shoulder blade.
- The spine should be nearly level from the top of the shoulders to the base of the tail.
- Goats should act comfortable in motion, without favoring any of their limbs.

Correct pastern angle is shown below.

Figure 1.5. Examples of pastern set of goats. Adapted from NSW Dept. of Primary Industries.

Balance/Pattern

Balance and pattern are different, but both aid to a higher quality image from the profile. A judge will consider both of these items in the show ring, so it is something to keep in mind when selecting your project.

- Balance refers to the symmetry of an animal and how well it's proportioned from the side.
    - The front half of the body should match the back half of the body in terms of length.
        - Structure plays a big role in balance, if an animal is built correctly, they will most likely be well balanced.
- Pattern strictly refers to the eye appeal and look of the goat, which includes:
    - Height of shoulder
    - Level topline
    - Symmetry in motion
    - How all the pieces of the goat "fit together"

Figure 1.6. Example of proper pattern and balance in a show goat

Daily Care and Management

Cleaning a barn and washing your animals is not always the most fun part of the project, but if you want to succeed, the work behind the scenes is often want can get you over the top and into the winner's circle. You don't have to have a new fancy barn or a shiny trailer to work hard and ensure that you're doing everything possible to ensure success come show day. Below are a few tips on what is essential for proper animal husbandry and going the extra mile to be your best.

Facilities

A large state of the art facility is not required for proper care of your animal. Here are important considerations for maximum performance, health, and safety of your goats:

- Pen Design:
    - Sheltered pen on an elevated surface that has 3 sides enclosed to protect from rain and flooding.
    - Should be a minimum of 40 inches tall.
    - Vertical bar panels are ideal to prevent trapping legs or the animals head, which can cause harm.
    - Traditional cattle panels are effective and will ensure that the goat cannot escape.
- Bedding
    - Dry, clean bedding is essential to:
        - Maintain hide and hair quality
        - Prevent stains
        - Prevent fungus
        - Reduce the potential for parasites

            - ✓ *The more moisture in the bedding, the higher the concern for parasites.*

- Animal Capacity
    - Recommend 1-2 goats per pen:
        - Having multiple goats per pen increases appetite and willingness to eat.
        - Individual penning is easier to monitor daily feed intake.
            - ✓ Individual pens also make cleaning easier; one goat creates less of a mess than two.

Weather Considerations

- When caring for younger goats, especially in the springtime, more care needs to be given to ensure a healthy start.
    - On colder days and nights, make sure goats have a dry enclosed area equipped with a heat lamp, if necessary.
    - If the goat you purchased was slick shorn, a "goat blanked" is a necessity.
        - Blankets can be expensive, but are vital in maintaining health.
            - ✓ May be purchased from any feed/supply store
- Although goats are very tolerant to heat, air flow and shade should be available at all times throughout the day during the summer months.
    - If pen is inside of a barn, a small fan may be necessary to keep your animal cool.

Water

- Water quality and freshness are some of most overlooked areas of importance when caring for an animal.

    - There are a variety of watering systems available, but clean fresh water should be always provided.
        - Automatic waters are a low maintenance alternative but can be rather expensive and a hassle to install.
        - If watering by bucket, use a three-gallon bucket and change water morning and evening.
- During warm summer months, monitor waters throughout the day.
- Changing and cleaning waters is never fun, but for the health and performance of your goat, it is a must to keep water intake high and water quality fresh.

Health

Keeping your show goat healthy is essential to your success come show day. Nutrition and health go hand in hand. If you have a healthy goat feed intake, gain will be higher, making it easier for your project to be on target weight going to the show. It is essential to evaluate and monitor health on a daily basis by checking signs such as snotty nose, droopy head and ears, lethargy, lack of appetite, and change in stool. If you notice any of these symptoms, contact your local veterinarian and administer the proper medications, following their guidance and direction. It is also important to read the label of any product and follow the appropriate withdrawal times that are safe for your show and situation. If you are unsure of your animal's health, ask someone who can assist you. This could be a project leader, extension agent, ag teacher, or veterinarian.

External Parasites

If you notice your goat biting its legs or scratching themselves, often there is a good chance that you are facing an external parasite.

- Common external parasites:
    - Lice
    - Mites
    - Flies
- Easy to control and treat once you notice that you have a problem.
    - Contact local veterinarian for specific pour-on treatments recommended for goats.
    - Left untreated, external parasites can eventually lead to appetite suppression and lack of growth.
- Impact hide and hair quality

Internal Parasites

Goats are known to be susceptible to internal parasites. There are more problems with internal parasites in goats than any other disease. It is recommended that you deworm your show goat every 14 days, regardless of the environment it is in.

- You may confirm that you have a parasitic problem by fecal testing with your local veterinarian.
    - In the case of all internal parasites, it is beneficial to be proactive rather than reactive in terms of treatment.
    - Contact your local veterinarian for specific treatment methods/prevention protocols.
- *Withdrawal Times*
    - As you get closer to you target show or get close to selling your project, ensure that the withdrawal date on wormers do not overlap the time you plan to sell your animal.
    - Having a relationship with your veterinarian is helpful to know these withdrawal times.

Caseous Lymphadenitis (CL)

Caseous Lymphadenitis, commonly referred to as “CL”, is a contagious bacterial infection.

- It appears as an abscess or small fluid filled pocket underneath the ears, or on the throat of your goat.
- Sensitive or painful to the touch.

- Initially, it appears as a quarter sized lump that can be confused with a fly bite or small abscess. It will quickly become larger, ranging in size from a golf ball to a baseball.
    - Do not panic, although they take a while to go down, it is best to let the abscess pop on its own. Basic biosecurity methods include:
        - It is recommended that you do NOT lance the abscess as it will only delay the healing process.
        - After it pops on its own, simply treat with an iodine spray and keep area clean of dirt and other foreign material.

Figure 1.7. Example of *Caseous Lymphadenitis* in a buck. Adopted from Boer Goats Profit Guide.

Figure 1.8. Example of *Caseous Lymphadenitis* in a doe. Adapted from Sales Creed Veterinary Services.

Show Fungus

If you plan on showing your goats at a jackpot or spring show, it is inevitable you will deal with the issue of show fungus. Although there are a few ways to prevent this infection, it is extremely contagious to both humans and animals. It also can prevent you from being able to exhibit your project at a show.

- Small, round, red patches appear on the skin of your goat and can be crusty to the touch.

    - Underneath the scab, is a red circular patch of skin where the fungus has appeared.
- There are a few ways to prevent fungal infections in your show projects. These will help ensure clear skin and no issue with health papers or “vet checks” when you arrive at the show.
    - After a show, immediately wash your goat with an antifungal shampoo before loading into your trailer or putting the blanket back on.
    - Keep facilities clean and dry.
    - Disinfect show halters and any show chains that are used on more than one animal.
        - For treatment, contact your veterinarian on information regarding proper medications.

Figure 1.9. Example of fungus located on the neck of a goat.

Figure 1.10. Example of fungus located on top of the shoulder of a goat.

Nutrition

After finding and purchasing a high-quality show project, proper nutrition is essential to maximize the genetic value of your animal. A poor diet, or lack of nutrition, can get in the way of accomplishing your show season goals. Let's walk through the steps of nutrition to make sure you will be on the right track!

Nutrients

There are four main essential nutrients in goat nutrition: water, protein, energy, and vitamins.

- Water
    - Water is undoubtedly the most important part of your animal's health.
        - Aids in digestion and feed intake.
        - Directly correlates to performance and animal appearance.
    - Clean and fresh water should be readily available 24/7.
        - If watering out of a bucket, the water should be changed twice a day.
    - Goats can drink upwards of three gallons of water per day.
- Protein
    - Protein is important as it strongly impacts muscle deposition and growth. Early stages of a goat’s life are when protein muscle deposition is at its highest rate.
    - Protein requirements reflect the stage of growth that your goat is going through.
        - Important for tissue development.
    - Feed choice and selection is often directly correlated to protein content of feed.
        - Younger goats (1-4 months of age)

- ✓ Complete feed with a protein of 18%-20% is recommended.
  - ➢ Helps develop the rapid growth of muscularity at this stage.
- Older goats (4 months of age and older)
  - ✓ Transition to a feed with a crude protein content of 15-17%.
    - ➢ Start declining in muscle deposition and increase in the amount of fat they begin to carry.
- Finishing your goats requires a lower protein to ensure a smooth and even fat cover.

- Energy/Carbohydrates
  - Energy intake is essential to the diet of your goat and is met through the carbohydrates and fats in grain.
  - Most show feeds contain 5% crude fat which aids in the physical appearance and health of your animal.
    - If too much fat is consumed, the composition of your goat will be compromised, and exercise may be needed to get rid of the access cover.
  - Compared to other species, goats do not transition to higher energy feed as they mature.
    - Need energy in a beginning ration to help develop into their potential.
  - Recommended fat levels in feed:
    - Younger goats (1-4 months of age) – 3-6%
    - Older goats (4 months of age and older) – 5%
  - Minerals:

        - Calcium, phosphorus, magnesium, sodium, potassium, sulfur, and chlorides
            - ✓ The most important minerals that keep rumen health and body development moving forward.
            - ✓ Recommended that a mineral supplement is provided at all times to ensure they are meeting their requirement.
            - ✓ A calcium to phosphorus ratio of 2:1 is recommended to prevent Urinary Calculi.
    - Vitamins:
        - Vitamins (A, D, E, & K)
            - ✓ Important to the goat's diet due to their inability to produce these vitamins.
            - ✓ Mineral/vitamin supplements contain proper levels of all essential vitamins.
- Roughage
    - With a solely grain-based diet, there can be concerns with rumen health, digestion, and feed intake.
        - A ¼ pound of roughage once daily helps meet fiber requirements while helping with overall digestion.
        - High quality show feeds will meet energy and protein requirements, so a grass hay is recommended:
            - ✓ Brome
            - ✓ Sudan

        - Do not overfeed hay or allow unlimited intake.
            - ✓ Will decrease grain consumption
    - Hay quality and fiber length is also important to take into account when feeding roughage.
        - Lower quality hay is digested slower
        - Short fiber length will speed up passage in the rumen, but actually decrease ruminal digestion.
    -

Early Life Nutrition

As soon as you bring your project home, expect stress and lack of appetite to deter the intake of your animal for a few days.

- As soon as you unload, make sure feed and water are available.
    - Ask the producer what feed the goat was on.
        - Slowly transition diet from old feed to new feed that you plan on feeding for the rest of the year.
            - ✓ Recommended to mix feed 50/50 for at least 2 days before transitioning completely to new feed.
        - If no intake has occurred within the first 24 hours, a handful of high-quality hay is necessary to maintain proper rumen function

Supplements

There are hundreds of feed additives suggested by feed companies that can do everything from build muscle, to correct structure, and add fat cover. With goats known for their picky appetite

and sensitive digestive system, it is often best to keep supplementation out of their diet and commit to a daily feeding schedule and balanced ration. Keeping goats on feed, especially in summer months, will keep you ahead of the game and on target for your endpoint goal.

Feeding Schedule

- Feeding your animal at a consistent time both morning and night is important in terms of daily consumption and feed intake.
- Feeding goats all at the same time, even in different pens, has shown an increase in performance.

Feed Quality

- If feed is dusty or has a lot of fines, cleaning out refusals or uneaten feed can ensure an accurate measurement of intake.
    - If feed has an abnormal amount of dust or mold, purchasing replacement feed may be necessary.
- If the goat is not cleaning up their feed, providing a full feeder is not the solution. Decreasing feed amount until they clean up the feed and gradually increasing the amount helps both rumen health and feed wastage.
- A clean feeder will help keep palatability high.
    - Will help maintain feed intake.

Weight Gain

- It is important to monitor weight gain throughout all stages of your animal's life, especially as you progress closer to your show.
    - Keep minimum and maximum weight guidelines in mind.
- As a rule of thumb, goats should gain at least 3 pounds per week.
- It is suggested that you weigh goats at least every two weeks to track average daily gain as well as current weight.

Feeding Recommendations

There are a variety of options when it comes to selecting a complete feed for your goat. There is a wide range in price and kind. Ultimately, if you are confused or do not have previous experience with a specific feed, contact the breeder who raised the goat. You could also reach out to a feed dealer you trust. Here are the recommended feed amounts for your goat's diet:

- A starting ration with crude protein level of 18%-20% and fat content of 3-6% should be fed ½ to ¾ pounds twice daily.
- After transitioning from a starter ration at approximately 4 months of age, a diet with a crude protein of 15-17% and fat content of 5% should be fed at 1-1 ¼ pounds twice daily.
- Goats generally eat more feed when being fed with other goats in surrounding pens.
- Vital that feeding times are consistent day to day.

Show Preparation

Halter Breaking

Patience is key when it comes to halter breaking your show goat. Do not start the process immediately after getting your project home. wait a few days for the goat to acclimate to its new home and environment. This allows the goat to get started on feed and keeps stress levels at a minimum. This will also help keep immune health in check.

- Patience is key in the process of halter breaking.
    - Goats are known to be strong willed and stubborn.
    - Start the process by tying your goat alongside the other sheep and goats that you may have with enough slack in the halter to allow the animal to be comfortable.
        - The natural reaction is for goats to often pull back and possibly flop down on their sides.
            - ✓ It is essential to stay with your animal at all times during this process.
            - ✓ If your goat falls over, simply stand him back up and allow him to stand upright.
            - ✓ When training, keep goats tied up for 45 minutes to an hour.
                - ➢ Repeat for 5 days or until goat seems comfortable in the halter.
- After your animal is broke to the halter, you can begin the leading process.
    - Do NOT drag your goat.
    - It will take time and lots of practice before your goat will walk willingly behind you.

        - Simply stand to the side or behind your goats, with the rope in your hand and allow them to walk freely with the halter.
            - ✓ This will familiarize them with the process and begin breaking them to lead.
            - ✓ Standing in front of your goat and dragging them does not equal progress.
                - ➢ It often intimidates your goat and delays the learning curve of responding to the halter.

Show Collar

If you decide to use a show collar instead of a halter to show your animal, practice at home is essential. Not only does your animal not look good being dragged by their neck in the show ring, but it can also be extremely harmful to their health.

- It is recommended that your entire hand can fit underneath the chain as it is held around the top of their neck.
    - If placed around the neck too tight, they will not respond to the leading process and struggle breathing.
    - You MUST work hard at home to ensure your animal corporates at the show.
- Same training protocols apply to show collars as they do for halter breaking.
    - When training your goat to walk, stand to the side or towards the back end of your goat encouraging them to move forward rather than pull backwards.
    - Standing in front of your project will instinctively move your goat in the opposite direction, not allowing it to move forward.
- There are many kinds of show collars to choose from that effective:

    - plastic chains
    - metal chains
    - chains with spikes
- Ultimately select the product that you feel most comfortable with.

Exercise

A healthy exercise program is very important in the growth and development of your goat. Exercise at different stages of a goat's life has different effects but are crucial in all stages. At a young age, light exercise will help with muscle growth and development, while exercise at heavier weights is important for maintaining muscle and keeping proper condition. Over exercising your goat is unnecessary and does more harm than good. As your animal grows, you can adjust the amount of exercise they require accordingly by weight and cover.

- There are multiple ways to exercise your goats:
    - Fenced Area
        - It is extremely effective to build or find a fenced off area free of excess grass/trees that you feel comfortable turning your goats loose in.
            - ✓ Allows the goats to run and they essentially can exercise themselves.
            - ✓ If your goat is not running on its own, simply get behind them and clap.
                - ➢ This will encourage them to move and allows them time to exercise outside of their individual pen or on a halter.
        - It is suggested to run your goats for 3-5 minutes per day.
    - Treadmilling

        - Can be very expensive alternatives that may be difficult to figure out.
    - Goat Walker
        - Can be very expensive alternatives that may be difficult to figure out.

Nearing Showtime

After all your hard work is completed at home, the reward of taking your animal to the show has finally come. There are several things that are important to remember when getting close to the show to make your animal look its best. Here are some helpful hints to know as you prepare for the big day.

Week Prior to Show

The week leading up to the show is extremely important in putting the final preparations on your goat before taking it to the show. As always, do your best to keep your animal on a regular feeding, exercise, and showmanship practice schedule to minimize stress leading up to the big day.

- Hydration is key going into show day, especially in the heat of the summer.
    - Recommended to give goats an electrolyte supplement starting 3 days before the show.
        - Electrolytes can be added to the water bucket or applied as a “drench”.
            - ✓ Mix solution as recommended by the supplement that you choose.
- To ensure your goat will cooperate at the show, practice the following:
    - Make sure goat has experience loading and offloading.
    - Having your goat on the fitting stand several times, allowing them to be comfortable with the situation.

        - Process will be much easier preparing your animal for the event.

Clipping

Clipping your goat in preparation for the show can be intimidating and seem foreign to those not familiar with it. With some practice, It is very simple to clip your goat and does not require years of experience to have your animal looking respectable.

- In preparation for shearing, it is always helpful to wash your goat and dry them completely with a blower.
    - Wet hair can clog up the clippers and make the process very difficult.
    - It is essential that all the moisture is out of the animal before you begin.
- Goats, unlike many other species, do not have to be clipped often throughout their lifetime.
    - Clipping once in late spring will allow goats to get rid of all old hair and grow fresh new hair for the summer.
- It is recommended that you use “cover coat” blades that fit several types of clippers.
    - This set of blades clips hair to the recommended length without getting hair too short.
        - Do not use blades such as “fines” or “surgical” as too much hair will be removed, and it will take away from the presentation of your animal.
- Try to clip your animal as close to the show as possible.
    - Clipping too early can cause your goat to grow too much hair or the skin can possibly get dry.
- After you clip your goat, wash your goat with soap and conditioner and dry them again to make sure you didn't miss any spots.

    - It is easy to overlook spots that you may need to run over again.
- After you have completed this process:
    - Spray the goat with aerosol fly spray.
    - Cover with a blanket to protect from external parasites.

Leaving for the Show

The trip to the fair or show can be a very stressful time for you, as well as your goat. This is a fun process, but keep in mind the reason you bought your animal was to learn and have a competitive event to display your project, hard work, and knowledge. Here are a few things to remember before heading to the fairgrounds:

- The electrolyte supplement should already be added to your water bucket, but it can be beneficial to start watering your goat every hour, instead of ad libitum.
    - This will get them adjusted to drinking when the water and electrolytes is offered at the show.
- Before leaving, feed half of what you normally feed to your goat.
    - This will ensure that your animal has enough feed to maintain energy and keep muscle tone but also keeps the goat's stomach at a proper fill level as showtime approaches.
- As you start packing for the show, below is a list of supplies you should pack.
    - This checklist should cover the basics of what you will need for the show, as well as preparation for the show.

Mark off each item as you pack to ensure that you don't forget something important!

Table 1.2. Checklist of items to pack for a goat show.

Item	Packed (*add "X" when packed*)
Feed	
Feeder	
Water Bucket	
Soap	
Short Water Hose	
Electrolytes	
Bedding	
Health Papers	
Goat Stand	
Blower	
Brush	
Show Sheen	
Hay	
Show Chain & Halter	

Arriving at the Show

After you have arrived at the fairgrounds, it is time to get your animal checked in, trailer unloaded and your goat settled into place. As stress levels rise for your animals, feed and water intake will likely decline. Stay calm and realize it will take time for your animal to adjust to the climate and begin eating and drinking normally. Have fun, stay focused, and enjoy what you've worked towards all year!

- After checking in and finding your pen assignment, make sure it has plenty of clean bedding and no wire or foreign unwanted materials before you stall your goat.
- Continue to offer your animal water with electrolytes to keep them hydrated and muscle tone fresh.
    - If your goat refuses to drink, drenching your animal is beneficial, if show regulations allow.
        - Check the rules.
- After getting the animal in place, feed half of a feeding and coordinate feeding times with how much you plan to feed at each meal.
    - Do not get your animal too full, as it will look bloated and less eye appealing to the judge.
    - Manage the amount of feed as the show becomes closer.
        - Feeding smaller amounts allows the goat to have enough feed to feel comfortable, yet not enough to get too full.
    - A small handful of high-quality hay can help keep your animal feeling well and healthy.
        - Also, will encourage goats to drink and stay hydrated.
- NEVER completely limit feed of the animal.
- Walking your goat around the barn allows for:
    - Proper exercise
    - Can help calm the animal
    - Will introduce the goat to unfamiliar areas in preparation for the show ring

Showtime

The time has finally come to experience what you've worked towards all summer! Enjoy the experience and remember to have fun and soak in the time you are a junior show exhibitor.

- When arriving at the fairgrounds on the morning of the show:
    - Feed your goat a half feeding.
    - Allow it to have plenty of water
        - Manage how much it drinks according to what time you show.
            - ✓ Gauge animals fill level as you move closer to entering the ring.
- After feeding, allow the animal to get out of the pen and get some exercise.
    - Will allow the animal to loosen up and get rid of a lot of pre-show nerves for both you and the goat.
- Wash and condition your goat.
    - Make sure you get it completely dry, allowing plenty of time before you enter the ring.
- After you get your animal completely dry, spray a light mist of show sheen and brush in with a soft bristled bush.
- Gives your animal a fresh appearance when entering the show ring.
- After you prepare your animal for the show ring:
    - Walk the goat with the show chain and set your goat up.
        - Provides you and your animal a last bit of practice before entering your class.
- Arrive at check-in with plenty of time before your class.
- Have fun!

Showmanship

Starting Out

It is essential to practice as frequently as possible with your goat at home to have in the showring. There is no such thing as too much showmanship practice. So, when you have free time during the day, putting the show collar on your project, walking them in a few circles and setting them up, can lead to great success.

- When you get your project, start building a relationship with it. This will allow your goat to settle down and become familiar with you.
- Start by just sitting in their pen or outside of their gate where they can see you and become familiar with your presence.
- Once your goat has become familiar with their new place and situation, you begin training them with the halter and show collar.
    - Patience is very important. It will allow the animal to build trust in your relationship, which will pay off in the long run.
- Teach your goat to set its legs and begin to learn the bracing technique:
    - "Bracing" refers to your goat pushing into your leg in order to enhance their muscle tone and essentially flex their top and leg muscles.
    - The handle of your goat will certainly improve when you brace an animal.
    - It is important to properly position yourself and the goat to get an appropriate brace.

Bracing Technique

When teaching your goat how to brace, knowing the proper technique for yourself is just as important. Practicing showing at both jackpot shows and at home is great preparation as you move forward.

- When setting up your goat, begin by placing the goat's legs in a square position that is comfortable for the animal.
- As the goat's legs are set, the front feet should be directly underneath the shoulders of the animal
- The rear legs of the animal should be placed approximately 3 inches behind the plane of the hip. **(See Reference 6)**
- After you have the animal's legs set into place, cup your hands around the goat's head.
    - Your left hand should be underneath the jaw, while the right hand should be lightly wrapped around the back of the head.
    - Do not put much pressure on the back of the animal's head, as it will be uncomfortable and have a shrugging reaction.

Figure 1.11. Proper goat leg placement.

Figure 1.12. Proper hand placement while showing a goat.

    - All the control you will need is with your left hand, if placed correctly.
        - It will take time to be comfortable with showing your project with the proper technique, do your best to not develop bad habits.
- Once you have the hand placement down, position your left leg in front of your goat and slightly apply pressure.
    - Slightly lift up the goat's front end to apply pressure to your leg and put their feet back on the ground.
    - DO NOT keep the front feet of your goat lifted up in the air.
- Your knee should be positioned on the base of the goat's chest and not on its right shoulder.
    - You do not want to cover the entire front end of your goat with your leg.
- Ensure that the animal does not get too stretched out and leg placement stays in the correct position.
    - If your goat moves, keep ahold of the chain and reposition feet and re-start the bracing procedure.

Walking

You will find detailed information in the *"Show Preparation"* section about showing your animal on the chain. It is very important that your animal leads naturally in the show ring. Walk your animal in the show ring the night before the show to practice and prepare for exhibition.

- Your goat should walk directly beside you.
    - You should never walk in front of your animal, as it will want to naturally pull backwards.

- Practice is crucial while preparing to show your goat, especially leading with a show chain.

Ring Etiquette

After all the practice is complete and you are prepared to enter the ring, there are a few last things to consider.

- Keep your goat evenly spaced when leading them.
- Keep the animal in a straight line when setting them up.
- Be respectful to the other exhibitors around you.
    - Treat others how you want to be treated.
- Remember this is a learning experience for everyone, make friends and have fun!

Showing Attire

After all the preparation has been put into your animal, it is important to be looking professional when you enter the ring. There are a few things to keep in mind when you decide what to wear:

- Nice jeans without holes, leather shoes, and a collared shirt is professional while still being practical and comfortable to show in.
- Do not wear something that draws attention to you rather than the animal you are showing.

Chapter 2 - Effects of sorghum grain as a replacement for corn on lamb growth performance and nutrient digestibility

Abstract

The United States is producing an increasing quantity of grain sorghum, also known by the common name of milo. This unique grain may be a viable energy source for sheep, but there is little information regarding its impact on growing lambs. The objective of this experiment was to evaluate the effects of substituting grain sorghum in place of corn in growing lamb diets. A total of 72 Rambouillet wethers (initially 33.9 ± 3.10 kg BW) were utilized in a completely randomized design and allotted to 1 of 4 dietary treatments over 35 d. Each pen contained 3 sheep and there were 6 pens per treatment. Dietary treatments included a corn-based control (42% corn/0% sorghum) or 10%, 20%, or 30% of sorghum replacing corn. All diets included titanium dioxide as an indigestible marker, and fecal samples were collected every 6 hr over a 3-day period at the end of the experiment for determination of total tract nutrient digestibility. Lambs, feeders, and feed additions were recorded weekly to determine average daily gain (ADG), average daily feed intake (ADFI) and gain to feed (G:F). Data were analyzed using the GLIMMIX procedure of SAS v9.4 (SAS Inst., Cary, NC) with pen as the experimental unit. There was no evidence ($P > 0.05$) that the inclusion of sorghum impacted any measured growth performance criteria. However, the higher price of sorghum at the time of the experiment led to lambs fed diets with 30% sorghum having a greater ($P = 0.017$) feed cost/lamb than the diets with lower concentrations of sorghum. Lambs fed increasing levels of sorghum had linearly improved ($P < 0.05$) apparent total tract digestibility of dry matter and organic matter, but there was no evidence of diet impacting the nutrient digestibility of crude protein, fiber, or ether extract. In conclusion, at least 20% sorghum can be used in place of corn without impacting feed

cost or nutrient digestibility. Up to 30% sorghum can be fed to lambs without altering growth to target specialized markets, but with potential impacts to feed cost and dry matter digestibility.

Introduction

The United States is the world leader in sorghum production (United Sorghum Checkoff, 2021). Compared to other cereal grains, sorghum is known to be more drought tolerant and efficient in dry arid climates (Mutava et al., 2011). As a feedstuff, sorghum contains 96% of the net energy content of corn for monogastric animals (NRC, 1998), and historically has been priced to be at 94 to 96% the price of corn to be cost-competitive in livestock diets as a source of energy. More recently, sorghum has had a price escalation due to growing demand in Chinese exports and domestic usage. These surging demands are largely due to sorghum having no genetically modified traits available on the commercial market, leading some grain processor to use sorghum in place of corn to target a consumer base interested in GMO-free foods.

As the demand for domestic and global lamb continues to grow, sheep producers look to corn and alternative grains for sources of energy. Historically some sheep producers would use sorghum in diets due to its price competitiveness to corn, but more, recently producers have begun to evaluate it as an energy source because of its GMO-free status for use in high-end retail and restaurant sales. However, there is limited published information regarding the use of sorghum in growing lamb diets. A review by Owens et al. (1997) summarized that most cattle feedlot studies have found no evidence of growth performance differences in steers fed corn vs. sorghum. However, very few studies are published using sheep or other small ruminants. What has been established in a limited capacity is regarding nutrient digestibility of the feedstuff; Streeter et al. (1990) demonstrated that that sorghum inclusion linearly decreased fecal weight and starch digestibility in lambs compared to those fed corn-based diets. It has been

hypothesized that animals fed sorghum-based diets have lower nutrient digestibility compared to those fed corn-based diets due to the proteinaceous matrix in the endosperm layer and harder peripheral endosperm of the sorghum berry (Gonzalez Garcia et al., 2016). However, there are few studies that have evaluated sorghum inclusion in growing lamb diets, especially in a controlled manner where feed intake is monitored. Thus, the objective of this experiment was to evaluate the growth performance, nutrient digestibility, and economic impact of growing lambs fed increasing levels of sorghum in place of corn.

Materials and Methods

All experimental procedures adhered to guidelines for the ethical and humane use of animals for research according to the Guide for the Care and Use of Agricultural Animals in Research and Teaching (FASS, 2010) and were approved by the Institutional Animal Care and Use Committee at Kansas State University (IACUC #4498).

Animals and Experimental Design

This experiment utilized 72, 6-month-old, Rambouillet wethers (initially 33.9 ± 3.10 kg BW). Lambs were stratified across treatments by body weight and allocated to pens of 3 lambs in a completely randomized design with 6 pens per treatment. Pens measured 3 m × 1.5 m and lambs were housed in an environmentally controlled building (13°C) at the Kansas State University Sheep and Meat Goat Center (Kansas State University, Manhattan, KS). Each pen was randomly assigned to 1 of 4 diets: 1) a corn-based control (42% corn/0% sorghum), 2) 10% sorghum (32% corn/10% sorghum), 3) 20% sorghum (22% corn/20% sorghum), or 30% sorghum (12% corn/30% sorghum).

Diets

The control diet was formulated to meet or exceed NRC (2006) nutrient requirements and included all forage to be a sole-source ration that did not require supplemental hay. No other ingredient quantity was adjusted to make diets as commercially relevant as possible. This resulted diets that analyzed to vary in CP from 15.8 to 17.7%, with increased CP as sorghum inclusion was increased (Table 1). All diets included 0.40% titanium dioxide as an indigestible marker for determination of nutrient digestibility, and were mixed and pelleted by Countryside Feed, LLC (Seneca, KS). Lambs were provided *ad libitum* access to clean water and feed via self-feeder throughout for the 35-d experiment. Sorghum and corn were ground to similar particle size and included in complete pellet. No supplemental forage was provided, and no refusals were collected. Feed samples were collected at the beginning and end of the experiment from feeders and pooled to create one sample per treatment.

Growth Performance

Lambs were weighed individually every 7 d to determine average daily gain (ADG). All feed additions were recorded at the time of addition. Feeder weights were recorded weekly to determine average daily feed intake (ADFI) and gain to feed (G:F).

Growth and ingredient prices were used to calculate diet cost (Eq. 2), feed cost (Eq. 3), and value of gain (Eq. 4). All prices were market value at the time of the experiment (April 2021).

$$Diet\ cost\ =\ Ingredient\ inclusion, \%\ \times Ingredient\ price, \% \quad \textbf{Eq. 2}$$

$$Feed\ cost = ADFI\ overall \times feed\ cost\ per\ kg\ of\ feed \times d\ on\ feed\ (35\ d). \quad \textbf{Eq. 3}$$

$$Value\ of\ gain = \frac{[(d\ 35\ BW \times market\ price\ at\ d\ 35) - (d\ 0\ BW \times market\ price\ at\ d\ 0)]}{Overall\ gain\ per\ lamb} \quad \textbf{Eq. 4}$$

Apparent Total Tract Digestibility of Nutrients

Fecal samples were collected from the median-weight lamb in each pen every 6 hr over a 3-day period at the end of the experiment for determination of total tract nutrient digestibility. Fecal material was obtained by rectal massage and collected directly into sterile plastic containers and stored at -20ºC until analyzed. Samples were thawed, then dried for 48 hours in a 55ºC forced-air oven and ground to pass through a 1-mm screen. Feed and fecal samples were analyzed for dry matter, organic matter, crude protein, crude fiber, ash, and ether extract by the University of Missouri Experiment Station Chemical Laboratories, (University of Missouri, Columbia, MO). Apparent total tract digestibility (ATTD) was then calculated using Eq. 1.

$$Digestibility, \% = 100 - \left(\frac{Ti_{\%,feed}}{Ti_{\%,feces}} \times \frac{Nutrient_{\%,feces}}{Nutrient_{\%,feed}}\right) \quad \textbf{Eq. 1}$$

Statistical Analysis

Data were analyzed using the GLIMMIX procedure of SAS v9.4 (SAS Inst., Cary, NC) with pen as the experimental unit for performance and economic data, and individual animal as the experimental unit for nutrient digestibility. Linear and quadratic contrasts were utilized to evaluate trends in the effect of sorghum inclusion level. An alpha of 0.05 was used to determine the level of significance for all response criteria.

Results and Discussion

There was no evidence ($P < 0.05$) that dietary treatment impacted final BW, ADG, ADFI, or G:F (Table 2). This conflicts with the results reported by Bowen et al. (2006), who found that growing Merino wethers fed sorghum had reduced ADG compared to those fed a complete commercial feedlot pellet. However, the Bowen et al. (2006) study provided sorghum as a supplemental pellet with *ad libitum* and unmeasured access to forage over the 42-d trial, whereas our experiment utilized a pellet with forage included as a sole-source ration.

The substantial price difference between corn ($0.0405/kg) and sorghum ($0.0453) at the time of the experiment in April 2021 led linearly greater feed costs with increasing inclusion of sorghum ($P = 0.017$). Sorghum grain was near a 10-year high at the time but have continued to remain high relative to corn (Kansas State University, WASDE). However, there was no evidence that sorghum inclusion impacted ($P > 0.10$) value of gain. Because feed cost per lamb was a function of commodity prices rather than intake in the current experiment, these results are likely to change as the commodity markets fluctuate.

Sorghum inclusion linearly reduced ($P = 0.013$) the apparent total tract digestibility of dry matter, but there was no evidence ($P > 0.10$) that it impacted digestibility of any other measured nutrient. This is contrary to results reported by Streeter et. al (1990), where increasing sorghum levels relative to corn led to similar dry matter digestibility but reduced organic matter and starch digestibility in feedlot steers. This could be related to an increasing tannin content with increasing levels of sorghum in the diet. Tannins are phenolic compounds that precipitate proteins, which can result in the reduction of protein digestibility. In that research, the authors speculated that the observed organic matter and starch digestibility differences were due to sorghum having greater resistance to digestive action compared to corn. Rooney and Pflugfelder (1986) described that sorghum has a harder peripheral endosperm layer compared to the floury starch endosperm layer found in corn. Ruminal starch digestion is considered one of the most important factors in dictating growth performance of ruminants fed grain-based diets (Stock et al., 1986, Huntington 1997). Waldo (1973) described that 74% starch in corn was fermented during *in vitro* simulation of a beef animal, while only 42% of starch in grain sorghum was fermented to volatile fatty acids. Decreased ruminal fermentation leads to greater starch flow to the small intestine (Theurer 1986) and result increasing quantities of starch transported to the

large intestine where the digestive efficiency of starch is the lowest (Harmon and McLeod 2001). The current experiment saw reduced dry matter digestibility, but no impact in other nutrients or overall growth performance, suggesting that the growing lambs were able to compensate for potentially lower ruminal starch digestibility, but additional research with greater replication is warranted to confirm these results.

In conclusion, at least 20% sorghum can be used in place of corn without impacting feed cost or nutrient digestibility. Up to 30% sorghum can be fed to lambs without altering growth to target specialized markets, but with potential impacts to feed cost and dry matter digestibility. This trial provides crucial data comparing sorghum grains to corn in the limited field of feedlot lamb nutrition. With increasing domestic sorghum production and lamb demand, additional research in this area is warranted.

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Table 2.1. Ingredient, chemical composition, and cost of growing lamb diets that contain varying concentrations of sorghum[1].

	Concentration of grain sorghum, % as-fed			
Item;	0	10	20	30
Ingredient, % as-fed				
Corn	42.12	32.12	22.12	12.12
Grain sorghum	0.00	10.00	20.00	30.00
Soybean meal	15.00	15.00	15.00	15.00
Soybean hulls	35.64	35.64	35.64	35.64
Molasses	2.50	2.50	2.50	2.50
Calcium carbonate	1.58	1.58	1.58	1.58
Ammonium chloride	1.00	1.00	1.00	1.00
Dicalcium phosphate	0.96	0.96	0.96	0.96
Salt	0.30	0.30	0.30	0.30
Premix[2]	0.50	0.50	0.50	0.50
Titanium dioxide	0.40	0.40	0.40	0.40
Analyzed chemical composition, % dry matter				
Crude protein	15.8	16.3	17.7	17.7
Crude fiber	12.1	13.1	12.3	13.3
Ash	7.6	7.3	6.7	7.3
Ether extract	1.5	0.9	1.6	1.3
Diet cost, $/kg[3]	0.059	0.060	0.062	0.063

[1]Dietary treatments were fed to 72 growing Rambouillet wethers (3 lambs/pen, 6 pens/treatment) for 35 d as a sole-source ration.
[2]Provided (per kg) 19 g Mg, 3 g Zn, 3 g Fe, 2 g Mn, 300 mg Cu, 100 mg Co, 1 mg Se, 100 mg I, 100 mg vitamin E, 500,000 IU vitamin A, and 100,000 IU vitamin D_3.
[3]Calculated using ingredient (per kg) costs as available in Manhattan, KS on April 5, 2021: corn $0.040, grain sorghum $0.055, soybean meal $0.095, soybean hulls $0.043, molasses $0.031, calcium carbonate $0.027, ammonium chloride $0.044, dicalcium phosphate $0.182, salt $0.007, premix $0.615, and grind/mix $0.013.

Table 2.2. Impact of increasing concentrations of sorghum on growing lamb growth performance and feed cost[1].

	Dietary inclusion of grain sorghum, % as-fed					*P* =	
Item;	0	10	20	30	SEM	Linear	Quadratic
BW, kg							
d 0	33.5	33.8	33.7	34.5	1.17	0.689	0.770
d 35	46.2	46.5	45.5	47.2	1.58	0.764	0.673
ADG, kg/d	0.35	0.36	0.34	0.36	0.021	0.973	0.718
ADFI, kg/d	1.75	1.73	1.68	1.85	0.054	0.324	0.092
G:F, kg/kg	0.20	0.21	0.20	0.20	0.011	0.600	0.704
Feed cost, $/lamb[2]	3.61[b]	3.63[b]	3.65[b]	4.08[a]	0.059	0.017	0.082
Value of gain, $/kg of gain[3]	0.30	0.29	0.31	0.32	0.008	0.203	0.870

[1]Dietary treatments were fed to 72 growing Rambouillet wethers (3 lambs/pen, 6 pens/treatment) for 35 d as a sole-source ration.

[2]Calculated as: feed cost per kg of feed × ADFI over 35 d experiment

[3]Calculated as: feed cost per lamb ÷ BW gained from d 0 to d 35.

Table 2.3. Impact of increasing concentrations of sorghum on apparent total tract nutrient digestibility in growing lambs[1].

	Dietary inclusion of grain sorghum, % as-fed					*P* =		
Item;	0	10	20	30	SEM	Treatment	Linear	Quadratic
Apparent digestibility								
Dry matter, % as-fed	74.9[a]	74.7[a]	71.9[b]	70.5[b]	1.26	0.062	0.013	0.659
Organic matter, % DM	71.9	74.1	70.4	75.0	2.52	0.103	0.037	0.151
Crude protein, % DM	73.8	71.7	70.9	71.7	0.92	0.171	0.101	0.124
Crude fiber, % DM	32.5	34.9	23.7	24.9	5.31	0.384	0.167	0.906
Ether extract, % DM	71.2	66.6	64.7	69.4	6.47	0.424	0.361	0.478

[1]Dietary treatments were fed to 72 growing Rambouillet wethers (3 lambs/pen, 6 pens/treatment) for 35 d as a sole-source ration. Diets contained 0.40% TiO_2, which served as an indigestible marker. Diet and fecal samples were collected every 6 hours from d 8 to 11 and pooled per pen prior to being analyzed for proximate analysis and calculation of apparent nutrient digestibility.

Chapter 3 - Efficacy of anthelmintic products on growing Spanish goats

Abstract

Deworming practices are essential in animals, especially in animals susceptible to parasites in a grazing environment, such as goats. However, there is limited published data comparing anthelmintic products, especially in growing Spanish goats. The objective of this experiment was to evaluate the impact of varying oral anthelmintic treatments on fecal egg count and growth performance of growing Spanish goats. A total of seventy-two intact male goats (Spanish, 25.17 ± 3.0 kg) were obtained from the same commercial grazing operation. Goats were weighed upon arrival and allocated to elevated pens in an indoor facility to balance body weight. Pens were randomly assigned one of four oral anthelmintic treatments in a completely randomized design, which were administered according to manufacturers' recommendations on d 0. Anthelmintic treatment included: Control (no treatment administered); 2) moxidectin (0.40 mg/kg; Elanco Animal Health, Greenfield, IN); 3) fenbendazole (10.00 mg/kg; Merck Animal Health, Rahway, NJ); or 4) albendazole (20.00 mg/kg; Zoetis Animal Health, Parsippany, NH). There were 3 goats/pen and 6 pens/treatment. Feces were collected weekly, along with animal weights and feed disappearance to calculate reduction in fecal egg count from d 0, average daily gain, average daily feed intake, and feed efficiency. Data were analyzed using the GLIMMIX procedure of SAS v.9.4 (SAS Inst., Cary, NC). There was no evidence ($P > 0.05$) that treatment impacted any measured response criteria. Compared to the control, the addition of an anthelmintic, regardless of type, reduced ($P < 0.05$) Eimeria eggs on d 7 and total eggs on d 28. The results of this study showed limited efficacy of anthelmintics in Spanish goats; which is contrary to other studies. These results may have been impacted by all animals being housed in

elevated pens with no exposure to dirt or feces. Additional research is therefore warranted to compare anthelmintic efficacy in more commercially relevant environments.

Introduction

Gastrointestinal parasitic infection is one of the most important concerns for livestock producers in the United States, causing devastating economic losses (Adediran and Uwalaka., 2015). To combat these effects, producers use oral or injectable anthelmintic products to control internal and external parasites. This is especially important in goats, which typically have high parasite levels due to grazing management practices (Kaplan 2004). Anthelmintic efficacy is measured by collecting fecal samples and analyzing the type and quantity of eggs on an equal volume basis. These results are often reported as a reduction in fecal egg count compared to initial levels (Coles et al., 2006).

While anthelmintic administration is common, there are few studies directly comparing various anthelmintic agents in growing goats, especially in Spanish breeds. Osti et al., (2016), suggest increasing meat goat populations such as Spanish goats can be attributed to rising consumer demand with increased ethnic diversity. Comparative to other meat goat breeds such as Boer, Spanish does indicate a higher stayability and cumulative kid production rates on an annual basis, aiding to their popularity (Pellerin and Browning., 2012). Spanish does consistently show a greater resistance to parasite exposure than Boer does based upon endoparasite caused illness and FEC (Browning et al., 2011, Nguluma et al., 2013). Spanish goat populations have been transformed due to environmental exposure and natural selection in their native land of Texas for up to 500 years which could have genetically built up a greater parasitism resistance (Browning et al., 2011).

Therefore, the objective of this experiment was to evaluate the impact of varying oral anthelmintic treatments on fecal egg count and growth performance of growing Spanish goats.

Materials and Methods

All experimental procedures adhered to guidelines for the ethical and humane use of animals for research according to the Guide for the Care and Use of Agricultural Animals in Research and Teaching (FASS, 2010) and were approved by the Institutional Animal Care and Use Committee at Kansas State University (IACUC #4498.4). FECRT was utilized the Modified Wisconsin Sugar Floatation Technique by the Kansas State University Veterinary Diagnostic Laboratory.

Animals and Experimental Design

A total of 72 intact male Spanish goats (25.2 ± 3.0 kg) were utilized over 28 d to evaluate the efficacy of varying anthelmintic treatments in growing Spanish Goats. were obtained from the same commercial grazing operation. Goats were weighed upon arrival and allocated to elevated pens in an indoor facility to balance body weight. Pens measured 3 m × 1.5 m and lambs were housed in an environmentally controlled building (13° C) at the Kansas State University Sheep and Meat Goat Center (Kansas State University, Manhattan, KS). Pens were randomly assigned one of four oral anthelmintic treatments in a completely randomized design, which were administered orally according to manufacturers' recommendations on d 0. Anthelmintic treatment included: Control (no treatment administered); 2) moxidectin (0.40 mg/kg; Elanco Animal Health, Greenfield, IN); 3) fenbendazole (10.00 mg/kg; Merck Animal Health, Rahway, NJ); or 4) albendazole (20.00 mg/kg; Zoetis Animal Health, Parsippany, NH).

There were 3 goats/pen and 6 pens/treatment. Goats were provided *ad libitum* access to a commercial goat feed and water throughout the duration of the experiment, which was 28-d.

Fecal Egg Count and Growth Performance

Fecal samples were collected on d 0, 7, 14, 21, and 28 by rectal massage into sterile plastic containers. Samples were submitted to the Kansas State University Veterinary Diagnostic Laboratory for quantitative fecal egg count. FEC were reported as a reduction from d 0 and represented in $\log_{10}$ format. Goats were weighed individually on d 0, 7, 14, 21, and 28 to determine average daily gain, average daily feed intake, and feed efficiency. Growth and anthelmintic prices were used to calculate value of gain (Eq. 1) and income over product cost (Eq. 2). All prices were market value at the time of the experiment (April 2022).

$$Value\ of\ gain = \frac{[(d\ 28\ BW \times market\ price\ at\ d\ 28) - (d\ 0\ BW \times market\ price\ d0)]}{Overall\ gain\ per\ goat} \quad \textbf{Eq. 1}$$

$$Income\ over\ product\ cost = \frac{Value\ of\ gain}{Total\ feed\ and\ anthelmintic\ cost} \quad \textbf{Eq. 2}$$

Statistical Analysis

Goats were weighed and fecal samples collected individually, but feed was provided per pen, which resulted in the experimental unit for BW, ADG, and fecal egg count being the animals, and the experimental unit for ADFI, G:F, value of gain, and income over product cost being the pen. Data were analyzed using the GLIMMIX procedure of SAS v9.4 (SAS Inst., Cary, NC), which included treatment as a fixed effect. A pre-planned contrast of dewormer vs. none was included. Data were considered significant if $P < 0.05$.

Results and Discussion

There was no evidence ($P > 0.05$) that treatment impacted any measured response criteria (Table 2). Compared to the control, the addition of an anthelmintic, regardless of type, reduced

($P < 0.05$) Eimeria eggs on d 7 and total egg count on d 28 as indicated in table 3.2. However, Eimeria reduction is an indirect response as anthelmintics administered did not target that specific parasite. The results of this study showed limited efficacy of anthelmintics in Spanish goats; which is contrary to other studies. Specifically, Cringoli et al., (2009), reported that moxidectin was highly effective in small ruminants. However, that study utilized lactating ewes, whose physiology obviously differs from that of growing intact male Spanish goats. Additionally, Goolsby et al., (2017) described that moxidectin, ivermectin, and albendazole had significantly lower FEC compared to control group, while the group treated with levamizole did not differ. The current study concurs with findings by Byaruhanga and Okwee-Acai (2013), that albendazole shows no reduction in FEC of goats compared to group without anthelmintic treatment.

We propose two possible explanations for the lack of treatment-specific responses in this study. First, goats were housed in elevated pens after the oral anthelmintic was administered. This prevented goats from being exposed to soil and growing forages that typically provides a continual source of parasite exposure to animals. Without reintroduction to parasites through exposure through forages close to ground or fecal material, anthelmintic effectiveness may have been altered. Nearly 80% of infectious parasites within the first 5 cm of vegetation (Kumar et al., 2013). As parasite larvae are shed through manure, elevated, slated surfaces allow for the passing of fecal material and a prevention of parasite reintroduction to goats. A second possible explanation for the lack of response to anthelmintic agents in this study is that the goats may have developed resistance to their active ingredients. Development of anthelmintic resistance is now a problem within goats worldwide and is extremely prevalent in goats (Jackson and Coop, 2000). Nutritional changes are known to impact anthelmintic resistance (Hoste et al., 2005). The

goats in this project experienced a relatively abrupt nutritional change, from a forage-based grazing setting to a feedlot-based diet with no supplemental forage. This nutritional change occurring simultaneously with anthelmintic administration may have overshadowed any potential anthelmintic response; a response reported by others (Athanasiadou et al., 2003; Min et al., 2004; and Waghorn and McNabb, 2003). However, others have reported that less extreme changes in diet, such as protein source instead of level, has no evidence of impacting anthelmintic efficacy (Singh et al., 1995).

There was no evidence ($P > 0.05$) that anthelmintic treatment impacted any growth performance or economic variable measured (Table 2). These results conflict with findings of Khallaayoune and Stromberg (1992), which indicated that anthelmintic treatment of growing lambs increased post-weaning growth. However, that study utilized a longer time of study compared to our 28 days experiment. Likewise, anthelmintic treatment has been clearly demonstrated to improve stocker calf growth performance (Williams et al., 1999; Rehbein et al., 2013; and Backes et al., 2021). While there are limited published studies in goats, especially with Spanish-based genetics.

In summary, the results of this study showed limited efficacy of anthelmintics in Spanish goats, which is contrary to other studies. These results may have been impacted by all animals being housed in elevated pens with no exposure to dirt or feces or due to anthelmintic resistance. Given the growing demand for goats and their known challenges with parasites, additional research is warranted to compare anthelmintic efficacy in more commercially relevant environments.

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Table 3.1. Nutrient Analysis of total mixed ration fed to Spanish bucks from d 0 to d 28[1].

Nutrient analysis, % DM	TMR
Crude Protein, %	18.40
Ether Extract, %	4.23
Acid detergent fiber, %	24.90
Ash, %	7.63

[1]Dietary treatment were fed as a sole source ration to 72 Spanish bucks in a completely randomized design with 6 replication pens per treatment during the 28-d phase.

Table 3.2. Reduction of fecal egg count according to egg type in anthelmintic-treated Spanish goats[1].

	Anthelmintic Treatment					*P* =	
Item;	Control	Moxidectin[2]	Fenbendazole[3]	Albendazole[4]	SEM	Treatment	Dewormer vs. none
Eimeria							
d 7	2.7	3.5	3.0	3.2	0.27	0.097	0.030
d 14	2.8	3.1	3.0	3.2	0.22	0.410	0.118
d 21	2.8	3.1	3.0	3.1	0.20	0.752	0.282
d 28	2.3	2.7	2.9	2.7	0.29	0.531	0.169
Strongyloides							
d 7	1.2	1.4	1.0	1.4	0.20	0.261	0.557
d 14	1.3	1.4	1.0	1.3	0.18	0.339	0.859
d 21	1.3	1.4	1.0	1.4	0.18	0.328	0.847
d 28	0.5	0.5	0.3	0.6	0.17	0.514	0.777
Strongyle							
d 7	2.7	2.9	2.7	3.0	0.14	0.136	0.324
d 14	2.8	2.9	2.8	2.8	0.18	0.962	0.767
d 21	2.9	2.9	3.1	2.8	0.13	0.396	0.895
d 28	2.2	2.8	2.1	2.6	0.56	0.239	0.338
Trichuris							
d 7	1.1	1.3	1.0	1.2	0.16	0.337	0.705
d 14	1.2	1.3	1.0	1.2	0.18	0.536	0.902
d 21	1.2	1.1	1.0	1.2	0.24	0.908	0.774
d 28	0.3	0.3	0.5	0.6	0.13	0.244	0.623
Total							
d 7	3.0	3.2	3.2	3.5	0.20	0.310	0.235
d 14	3.2	3.2	3.2	3.4	0.16	0.642	0.467
d 21	3.3	3.4	3.3	3.4	0.15	0.938	0.676
d 28	2.2	3.2	3.0	2.9	0.28	0.091	0.016

[1]A total of 72 Spanish intact male goats (25.17 ± 3.0 kg) were used in a completely randomized design. Goats were administered one of four oral anthelmintic treatments on d 0. Goats were then housed in pens (3 goats/pen, 6 pens/treatment) and fed the same basal diet for 28 d. Fecal samples were collected weekly and analyzed for quantitative egg count. Results are reported in reduction from d 0.

[2]Tradename Cydectin®, Elanco Animal Health, Greenfield, IN. Contained 0.40 mg/kg anthelmintic per label directions.

[3]Tradename Safe-Guard®, Merck Animal Health, Rahway, NJ. Contained 10.00 mg/kg anthelmintic per label directions.

[4]Tradename Valbazen®, Zoetis Animal Health, Parsippany, NJ. Contained 20.00 mg/kg anthelmintic per label directions.

Table 3.3. Impact of anthelmintic treatment on growth performance of Spanish goats[1].

	Anthelmintic Treatment					*P* =	
Item;	Control	Moxidectin[2]	Fenbendazole[3]	Albendazole[4]	SEM	Treatment	Dewormer vs. none
BW, kg							
d 0	25.3	24.6	25.1	25.4	0.73	0.845	0.783
d 28	29.6	30.5	31.3	30.5	1.35	0.821	0.440
ADG, kg/d	0.24	0.28	0.26	0.26	0.042	0.739	0.382
ADFI, kg/d	1.76	1.55	1.76	1.82	0.321	0.846	0.846
G:F	0.15	.0.19	0.15	0.15	0.024	0.425	0.418
Value of gain, $/kg of gain[4]	11.56	11.82	14.58	12.45	1.117	0.191	0.258
Income over product cost, $[5]	4.08	3.19	3.87	4.33	0.598	0.557	0.664

[1]A total of 72 Spanish intact male goats (25.17 ± 3.0 kg) were used in a completely randomized design. Goats were administered one of four oral anthelmintic treatments on d 0. Goats were then housed in pens (3 goats/pen, 6 pens/treatment) and fed the same basal diet for 28 d.

[2]Tradename Cydectin®, Elanco Animal Health, Greenfield, IN. Contained 0.40 mg/kg anthelmintic per label directions.

[3]Tradename Safe-Guard®, Merck Animal Health, Rahway, NJ. Contained 10.00 mg/kg anthelmintic per label directions.

[4]Tradename Valbazen®, Zoetis Animal Health, Parsippany, NJ. Contained 20.00 mg/kg anthelmintic per label directions.

[5]Calculated as: [(Diet cost × ADFI) + anthelmintic cost]/BW gained during the experiment

[6]Calculated as: Value of gain/total feed and anthelmintic cost

Chapter 4 - Effects of increasing soybean meal concentrations to alter dietary crude protein level on the growth, nutrient digestibility, and carcass characteristics of growing Easycare lambs

Abstract

A common sheep industry practice is to substitute soybean meal (SBM) in place of corn for growing lambs in a feedlot setting, but there is limited data evaluating its impact, especially in hybrid hair sheep. The objective of this experiment was to evaluate the effect of increasing levels of crude protein (CP) by substituting SBM place of corn in growing Easycare lambs. A total of 77 Easycare (Dorper × Katahdin × Romanov) lambs were fed one of three dietary treatments in a Latin square design with 7 replicate pens per treatment during three 28-d phases. Dietary treatments included a control (7.7% SBM/89.5% corn) or the control with 11.7% or 15.7% SBM at the expense of corn. At the end of each phase, fecal samples were collected from six lambs per pen and analyzed to determine nutrient digestibility. After phase 1, five male lambs per treatment with the weight closest to the median were slaughtered and carcass data collected. Lamb ADG was impacted ($P = 0.0004$) by a sex × SBM interaction, with wethers being fed 7.7% SBM having reduced ($P < 0.05$) ADG compared to all ewes or wethers being fed 11.7 or 15.7% SBM diets. Increasing levels of SBM linearly increased lamb BW and ADG but did not impact any other growth performance variable. Increasing levels of SBM also increased ($P < 0.05$) apparent total tract digestibility of dry matter, organic matter, crude protein, and ether extract, but not ($P > 0.05$) crude fiber. Finally, there was no evidence ($P > 0.05$) that dietary treatment impacted carcass characteristics. These results suggest that growing easy care castrated males benefit from

adding at least 4% SBM in place of corn to increase dietary CP, and that additional research is warranted to evaluate longer-term impacts on cost and carcass composition.

Introduction

Soybean meal (SBM) is a valuable protein source in livestock diets (Hymowitz, 2008). Historically, SBM supplementation has been greater in monogastric than ruminant diets due to its relatively balanced amino acid profile demanding a higher price than other protein sources. However, when economics support its use, SBM is effective in ruminant diets. Comerford et al. (1992) reported that SBM supplementation in feedlot cattle diets improved average daily gain (ADG), yield grade (YG), and ribeye area (REA). Likewise, Loerch et al. (1981) reported that lambs fed supplemental SBM had great ADG, lower average daily feed intake (ADFI), and improved feed efficiency (G:F) compared to those fed a basal diet or other protein sources, such as blood meal, meat and bone meal, or dehydrated alfalfa. Subsequent research on protein sources or levels in growing lambs has been limited, but this early study has led to lamb feedlots increasing SBM levels in lamb finisher rations in commercial settings with success. However, this management protocol has not been evaluated scientifically to confirm its value or determine its physiological basis.

The lack of published nutritional research in small ruminants is not new but has greater consequences now that global lamb demand is increasing. The price of lamb has increased significantly over the past twelve months, with net lamb carcass cutout value 53.7% greater than a year ago (USDA, 2022). However, corn and most commodity prices are also up 60% (USDA, 2022). With whole corn being the primary portion of their diet, lamb feeders are looking for opportunities to reduce diet costs or optimize efficiency (Gallo et al., 2014). These changing market dynamics have created an increased urgency to understand methods to increase G:F in

growing lambs. This is especially true in the hybrid hair sheep market, where there is high demand for lamb product due to the animals' resistance to parasites and easy care. However, nutritional research in these hybrid animals is even more limited. Therefore, the objective of this experiment was to evaluate the effect of increasing levels of crude protein (CP) by substituting SBM place of corn in growing Easycare lambs.

Materials and Methods

All experimental procedures adhered to guidelines for the ethical and humane use of animals for research according to the Guide for the Care and Use of Agricultural Animals in Research and Teaching (FASS, 2010) and were approved by the Institutional Animal Care and Use Committee at Kansas State University (IACUC #4498.1).

Animals and Experimental Design

Seventy-seven Easycare lambs (Dorper × Katahdin × Romanov; initially 26.75 ± 1.87 kg) were utilized in a Latin square design. Lambs were acclimated for 7 days to the control diet, then balanced for body weight and sex, and randomly allotted to pens. There were 11 lambs per pen and 7 pens per treatment during three 28-day phases. Animals were housed at the Kansas State University Sheep and Meat Goat Center (Manhattan, KS). Lambs were assigned to 1 of 3 diets: 1) a corn-SBM-based control (89.5% corn/7.7% SBM), 2) 11.7% SBM (85.5% corn/11.7% SBM), or 3) 15.7% SBM (81.5% corn/15.7% SBM). Diets were fed for 28-days during three separate phases. A 14-day washout period was used between each phase, during which the basal diet was fed to all animals. Each pen of animals was fed each of the three dietary treatments.

Diets

The control diet was formulated to meet or exceed NRC (2012) nutrient requirements and

included all forage to be a sole-source ration that did not require supplemental hay. This resulted in diets that analyzed with 11.0, 12.8, and 14.8% CP for the control, 4% SBM, and 8% SBM treatments, respectively (Table 1). All diets included 0.40% titanium dioxide as an indigestible marker for determination of nutrient digestibility and were mixed and pelleted at Valley View Milling (Seneca, KS). Lambs were provided *ad libitum* access to clean water and feed via self-feeder for 28 days. No supplemental forage was provided, and no refusals were collected. Feed samples were collected at the beginning and end of the experiment from feeders and pooled to create one sample per treatment.

Growth Performance and Carcass Data

Lambs were weighed individually every 7 d to determine average daily gain (ADG). All feed additions were recorded at the time of addition. Feeder weights were recorded weekly to determine average daily feed intake (ADFI) and gain to feed (G:F).

Growth and ingredient prices were used to calculate diet cost value of gain (Eq. 1) and income over feed cost (Eq. 2). All prices were market value at the time of the experiment (April 2022).

$$Value\ of\ gain = \frac{[(d\ 84\ BW \times market\ price\ at\ d\ 84) - (d\ 0\ BW \times market\ price\ at\ d\ 0)]}{Overall\ gain\ per\ lamb} \quad \textbf{Eq. 1}$$

$$Income\ over\ feed\ cost = Value\ of\ gain - total\ feed\ cost \quad \textbf{Eq. 2}$$

Upon completion of Phase 1, five male lambs per treatment with the weight closest to the median were slaughtered and carcass data collected in a USDA-inspected facility, along with 4 light weight lambs being removed from trial. This resulted in the use of 77 lambs in growth performance calculations for Phase 1 and 58 lambs for each of Phase 2 and 3.

Apparent Total Tract Digestibility of Nutrients

On the final day of each phase, fecal samples from six ewes were collected from each pen and pooled by pen. Fecal material was obtained by rectal massage and collected directly into sterile plastic containers and stored at -20ºC until analyzed. Samples were thawed, then dried for 48 hours in a 55ºC forced-air oven and ground to pass through a 1-mm screen. Feed and fecal samples were analyzed for dry matter, organic matter, crude protein, crude fiber, ash, and ether extract by Midwest Laboratories (Omaha, NE). Apparent total tract digestibility (ATTD) was then calculated using Eq. 3.

$$Digestibility, \% = 100 - \left(\frac{Ti_{\%,feed}}{Ti_{\%,feces}} \times \frac{Nutrient_{\%,feces}}{Nutrient_{\%,feed}}\right) \quad \textbf{Eq. 3}$$

Statistical Analysis

Lambs were weighed individually, but feed was provided per pen, which resulted in the experimental unit for BW, ADG, nutrient digestibility, and carcass characteristics being the animal, and the experimental unit for ADFI, G:F, value of gain, and income over feed cost being the pen. Therefore, a sex × SBM level interaction was considered for BW and ADG, but only the main effect of SBM level was considered for all other response criteria. Data were analyzed using the GLIMMIX procedure of SAS v9.4 (SAS Inst., Cary, NC).

An alpha of 0.05 was used to determine the level of significance for all response criteria. When significant, treatment means were separated by pairwise comparisons with the Tukey-Kramer multiple comparison adjustment. Linear contrasts were used to evaluate trends in the effect of increasing SBM inclusion.

Results and Discussion

The interaction between sex and SBM level impacted ($P = 0.004$) ADG, but not final BW (Table 2). While increasing SBM inclusion linearly increased ($P < 0.05$) final body weight, the effect in ADG was most magnified when considering the impact of sex. Specifically, wethers fed 7.7% SBM had reduced ($P < 0.05$) ADG compared to any other treatment, including ewes fed 7.7% SBM and wethers fed 11.7% SBM. We hypothesize this interaction was due to Easycare wether lambs requiring greater CP relative to that recommended in NRC (2012). Bangar et al. (2021) reported similar results, where wether lambs required greater CP relative to ewe lambs at the same age. Likewise, Chegini et al. (2019) and Manera et al. (2014) have both reported that published NRC levels for CP may be too low in some breeds; both observed an improvement in ADG when lambs were fed greater levels of protein.

Because feed was delivered in a single feeder per pen and each pen contained a balance of ewes and wethers, the factor of sex was not considered in any feed-related response criteria. There was no evidence ($P > 0.05$) that SBM level impacted ADFI, value of gain, or income over feed cost. This differs from what was reported by Obeidat et al. (2019), who found that Awassi lambs fed increasing levels of SBM had linearly improved final weight, ADG, and dry matter intake of the supplemental pellets. Our study differs slightly from that of Obeidat et al. (2019), in that the authors provided *ad libitum* access to low-quality forage, and they recommended that subsequent research evaluate the impact of increasing SBM with more tightly controlled intake parameters. The current study has an advantage in that intake of all feedstuffs was measured, and this may be responsible for differences between the two studies in ADFI and G:F. A possible limitation of this study is that feed and water access were not restricted prior to weighing lambs, so animal gut fill may have contributed to greater variability in final BW.

While differences in G:F were not observed, there was clear indication that increased SBM inclusion improved nutrient digestibility. Increasing levels of SBM linearly increased ($P < 0.05$) apparent total tract digestibility of dry matter, organic matter, crude protein, and either extract (Table 3). There was no evidence ($P > 0.05$) that diet impacted apparent crude fiber digestibility. Previous research has hypothesized that elevated ruminal N from supplemental dietary CP improves nutrient passage rate in ruminant animals (Hannah et al., 1991). This leads to optimized microbial fermentation and increases nutrient digestibility (Wahyono et al, 2022).

Finally, there was no evidence ($P > 0.05$) that SBM level impacted dressing percentage, loin eye area, backfat thickness, or final yield grade (Table 4). These results align with those reported by Field et al. (1990) and Fluharty et al. (1999), who also reported no differences in carcass measurements of lambs slaughtered at a similar. Easy care lambs are smaller and have a lighter slaughtered weight than their wool-breed contemporaries. For example, Lloyd et al. (1980) reported that additional time on feed and a greater slaughter weight of lambs will increase fat thickness and increase yield grade. Feeding lambs to heavier weights prior to slaughter may have led to more discernable variations in carcass characteristics. For example, Jaborek et al. (2017), reported that increasing energy and a reduction in protein in lamb diets increased backfat thickness and yield grade of slaughtered lambs. The lack of difference for carcass characteristics may be directly related to a smaller carcass weight of lambs slaughtered in this study.

In conclusion, the results from this experiment suggest that ADG and nutrient digestibility can be optimized in easy care lambs by feeding at least 11.7% SBM. This study adds to the growing evidence that the current NRC (2012) underestimates the CP requirement for growing wether lambs. Given the increasing demand for lamb and limited published research in

the area, further research is warranted to better understand nutritional requirements in all small ruminants, but especially hybrid hair sheep.

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Table 4.1. Ingredient and chemical composition of growing lamb diets containing varying concentrations of soybean meal[1].

	Concentration of soybean meal, % as-fed		
Item;	7.7	11.7	15.7
Ingredient, % as-fed			
Corn	89.5	85.5	81.5
Soybean meal	7.7	11.7	15.7
Wheat middlings	0.63	0.63	0.63
Fish meal	0.13	0.13	0.13
Monocalcium phosphate	0.12	0.12	0.12
Ammonium chloride	0.15	0.15	0.15
Limestone	0.88	0.88	0.88
Salt	0.07	0.07	0.07
Titanium dioxide	0.40	0.40	0.40
Vitamin premix	0.10	0.10	0.10
Lasalocid	0.01	0.01	0.01
Yeast	0.25	0.25	0.25
Analyzed chemical composition, % as-fed			
Dry matter	86.9	87.4	87.3
Organic matter	97.0	96.8	96.4
Crude protein	11.0	12.8	14.8
Ether extract	3.5	3.4	3.3
Acid detergent fiber	2.6	2.8	2.4

[1]Dietary treatments were fed as a sole source ration to 77 easy care (Dorper × Katahdin × Romanov) lambs in a Latin square design with 7 replicate pens per treatment during three 28-d phases.

[2]Provided (per kg) 19 g Mg, 3 g Zn, 3 g Fe, 2 g Mn, 300 mg Cu, 100 mg Co, 1 mg Se, 100 mg I, 100 mg vitamin E, 500,000 IU vitamin A, and 100,000 IU vitamin D_3.

Table 4.2. Impact of increasing concentrations of soybean meal on growing easy care lamb growth performance and feed cost[1].

Soybean meal level, %:	7.7		11.7		15.7			*P* =			
Sex:	Ewe	Wether	Ewe	Wether	Ewe	Wether	SEM	SBM Level Linear	SBM Level	Sex	Sex × SBM level
n =	33	34	33	34	33	34					
BW, kg											
d 0	26.5	25.5	24.8	27.7	27.7	28.3	1.87	0.229	0.435	0.529	0.514
d 28	34.6	31.2	33.0	35.8	35.7	37.5	2.08	0.045	0.133	0.798	0.194
ADG, kg/d	0.29[a]	0.20[b]	0.29[a]	0.29[a]	0.29[a]	0.32[a]	0.021	0.002	0.005	0.282	0.004
n =	7		7		7						
ADFI, kg/d	1.21		1.34		1.25		0.183	0.587	0.855	n/a	n/a
G:F	0.23		0.22		0.26		0.023	0.589	0.451	n/a	n/a
Value of gain, $/kg of gain[2]	0.43		0.49		0.41		0.045	0.300	0.429	n/a	n/a
Income over feed cost[3]	4.48		3.99		5.11		0.439	0.404	0.238	n/a	n/a

[1]Dietary treatments were fed as a sole source ration to 77 Easycare (Dorper × Katahdin × Romanov) lambs in a Latin square design with 7 replicate pens per treatment during three 28-d phases. After phase 1, five male lambs per treatment with the weight closest to the median were slaughtered and carcass data collected, leading to 77 lambs in Phase 1 and 58 lambs in each of Phase 2 and 3. Lambs were weighed individually, but feed was provided per pen, leading to the experimental unit for BW and ADG being the animal and the experimental unit for ADFI, G:F, value of gain, and income over feed cost being the pen. Lamb sex was balanced across pens.

[2]Calculated as: (Diet cost × ADFI)/BW gained during the experiment

[3]Calculated as: Value of gain/total feed cost

[ab]Means within a row that do not share a common superscript differ $P < 0.05$.

Table 4.3. Impact of increasing concentrations of soybean meal on apparent total tract nutrient digestibility in growing easy care lambs[1].

	Dietary inclusion of soybean meal, % as-fed				*P* =	
Item;	7.7	11.7	15.7	SEM	SBM Level	Linear
n =	18	18	18			
Apparent digestibility						
Dry matter, % as-fed	78.2[b]	84.6[a]	85.5[a]	1.45	0.004	0.002
Organic matter, % DM	62.5[b]	75.6[a]	77.9[a]	1.41	< 0.0001	< 0.0001
Crude protein, % DM	63.9[b]	73.3[a]	70.4[ab]	2.00	0.012	0.034
Crude fiber, % DM	48.9	52.9	46.5	4.90	0.653	0.734
Ether extract, % DM	77.8[b]	84.5[a]	85.8[a]	1.51	0.003	0.002

[1]Dietary treatments were fed as a sole source ration to 77 Easycare (Dorper × Katahdin × Romanov) lambs in a Latin square design with 7 replicate pens per treatment during three 28-d phases. At the end of each phase, fecal samples were collected from six lambs per pen and analyzed for nutrient concentration.

[ab]Means within a row that do not share a common superscript differ $P < 0.05$.

Table 4.4. Impact of increasing concentrations of soybean meal on carcass characteristics of growing easy care lambs[1].

	Soybean meal level, %				*P* =	
	7.7	11.7	15.7	SEM	SBM Level	Linear
n =	5	5	5			
Live weight, kg	26.3	26.7	27.6	1.17	0.733	0.831
Dressing percentage, %	44.7	48.6	47.3	1.54	0.226	0.098
Loin eye area, cm^2	8.1	7.4	9.0	1.09	0.570	0.626
Backfat, cm	0.2	0.2	0.2	0.03	0.804	0.574
Yield grade	1.1	1.2	1.1	0.12	0.794	0.467

[1]Dietary treatments were fed as a sole source ration to 77 Easycare (Dorper × Katahdin × Romanov) lambs in a Latin square design with 7 replicate pens per treatment during three 28-d phases. After phase 1, five male lambs per treatment with the weight closest to the median were slaughtered and carcass data collected.