FERMENTABLE FIBER FOR MILKING SHEEP ON THE STAR SYSTEM

Nikola Kochendoerfer
Cornell University
Ithaca, New York, USA

Introduction

The US imports 50 to 60% of the world's annual exports in sheep dairy products, enumerating a demand that has risen by 30% in the past 20 years as measured by imports (Thomas, 2014). Considering the vast forage availability and idle acreage in the Northeastern US, this deficiency in domestic production presents huge opportunities. One of the reasons that sheep dairy production in the US is still in early stages is its seasonal character. That goes in hand with major limitations and difficulties for sheep dairy producers listed in the literature, ranging from uneven labor loads, uneven distribution of nutrient requirements of the flock, seasonal income, and difficulties to synchronize lambing seasons (Sitzia et al., 2015). Compared to Europe there hasn't been nearly as much effort put into genetic improvement and, except at the University of Wisconsin Spooner station, little research into new management strategies. In addition, due to stringent import restrictions, little new genetic material is available for breeding.

With a focus on nutrition, this paper and the corresponding presentation discuss design, course, and cornerstones of a recently started two-year research project here on the Cornell campus, milking 45 Finnsheep × Dorset meat ewes in short lactations year-round on the STAR accelerated lambing system.

Acknowledging advantages and disadvantages of seasonal production for family and other small-holder farms, the study aims for a two-fold approach: 1) a management blueprint for adding a second value to meat sheep production and 2) nutritional guidelines toward maintaining health, high level production, and optimal body condition in ewes being milked in an intense, accelerated system, with the goal to milk a high number of sheep in the first part of lactation. The question raised and hoped to be answered throughout this project is what diet best supports high productivity in ewes (namely high milk yields), the ability to breed out of season, and a high number of offspring.

Methods

The STAR accelerated lambing system, developed by Brian Magee and Doug Hogue at Cornell University in the 1980s, is adapted to a total dairy situation in this project, with lambs removed from their dams within the first 12 hours and reared artificially. The participating ewes are in three STAR groups and milked in consecutive 73 to103-day lactations, for five successive lactations per year, while being managed in two groups: 1) lambing and lactating (⅓ of the ewes at a time) and 2) gestating (⅓ of the ewes) and breeding (⅓ of the ewes). Each ewe on the schedule will lamb 1.67 times a year, with 7.6 months between each lambing. Each ewe will be rebred during days 73 to 103 into lactation. The lactating ewes are kept in a barn and are randomly assigned to one of three diets containing different levels of pfNDF (potentially fermentable NDF), 30, 35, and 40%, respectively. There are 12 ewes in each STAR group, with 4 ewes fed each diet. The ewes undergo an adaption period to their assigned diet prior to lambing, and are fed their diets twice daily ad libitum with a small amount of hay being offered. Feed refused and amount of feed offered is recorded twice daily. Digestibility may be measured using chromic oxide as a marker. Body weights are collected weekly during lactation, as well as before breeding and at scanning for pregnancy at 73 days after the start of breeding. Milk yields are recorded twice daily for each ewe and milk samples are collected weekly and analyzed for protein and fat content, fatty acid composition, and somatic cell count.

This project will allow us to collect a rigorous data set that will follow the participating ewes through up to three lactations in different seasons. We expect to be able to derive complete lactation curves from each participating ewe under each dietary regimen that will help to refine recommended levels of fermentable fiber in diets of lactating ewes.

Background

Most studies with data for lactation curves of traditional meat sheep were done by either weigh-suckle-weigh methods of ewes nursing lambs or in mixed milking and nursing systems (Table 1). These data don't qualify as predictors for milk yields for meat sheep milked from day one in a dairy environment. The data from this project will help to close that gap in the literature. Furthermore, we will try to keep the experience of the participating ewes as close to an actual farm environment as possible to allow for a more accurate assessment of the feasibility of adapting the STAR system with meat sheep to sheep dairying.

In a review of dairy sheep research at Spooner, Wisconsin, data of East Frisian, East Frisian cross bred, and Dorset ewes, predict their lactation lengths to 188.6, 126.2 , and 97.2 days respectively (Thomas, 2014). Utilizing meat sheep for dairying, lactation is significantly shortened to between 73 and 103 days. This may provide a significant opportunity. According to the literature for dairy sheep, 25% of total milk production happens in the first 30 days of lactation (Folman et al., 1966). Even though peak lactation dates range from 7 to 30 days for meat sheep (Cardellino, 2002; Peterson, 2005) higher yields in the first part of lactation could be skimmed off and might subsequently generate higher total yield averages which, when accumulated over one year of production, might result in yields approaching those of dairy sheep in one annual lactation.

Table 1. Milk potential of non-dairy sheep

Non-dairy sheep breeds	Peak milk yields g/d	Literature
Suffolk and Targhee ewes	3,744 g/d (8.25 lb)	(Ramsey et al., 1998)
Targhee ewes	2,459 g/d (5.42 lb)	(Reynolds, 1991)
Hamphire ewes	3,584 g/d (7.90 lb)	(Gardner and Hogue, 1966)
Crossbred ewes	3,680 g/d (8.11 lb)	(Cardellino and Benson, 2002)

Because they will be lambing 1.67 times per year, meat sheep breeds managed under the STAR accelerated lambing schedule will likely produce more lambs per year than dairy sheep. Data from the Spooner, Wisconsin station showed that dairy ewes produced 1.85 lambs per year for East Frisian, and 1.69 per year for Lacaune (Thomas, 2014), while in comparison the Cornell flock with its Finnsheep × Dorset is above 2 per year and could be much higher. The number of offspring not only matters for revenue generated from selling lambs for meat or breeding purposes, but it also highly impacts lactation and milk yield (Peterson, 2005). Yields increase up 63% for twin vs single lambs (Snowder and Glimp, 1991), and 20% for triplets vs twins (Loerch et al., 1985). The highest differences were observed in early lactation between ewes with single and twin lambs (Cardellino, 2002). When working toward a dual purpose system, a high number of offspring is crucial to ensure economic sustainability.

Although, McKusick (2001) observed that lambs reared artificially had a lower BW at 120 days, that might depend upon the management of artificial rearing. Work at Spooner, Wisconsin suggests great success with rearing artificially (Berger, 1993). Data collected in the first lactation period of our project indicate that lambs reared artificially can grow at least as fast as lambs reared by ewes with average daily gains of 300 g (0.66 lb) during the first 3 to 4 weeks of growth.

Late lactation milk often has a higher somatic cell count (Pulina et al., 2006) which might be another advantage of shorter lactations even though this might be offset by an overall higher somatic cell count for ewes in a total dairy environment with lambs removed shortly after birth (McKusick, 2001). Studies comparing different weaning systems suggest that the milk fat content is higher for ewes in total dairy situations milked from day 1 (McKusick, 2001), possibly another benefit of the proposed system.

A further contemplation is the reevaluation of traditional lambing times. Studies show that ewes bred in June and lactating beginning in November have reached higher lactation yields, suggesting that traditional lambing times might have disadvantages (Sitzia et al., 2015).

Taking the aforementioned data into consideration, the management of meat ewes utilized for dual purpose production with ⅓ of the flock lactating at any given time throughout the year, and adding a second value, milk, seems feasible given nutritional management to ensure optimal body condition during breeding to enable aseasonality, and a high number of offspring, as well as reduced negative nutrient balance in early lactation.

Nutritional Aspects

Potentially fermentable fiber (pfNDF) is defined and calculated as NDF – 1 × maintenance INDF, with 1 × maintenance INDF being determined by the concentration of indigestible dry matter at 1 × maintenance (Thonney, 2017), minus 10 to15% metabolic fecal losses (Van Soest, 1994). Due to their high content of pfNDF and pectins (that are fermented like NDF), soy hulls are being used in this study to research ideal dietary levels to support high level production in an accelerated, dual-purpose system. Previous research at Cornell showed that pfNDF and INDF were better predictors of intake in growing lambs than NDF alone (Thonney and Hogue, 2013). Many highly relevant feed stuffs and forages share the nutritional trait of high pfNDF content. Therefore, guidelines derived by feeding soy hulls can be adapted to other feeding strategies and can be useful for dairy sheep farmers throughout North America.

There is evidence in the literature that level of intake influences digestibility (Tyrrell and Moe, 1975; Bodensteiner et al., 2000; Hein et al., 2009). With higher intake, passage rate increases and digestibility decreases. This might ensure a high nutrient supply, yet possibly be uneconomical. Passage rate decreases and digestibility increases with lower levels of intake. According to research done at Cornell, the source of NDF impacts intake and, subsequently, digestibility (Schotthofer et al., 2007; Thonney and Hogue, 2007). This must be considered when assessing economic sustainability of feeding strategies.

It has been suggested that soy hulls increase the risk of acidosis due to a lack of physically-effective fiber in dairy cows (Mertens, 1997). However, this doesn’t appear to be the case with sheep. Lactating ewes have been fed a 70% soy hull diet ad libitum with no forage at Cornell without any incidences of acidosis. In contrast, including minimum levels of pfNDF in diets fed to sheep that ensure maximum intake allows for healthy rumen function (Schotthofer, 2007; Schotthofer et al., 2007; Hein et al., 2010). This is supported by findings suggesting that sheep are able to consume diets with small particle size without subclinical acidosis better than cows (Nudda et al., 2004).

The three diets formulated for this experiment differ in their levels of pfNDF: 30, 35, or 40%, respectively (Table 2), and are fed ad libitum with a small amount of hay.

Table 2. Composition of experimental diets (% of DM).

Ingredient	30% pfNDF	35% pfNDF	40% pfNDF
Soy hulls	43.60	52.10	60.60
Corn	41.20	33.40	25.60
Soybean meal	10.30	9.91	9.42
Vegetable oil	2.22	2.23	2.23
Cornell sheep premix	1.06	1.06	1.06
Ammonium chloride	0.78	0.78	0.78
Calcium carbonate	0.56	0.33	0.11
Salt	0.22	0.22	0.22
Estimated components			
DM	89.93	89.85	89.77
DDM	79.97	79.95	79.22
CP	16.10	16.11	16.10
NDF	36.37	41.72	47.07
pfNDF	**30.61**	**35.56**	**40.52**
INDF	**5.87**	**6.27**	**6.66**
NSCHO	38.93	33.67	28.44
EE	4.95	4.80	4.65
Ash	4.15	4.19	4.23

Instead of balancing on an estimated dry matter intake, the diets are balanced on their carbohydrate fractions, mainly the concentration of pfNDF, followed by crude protein, minerals, and vitamins. This approach is taken to ensure increased feed intake and decreased INDF content in the diets to effectively provide high levels of absorbed nutrients (Thonney, 2017).

Anecdotal data with ewes nursing triplets at Cornell documented the production by a set of dams limited to about 2 pounds of hay and offered Agway High Energy Lamb pellets ad libitum. These ewes consumed up to 7% of their body weights with both their lambs and them gaining weight in early lactation. Added to the results from a study of individually-fed ewes nursing triplets by (Schotthofer et al., 2007), this indicates that digestibility at such high levels of intake might not be reduced as drastically for lactating sheep as previously observed for growing lambs. It also indicates improved nutrient balance in early lactation that allows the ewe to not only support the high demand of nutrients for milk production, but also to maintain or improve her condition. This becomes highly important considering findings of a study done with Finnsheep × Dorset and Rambouillet ewes: The ewe's body weight during breeding is significantly correlated with their level of milk production in the subsequent lactation (Reynolds, 1991).

Increasing dietary pfNDF results in a higher VFA production in the rumen (Araujo, 2008) which might influence milk composition. Therefore, in collaboration with Dr. Dave Barbano from the Cornell Food Science Department, we are measuring protein and fat content, fatty acid composition, and milk urea nitrogen as well as somatic cell counts to further asses the effect of different levels of pfNDF on milk composition.

Guidelines in the literature suggest ideal levels of 37% NDF for feeding dairy ewes (Pulina, 2004). Should these be the same for meat sheep managed and milked under the STAR system?

The anticipated result of the digestion trial of this study will provide a benchmark for dietary pfNDF levels to ensure high milk production, maintenance of body condition, aseasonality, high numbers of offspring, and circumvention of nutritional diseases, while upholding appropriate digestibility to ensure economic sustainability.

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References

Araujo, R. C. P., A.V.;Susin, I.; Urano, F.S.; Mendes, C.Q.; Rodrigues, G.H.; Packer, I.U. 2008. Apparent digestibility of diets with combinationsof soybean hulls and coastsross (Cynodon sp.) hay offered to ram lambs. Sci. Agric. 65: 581-588.

Berger, Y. M. S., R.A. 1993. Raising lambs on milk replacer. Proceedings Spooner Sheep Day: 39-47.

Bodensteiner, K. J., K. P. McNatty, C. M. Clay, C. L. Moeller, and H. R. Sawyer. 2000. Expression of growth and differentiation factor-9 in the ovaries of fetal sheep homozygous or heterozygous for the Inverdale prolificacy gene ($FecX^I$). Biology of Reproduction 62: 1479-1485.

Cardellino, R. A., and M. E. Benson. 2002. Lactation curves of commercial ewes rearing lambs. Journal of Animal Science 80: 23-27.

Cardellino, R. A. B., M.E. 2002. Lactation curves of commercial ewes rearing lambs. Journal of Animal Science 80: 23-27.

Folman, Y., R. Volcani, and E. Eyal. 1966. Mother-Offspring Relashionships in Awassi Sheep .1. Effect of different suckling regimes and Time of Weaning on Lactation Curve and Milk Yield in Dairy Flocks. Journal of Agricultural Science 67: 359-&.

Gardner, R. W., and D. E. Hogue. 1966. Milk production, milk composition and energetic efficiency of Hampshire and Corriedale ewes fed to maintain body weight. J. Anim. Sci 25: 789-795.

Hein, D. C., M. L. Thonney, D. A. Ross, and D. E. Hogue. 2009. Effect of level of intake on digestibility of NDF in soy hulls. In: Cornell Nutrition Conference. p 61-68.

Hein, D. C., M. L. Thonney, D. A. Ross, and D. E. Hogue. 2010. Effect of level of intake on digestibility of NDF of soybean hull diets in sheep. Journal of Dairy Science 93: 785-785.

Loerch, S. C., K. E. McClure, and C. F. Parker. 1985. Effects of Number of Lambs Suckled and Supplemental Protein-Source on Lactating Ewe Performance. Journal of Animal Science 60: 6-13.

McKusick, B. C. T., D.L.; Berger, Y.M. 2001. Effect of weaning system on commercial milk production and lamb growth of East Friesian dairy sheep. Journal of Dairy Science 84: 1660-1668.

Mertens, D. R. 1997. Creating a system for meeting the fiber requirements of dairy cows. Journal of Dairy Science 80: 1463-1481.

Nudda, A., S. Fancellu, F. Porcu, F. Boe, and A. Cannas. 2004. Responses of milk fat composition to dietary non-fiber carbohydrates in Sarda dairy sheep. Journal of Animal Science 82: 310-310.

Peterson, S. W. K., P.R.; Morris, S.T.; Lopez-Villalobos, N.; Morel, P.C.H. 2005. Milk production in East Friesian-cross ewes lambing year round. Proceedings of the New Zealand Society of Animal Production 65: 173-177.

Pulina, G. 2004. Dairy Sheep Nutrition. CABI Publishing, Wallingford, Oxfordshire, UK.

Pulina, G., A. Nudda, G. Battacone, and A. Cannas. 2006. Effects of nutrition on the contents of fat, protein, somatic cells, aromatic compounds, and undesirable substances in sheep milk. Animal Feed Science and Technology 131: 255-291.
Ramsey, W. S., P. G. Hatfield, and J. D. Wallace. 1998. Relationships among ewe milk production and ewe and lamb forage intake in Suffolk and Targhee ewes nursing single or twin lambs. Journal of Animal Science 76: 1247-1253.
Reynolds, L. L. B., D.L. 1991. Assessing dairy potential of Western White-Faced ewes. Journal of Animal Science 69: 1354-1362.
Schotthofer, M. A. 2007. Effect of Level of Fermentable NDF on Feed Intake and Production of Lactating Ewes, Cornell University, Ithaca, NY.
Schotthofer, M. A., M. L. Thonney, and D. E. Hogue. 2007. Effect of level of fermentable NDF on feed intake and production of lactating ewes. Journal of Animal Science 85: 180-181.
Sitzia, M. et al. 2015. Feeding and management techniques to favour summer sheep milk and cheese production in the Mediterranean environment. Small Ruminant Research 126 (Suppl. 1): 43-58.
Snowder, G. D., and H. A. Glimp. 1991. Influence of Breed, Number of Suckling Lambs, and Stage of Lactation on Ewe Milk-Production and Lamb Growth Under Range Condiitons. Journal of Animal Science 69: 923-930.
Thomas, D. L. 2014. Dairy sheep production research at the University of Wisconsin-Madison - a review. Journal of Animal Science and Biotechnology.
Thonney, M. L. 2017. Sheep nutrition: formulated diets. In: J. P. C. Greyling (ed.) Achieving Sustainable Production of Sheep. Burleigh Dodds Science Publishing Limited Cambridge.
Thonney, M. L., and D. E. Hogue. 2007. Formulation of ruminant diets using potentially-fermentable NDF and nonstructural carbohydrates. In: Cornell Nutrition Conference. p 113-123.
Thonney, M. L., and D. E. Hogue. 2013. Fermentable fiber for diet formulation. In: Cornell Nutrition Conference, Syracuse, NY. p 174-189.
Tyrrell, H. F., and P. W. Moe. 1975. Effect of intake on digestive efficiency. J. Dairy Sci 58: 1151-1163.
Van Soest, P. J. 1994. Nutritional Ecology of the Ruminant. 2nd ed. Comstock Publishing Associates (Cornell University Press), Ithaca, NY.