Sheep & Goat Research Journal
Volume 37, 2022 - January

Genetic Make-up, Milk Production, and Infrared Predicted Milk Constituents in a Commercial Dairy Sheep Flock of Variable Breed Composition[1]

Nikola Kochendoerfer[*2], *Shadirah J. Shepherd*[‡], *Christian J. Posbergh*[†], *Heather J. Huson*[*], *David M. Barbano*[§], *Michael L. Thonney*[*]

* *Department of Animal Science, Cornell University, Ithaca, NY 14850*

‡ *Faculty of Veterinary and Agricultural Sciences, University of Melbourne, Australia.*

† *Department of Animal and Range Sciences, Montana State University, Bozeman, MT 59717*

§ *Department of Food Science, Cornell University, Ithaca, NY 14850*

[1] *This work was supported by Hatch under 1010681 from the USDA National Institute of Food and Agriculture.*

[2] *Corresponding Author: nk584@cornell.edu*

Summary

The effect of genetic contributions from East Friesian and Lacaune dairy sheep on daily milk and total lactation yield, lactation persistency, and milk component yield and concentration were quantified in a commercial US dairy sheep flock with no pedigree records and variable breed composition. A set of randomly selected ewes (n = 20) was genotyped for 54,241 SNPs on the Illumina Ovine 50K SNP beadchip. Breed composition was determined using a model containing four reference breeds (East Friesian, Lacaune, Finnsheep, and Dorset), analyzed for breed admixture, and the model returned a range of 37.4 to 67.8% dairy breed percentage (East Friesian and/or Lacaune) among the 20 ewes. Milk weights and milk samples were collected twice per month through the 171-day lactation. No model with sensical Wood lactation curve parameters could be fitted to data for three ewes, reducing the dataset to 17 ewes for milk production and milk component analysis with an average dairy breed percentage of 54.1%. Regression on dairy breed percentage only affected (P = 0.023) the estimate for the c parameter of the lactation curve, indicating a greater lactation persistence for ewes with greater dairy breed percentage. In this exploratory on-farm trial, genetic dairy breed percentage predicted differences in the shape or duration of the lactation curve. However, there was no effect on milk, fat, or protein yield, nor on milk fatty acids, which differed from published findings in US sheep dairy research flocks.

Key Words: Sheep, Milk Yield, Dairy Breed, Milk Components

©2022, *Sheep & Goat Research Journal*

Introduction

Traditional European dairy sheep breeds available in the US are East Friesian and Lacaune. East Friesian cross rams were first imported via Canada in 1993; Lacaune genetics were first imported as semen from three rams in the UK and two rams via Canada in 1998 (Thomas et al., 2014). Due to the limited availability of purebred dairy sheep genetics, crossbreeding with domestic meat breeds like the Dorset or Finnsheep is a strategy that US dairy sheep producers have employed for many years (Kochendoerfer and Thonney, 2019).

Commercial US dairy sheep flocks have an estimated average lactation yield of 178 kg of milk per ewe (National Research Council, 2008) compared to commercial East Friesian and Lacaune flocks in Europe producing up to 504 kg in 200-day lactations (Thomas and Haenlein, 2017) and 240 kg in 165-day lactations, respectively (Barillet et al., 2001).

More recently, efforts led by the Dairy Sheep Association of North America (DSANA), in collaboration with the Centre d'Expertise en Production Ovine du Quebec and GenOvis, two Canadian organizations concerned with genetic improvement of North American dairy sheep, are aiming to estimate breeding values to increase productivity. The DSANA coordinated the importation of Lacaune semen in 2019 from government controlled and regulated flocks in France. Yet the increase in genetic merit of US dairy sheep flocks may be slowed due to stringent import restrictions of genetic materials, costly artificial insemination services, and low artificial insemination conception rates (Alvarez et al., 2019).

Earlier investigations into the utilization of traditional US meat sheep breeds in dairy production returned poor suitability due to very low milk yields in lactations of up to 130 days (Sakul and Boylan, 1992a, b). Thomas et al. (2000) reported much greater yields for East Friesian-meat breed crossbreds than for meat breed crossbreds. However, some of the meat breeds utilized in these earlier investigations have a significant advantage in a trait other than milk yield over purebred dairy breeds (especially Dorset, Finnsheep, and their crosses) because they are aseasonally polyestrous and could be used for year-round sheep dairy systems. Dairy sheep globally and in the US are seasonally polyestrous, and European data suggests that these breeds would likely be seasonal in the US, leading to seasonal supply of fresh milk (Pulina et al., 2007). The utilization of breeds with higher out of season conception rates could be an opportunity for the US dairy sheep industry to produce milk year-round. This would lead to a consistent supply of fresh milk for processing without relying on frozen milk. Increasing milk production per ewe in year-round milking systems could decrease the dependency on costly imported genetics.

Greater peak milk yields were found for meat ewes in weigh-suckle-weigh studies (Ramsey et al., 1998; Cardellino and Benson, 2002) and earlier findings show that even low genetic contributions from dairy breeds lead to greater milk production and persistency (Berger, 2004). The objective of this exploratory trial was to illuminate the influence of dairy genetics on the shape of lactation curves, lactation yield, persistency, and milk composition in a small set of commercial crossbred dairy ewes with no pedigree records and variable breed composition.

Materials and Methods

Animals

All procedures involving animals were approved by the Cornell University Institutional Animal Care and Use Committee (protocol 2016-0069). Data were collected on a 600 ewe dairy sheep farm between the months of February and August 2017. A random subset of 25 ewes, second parity and older, within a 2-d period of a lambing group of 360 ewes was selected for the experiment. Of the 25 ewes enrolled in the trial, one died within the first week and her data were excluded from further analyses. On the day of blood sampling, four ewes could not be located due to a pen mix-up and were removed from subsequent analyses. A total of 20 ewes were genotyped, and their records constituted the experimental dataset. The 20 ewes were on days 1 and 2 of lactation and were assigned an individual identification number and received leg bands and painted numbers on their backs for identification throughout the trial.

This commercial sheep dairy operates with a 60-stanchion, low-line, Greenoak Dairy Equipment, pit parlor. Milking equipment was operated at 40.6 kPa vacuum pressure, a pulsation rate of 160 ppm, and a pulsation ratio of 50:50. Ewes were pre-dipped and stripped, wiped, milked, and dipped. The 6-hour milking shifts began at 500 and 1700. Parlor times for the trial ewes were 1000 and 2200 The ewes were housed in groups of 180, and all trial ewes were housed in the same group throughout the experiment.

Feed

The ewes were fed a total mixed ration consisting of corn and grass-silage, soyhull pellet, soybean meal, and Cornell Sheep Mineral-Vitamin Premix (50% salt, 45.9% corn gluten feed as carrier, 0.5% feed grade oil, 2,500 ppm Manganese, 4,250 IU/lb Vitamin E, 30 ppm Selenium, 2,000 ppm Zinc, 160 ppm Iodine, 120,000 IU/lb Vitamin A, 15,000 IU/lb Vitamin D, 20 ppm Cobalt, and 70 ppm Molybdenum) once daily. The feed was pushed up twice per day after feeding. Feed was sampled on the same days that milk yields were recorded, and milk samples were collected. The feed samples were analyzed with near-infrared spectrometry for total mixed rations by the Dairy One Forage Laboratory, Ithaca, NY, and contained 48.0% dry matter, 17.2% crude protein, 39.3% amylase and ash corrected neutral detergent fiber, 30.7% non-fiber carbohydrate, and 3.4% ether extract.

Breed Composition

Based on the owner's information, the suspected breed composition was predominantly East Friesian, Lacaune, Finnsheep, and Polled Dorset. Whole blood was drawn via jugular venipuncture from each ewe into a vacutainer containing K_2EDTA anti-coagulant. DNA was extracted from whole blood following the Qiagen Puregene Protocol (Gentra Systems, Inc. Minneapolis, MN, USA). The ewes were genotyped for 54,241 Single Nucleotide Polymorphisms (SNPs) on the Illumina Ovine 50K SNP beadchip (Kijas et al., 2014).

Additional genotypes (49,034 SNPs) from East Friesian, Lacaune, and

©2022, *Sheep & Goat Research Journal*

Finnsheep were obtained from the International Sheep Genome Consortium HapMap project (Kijas et al., 2014) and Polled Dorsets (606,006 SNPs) from a previous study (Posbergh et al., 2019). Twenty random individuals from each of the breeds were selected as reference individuals for subsequent ADMIXTURE analysis (Alvarez et al., 2004). Genotypes were merged and quality control filtered using Golden Helix SNP & Variation Suite software (v8.7.2 win64; Golden Helix, Bozeman, MT, USA *www.goldenhelix.com*). SNPs were excluded from the analysis if the SNP call rate was less than 0.90, had more than two alleles, had a minor allele frequency less than 0.05, or was located on the sex chromosomes. After filtering, 40,307 autosomal SNPs were left for subsequent analysis. The ADMIXTURE software version 1.3.0 (Alexander et al., 2009) was utilized to examine admixture between the twenty ewes and eighty reference animals using the filtered genotypes. Cross-validation error was used to determine the most probable number of K populations within the dataset (Alexander et al., 2009). The genetic composition of the ewes was expressed in dairy breed (East Friesian and Lacaune) percentage.

Milk Yield And Analyses

Milk yields were collected at 13 timepoints throughout lactation, once weekly for the first 2 wk of lactation and then every 2 wk until the end of the trial at days in milk (DIM) 171. Milk yields were collected in the morning and multiplied by 2 for an estimate of daily milk yield. The milking parlor was not equipped with milk meters. The trial ewes were machine milked into tared buckets that were connected to the parlor low-line, and the milk was weighed and recorded for each ewe.

Milk samples for component analyses were collected on the same days of daily milk yield was estimated. Samples were collected into 57 ml vials, cooled to 4°C, and analyzed fresh with a Fourier transform mid-infrared spectrophotometer (Lactoscope FTA, Delta Instruments, Drachten, the Netherlands). Fat content was validated with Mojonnier ether extract reference chemistry according to AOAC method No. 989.05 (AOAC International, 2019), true protein by Kjeldahl analysis according to AOAC method No. 991.22 (AOAC International, 2019), and milk urea nitrogen (MUN) reference chemistry (Megazyme, catalogue No. K-URAMR). Milk fatty acids were validated by gas chromatography as described by Wojciechowski and Barbano (2016). Values predicted from infrared (IR) by cow milk calibrations (Wojciechowski and Barbano, 2016) were subsequently adjusted by the mean difference between IR predicted values and reference chemistry values of -0.065% for total fat; 0.343, -0.069, and -0.230 g/100 g milk for de novo, mixed origin, and preformed fatty acids, respectively; 0.269% for true protein, and -4.522 mg/100 g milk for MUN. Somatic cell counts (SCC) were measured with a fluorometric flow cytometer (Delta Instruments).

Statistical Analyses

All response variables were assumed normally distributed, except for SCC, which were converted to natural log values for analysis and then back transformed for presentation. A total of 245 daily milk yield records (5 to 13 records per ewe) and 238 daily milk composition records (4 to 13 records per ewe) were available for analyses. Wood's equation (Wood, 1967) [Eq. 1] was fitted with the *nls* package (Pinheiro et al., 2018), implemented in the R software (R Development Core Team, 2019), to daily milk yields for each ewe to estimate individual lactation curves. The equation parameters x, a, b, and c describe the DIM of each daily milk yield record, milk yield at parturition (i.e., x = 0), ascent of milk yield to peak yield, and the rate of decline of the lactation curve, respectively (Portolano et al., 1997). Total lactation milk yield was estimated by integration [Eq.2]. Peak daily milk yield [Eq.3] and DIM at peak daily milk yield [Eq.4] were also calculated.

Eq. 1 $$Y = ax^{b} \exp(-cx)$$

Eq. 2 $$Y = \frac{a}{c^{b+1}} \Gamma(b + 1)$$

Eq. 3 $$Y_{(max)} = a \left(\frac{b}{c}\right)^{b} \exp(-b)$$

Eq. 4 $$x = \frac{b}{c}$$

Step-down polynomial regression with deletion of higher order terms at $P > 0.05$ was used to select either linear, quadratic, or cubic equations to be fitted to daily milk component yields and concentrations for each individual ewe. Cubic equations were selected for true protein, fat, lactose, and preformed fatty acid concentrations, quadratic equations were selected for de novo fatty acid concentration, MUN, and SCC, and linear equations were selected for true protein, fat, lactose, de novo and performed fatty acid yield, as well as for mixed fatty acid concentrations and yields. The fitted curves were integrated and mean daily component yield and percentage were established through division by lactation length. Then, the effect of dairy breed percentage on the estimates for Wood's equation parameters, daily and total lactation milk yield, peak day and peak yield, lactation length, as well as daily milk component yields and concentrations, were analyzed with a linear model using *lm* in R (R Development Core Team, 2019). Survival analysis of lactation length in relation to dairy breed percentage was performed on the actual record of each individual ewe, using a Cox Proportional Hazard model with the survival package in R (Therneau, 2021). The statistical significance of dairy breed percentage was tested using a log-rank test (Therneau and Grambsch, 2000).

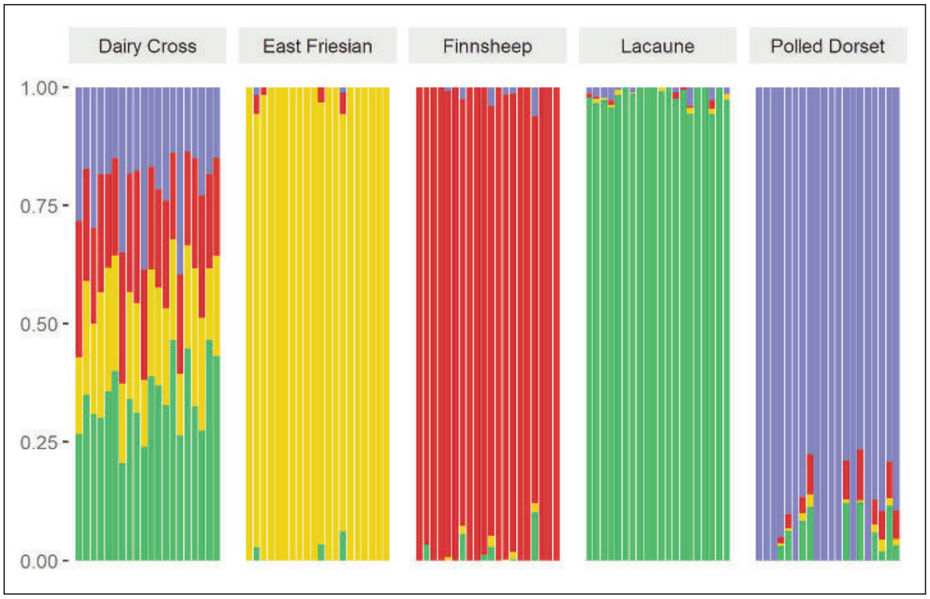
Results and Discussion

Breed Composition

Dairy breed percentage was determined by admixture analysis. The analysis was tested using K values from two through eight. Cross-validation error was lowest for $K = 5$ (0.57467). The cross-validation error difference was only 0.00128 between $K = 5$ (0.57467) and $K = 4$ (0.57595). Because our interest was in the breed composition of the crossbred group, we chose to use the model with $K = 4$ populations. Every purebred population (East Friesian, Lacaune, Finnsheep, and Polled Dorset) showed little within breed admixture, indicating purebred reference populations (Figure 1).

Based on the $K = 4$ admixture analysis, the crossbred ewes averaged 55.3% dairy breed composition, the sum of an average of 21.1% East Friesian and

Figure 1. ADMIXTURE analysis plot showing population assignments for *K* = 4. Each bar represents an individual animal for each breed, and each color represents a different *K* population generally reflecting the purebred reference breeds of East Friesian (yellow), Finnsheep (red), Lacaune (green), and Polled Dorset (blue).



34.2% Lacaune (Figure 1). The median dairy composition was 57.2%. The lowest dairy percentage ewe was 37.4% while the greatest had 67.8%. The lowest Lacaune percentage ewe was 20.6% while the lowest East Friesian ewe was only 12.9%. The greatest Lacaune percentage ewe was 46.5% while it was only 29.2% for the greatest East Friesian ewe.

The dairy compositions of these ewes were likely consistent with many commercial dairy ewes in the US, given the East Friesian and Lacaune breed importation and development history (Thomas et al., 2014). Utilizing SNPs likely yielded more accurate predictions of breed composition than would be expected from pedigree, even if known, as pedigree estimates assume progeny breed composition is equal to parental average breed composition (Sölkner et al., 2010).

Milk yield and composition

Not all ewes completed the 171 days of lactation. Dairy breed percentage did not significantly affect lactation length in the log-rank test for time to event analysis (*P* = 0.35). No model with sensical lactation curve parameters (infinite milk yield increase predicted) could be fitted to data for three ewes. Two of these ewes had lactations length less than 45 days, and 2 ewes expressed average SCC above 900,000 cells/mL. These ewes were excluded as outliers from the subsequent statistical analysis, reducing the dataset to 17 ewes for milk production and milk component analysis and an average dairy breed percentage of 54.1%. Five of the ewes did not express a peak after DIM 1. For these ewes, peak days and yields were assumed to be at DIM 1. Due to the small sample size (n=17) the following results should be interpreted with caution and regarded only as exploratory findings in a commercial sheep dairy flock.

The linear effect of percentage dairy breeding on the c parameter of Wood's equation was significant and negative (*P* = 0.023, Table 1), indicating an inverse relationship between dairy breed composition and lactation persistency. No effect was detected for the a and b parameters of the lactation curve. Peak milk yield was not affected by breed composition and is comparable to yields observed in winter lambing Comisana ewes (1.77 kg/day; Portolano et al., 1997) and Araucana Creole ewes (1.40 ± 0.3 L/day; Inostroza et al. 2020). Days in milk at peak yield was not affected by breed composition and occurred later than previously observed in dairy ewes (Cannas et al., 2002). Lactation length was similar to those reported by Thomas et al. (2000) where East-Friesian × Dorset crossbred ewes achieved lactation lengths of 126 days and no statistical effect of breed composition was detected.

Sakul and Boylan (1992b) reported much lower daily milk yields with purebred Finnsheep (526 ± 70 ml) and Dorset ewes (584 ± 51 ml) with up to 122 DIM, allowing our assumption that even low dairy breed percentage could lead to a meaningful increase in persistency in crossbred dairy ewes. Lactation yields were lower than reported for European dairy sheep flocks (Barillet et al., 2001; Hamann et al., 2004; González-García et al., 2015), even though reported lactation length was comparable. Milk yields were also lower than observed for US East Friesian and Lacaune crossbred dairy ewes (Murphy et al., 2017a) but higher than reported averages for US commercial sheep dairy flocks (National Research Council, 2008). Neither was affected by dairy breed percentage, which also had no effect on milk composition. Milk protein and fat concentrations were similar to values previously reported (Nudda et al., 2002; Padilla et al., 2018). The relationship between relative percentages of de novo synthesized, mixed origin, and preformed fatty acids was quadratic, with lowest contributions from mixed origin fatty acids (Table 1), similar to previous findings (Hampel et al., 2004; Kondyli et al., 2012; Mayer and Fiechter, 2012). The relative percentages of de novo synthesized, mixed origin, and preformed fatty acids were not affected by dairy breed percentage suggesting that the relative contribution of fatty acids is influenced more by nutrition than breed composition, similar to results reported by Tsiplakou et al. (2006), who came to a similar conclusion for the contribution to sheep milk fatty acid composition. The SCC were well below the highest allowable level for interstate shipment for sheep milk in the US (FDA, 2017).

This exploratory trial is limited by the lack of environmental and pedigree data for this small subset of commercial dairy ewes. Still, results may point towards opportunities of including meat sheep genetics in commercial flocks to achieve year-round lactation and producers should be advised to collect and record pedigree data as well as genotypic

 ©2022, *Sheep & Goat Research Journal*

Table 1. Fit of linear regression of lactation parameters and milk components on dairy breed percentage (East Friesian and Lacaune).

Item	Predicted mean[1]	Residual standard error	r^2	*P*-value of slope
Estimated lactation parameters from Wood's equation[2]				
a	1.33	1.406	0.007	0.749
b	0.184	0.253	0.000	0.972
c (slope = -0.000576 ± 0.000228)	0.0099	0.0087	0.299	0.023
Peak yield, kg	1.81	1.395	0.022	0.566
Peak day	31	43.5	0.130	0.156
DIM at dry off	122	57.0	0.018	0.606
Lactation yield, kg/lactation	180.0	159.80	0.000	0.989
Daily milk yield, kg/d	1.32	0.822	0.003	0.847
Daily milk components				
True protein, %	5.10	0.488	0.006	0.770
True protein, g/day	68.2	41.99	0.004	0.818
Fat, %	6.33	1.878	0.043	0.424
Fat yield, g/d	83.7	56.49	0.001	0.909
De novo fatty acids[3]				
g/100 g milk	2.39	0.352	0.143	0.134
g/d	32.3	20.8	0.001	0.929
g/100 g fatty acid	40.0	9.212	0.002	0.864
Mixed origin fatty acids[4]				
g/100 g milk	1.68	0.373	0.001	0.906
g/d	22.7	15.63	0.006	0.763
g/100 g fatty acid	28.7	3.532	< 0.001	0.995
Preformed fatty acids[5]				
g/100 g milk	1.92	1.256	0.004	0.816
g/d	25.3	18.03	0.001	0.924
g/100 g fatty acid	30.1	11.28	0.002	0.859
Anhydrous lactose, %	4.37	0.606	0.186	0.084
Anhydrous lactose, g/day	62.5	37.64	0.004	0.814
MUN, mg/100 g	13.8	4.71	0.002	0.873
SCC 10^3 (geometric means)	151.4	1.231	0.075	0.289

[1] At mean dairy breed percentage = 54.1%
[2] $Y = ax^b \exp(-cx)$
[3] C4 to C14
[4] C16, C16:1, C17
[5] ≥ C18

data to allow for future genetics research into the effect of breed composition on sheep milk production.

Conclusions

No effect of dairy breed percentage on milk yield or composition was detected in this sample of ewes from a US flock of commercial dairy sheep. However, the sample of ewes in this study (n =17) was very small and sampled in a single year with no knowledge of age or pedigree structure. The results differ with a much larger US research flock data set (Murphy et al., 2017a, b) that showed significant positive effects of both East Friesian and Lacaune breeding on milk, fat, and protein yields in dairy-meat breed crosses. However, there may be an opportunity for year-round, high producing dairy sheep systems that utilize optimum combinations of dairy and meat breeds when using meat breeds that have the ability to breed out of season. Including aseasonally polyestrous meat sheep breeds in dairy sheep flocks provides the opportunity to market fresh sheep milk products year-round.

Literature Cited

Alexander, D. H., J. Novembre, and K. Lange. 2009. Fast model based estimation of ancestry in unrelated individuals. Genome Res. 19:1655-1664. doi: https://doi.org/10.1101/gr.094052.109

Alvarez, I., L. J. Royo, I. Fernández, J. P. Gutiérrez, E. Gómez, and F. Goyache. 2004. Genetic relationships and admixture among sheep breeds from Northern Spain assessed using microsatellites. J. Anim. Sci. 82(8):2246-2252. doi: https://doi.org/10.2527/2004.8282246x

Alvarez, M., L. Anel-Lopez, J. C. Boixo, C. Chamorro, M. Neila-Montero, R. Montes-Garrido, P. de Paz, and L. Anel. 2019. Current challenges in sheep artificial insemination: A particular insight. Reproduction in Domestic Animals 54(S4):32-40. doi: https://doi.org/10.1111/rda.13523

AOAC International. 2019. Official Methods of Analysis 17th ed., AOAC International, Arlington, VA.

Barillet, F., C. Marie-Etancelin, M. Jacquin, G. Lagriffoul, and J. M. Astruc. 2001. The French Lacaune dairy sheep breed: Use in France and abroad in the last 40 years. Livestock Production Science 71:17-29. doi: https://doi.org/10.1016/S0301-6226(01)00237-8

Berger, Y. M. 2004. Breeds of sheep for commercial milk production. In: Proceedings of 10th Great Lake Dairy Sheep Symposium, Hudson, WI. p 14-20.

Cannas, A., A. Nudda, and G. Pulina. 2002. Nutritional Strategies to Improve Lactation Persistency in Dairy Ewes. In: 8th Great Lakes Dairy Sheep Symposium, Ithaca, NY. p 17-59.

Cardellino, R. A., and M. E. Benson. 2002. Lactation curves of commercial ewes rearing lambs. J. Anim. Sci. 80(1):23-27. doi: https://doi.org/10.2527/2002.80123x

FDA. 2017. Grade "A" Pasteurized Milk Ordinance. https://www.fda.gov/media/114169/download (Accessed 4/1/2020 2020).

González-García, E., A. Tesniere, S. Camous, F. Bocquier, F. Barillet, and P. Hassoun. 2015. The effects of parity, litter size, physiological state, and milking frequency on the metabolic profile of Lacaune dairy ewes. Domestic Animal Endocrinology 50:32-44. doi: https://doi.org/10.1016/j.domaniend.2014.07.001

Hamann, H., A. Horstick, A. Wessels, and O. Distl. 2004. Estimation of genetic parameters for test day milk production, somatic cell score and litter size at birth in East Friesian ewes. Livestock Production Science 87(2):153-160. doi: https://doi.org/10.1016/j.livprodsci.2003.09.015

Hampel, K., F. Schone, and V. Bohm. 2004. Composition and nutritional importance of ewe's milk and ewe's milk products. Deutsche Lebensmittel-Rundschau 100(11):425-430.

Inostroza, K., S. Bravo, G. Larama, C. Saenz, and N. Sepúlveda. 2020. Variation in Milk Composition and Fatty Acid Profile during the Lactation of Araucana Creole Ewes in a Pasture-Based System. Animals 10(1):92. doi: https://doi.org/10.3390/ani10010092

Kijas, J. W., L. Porto-Neto, S. Dominik, A. Reverter, R. Bunch, R. McCulloch, B. J. Hayes, R. Brauning, and J. McEwan. 2014. Linkage disequilibrium over short physical distances measured in sheep using a high-density SNP chip. Anim. Genet. 45:754-757. doi: https://doi.org/10.1007/s13258-017-0539-2

Kochendoerfer, N., and M. L. Thonney. 2019. Effect of forage inclusion in diets on milk yield and milk components of dairy crossbreed ewes managed on an accelerated lambing system Cornell Nutrition Conference No. 81. Cornell University, Syracuse, NY.

Kondyli, E., S. C., J. Samelis, and M. C. Katsiari. 2012. Chemical composition and microbiological quality of ewe and goat milk of native Greek breeds. Small Rumin. Res. 103(2):194-199. doi: https://doi.org/10.1016/j.smallrumres.2011.09.043

Mayer, H. K., and G. Fiechter. 2012. Physical and chemical characteristics of sheep and goat milk in Austria. International Dairy Journal 24(2):57-63. doi: https://doi.org/10.1016/j.idairyj.2011.10.012

Murphy, T. W., Y. M. Berger, P. W. Holman, M. Baldin, R. L. Burgett, and D. L. Thomas. 2017a. Estimates of genetic parameters, genetic trends, and inbreeding in a crossbred dairy sheep research flock in the United States1. Journal of Animal Science 95(10):4300-4309. doi: https://doi.org/10.2527/jas2017.1844

Murphy, T. W., Y. M. Berger, P. W. Holman, M. Baldin, R. L. Burgett, and D. L. Thomas. 2017b. Factors affecting ewe performance in a crossbred dairy sheep research flock in the United States1. Journal of Animal Science 95(5):1892-1899. doi: https://doi.org/10.2527/jas.2016.1175

National Research Council. 2008. Changes in the Sheep Industry in the United States: Making the Transition from Tradition. The National Academies Press, Washington, DC.

Nudda, A., R. Bencini, S. Mijatovic, and G. Pulina. 2002. The Yield and Composition of Milk in Sarda, Awassi, and Merino Sheep Milked Unilaterally at Different Frequencies. Journal of Dairy Science 85(11):2879-2884. doi: https://doi.org/10.3168/jds.S0022-0302(02)74375-0

Padilla, P., M. Izquierdo, M. Martínez-Trancón, J. C. Parejo, A. Rabasco, J. Salazar, and J. Á. Padilla. 2018. Polymorphisms of -lactoalbumin, -lactoglobulin and prolactin genes are highly associated with milk composition traits in Spanish Merino sheep. Livestock Science 217:26-29. doi: https://doi.org/10.1016/j.livsci.2018.09.012

Pinheiro, J., D. Bates, S. DebRoy, and D. Sarkar. 2018. _nlme: Linear and Nonlinear Mixed Effects Models. R package version 3.1-137. R Core Team

Portolano, B., F. Spatafora, G. Bono, S. Margiotta, M. Todaro, V. Ortoleva, and G. Leto. 1997. Application of the Wood model to lactation curves of Comisana sheep. Small Ruminant Research 24(1):7-13. doi: https://doi.org/10.1016/0921-4488(95)00842-X

Posbergh, C. J., M. L. Thonney, and H. J. Huson. 2019. Genomic Approaches Identify Novel Gene Associations with Out of Season Lambing in Sheep. Journal of Heredity 110(5):577-586. doi: https://doi.org/10.1093/jhered/esz014

 ©2022, Sheep & Goat Research Journal

Pulina, G., A. Nudda, N. P. P. Macciotta, G. Battacone, S. P. G. Rassu, and A. Cannas. 2007. Non-nutritional factors affecting lactation persistency in dairy ewes: a review. Italian Journal of Animal Science 6(2):115-141. doi: https://doi.org/10.4081/ijas.2007.115

R Development Core Team. 2019. R: A language and environment for statistical computing. R Foundation for Statistical Computing. Vienna, Austria.

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. J. Anim. Sci. 76(5):1247-1253. doi: https://doi.org/10.2527/1998.7651247x

Sakul, H., and W. J. Boylan. 1992a. Evaluation of United-States sheep breeds for milk-production and milk-composition. Small Ruminant Research 7(3):195-201. doi: https://doi.org/10.1016/0921-4488(92)90224-r

Sakul, H., and W. J. Boylan. 1992b. Lactation curves for several United States sheep breeds. Animal Production 54:229-233. doi: http://dx.doi.org/10.1017/S0003356100036849

Sölkner, J., A. Frkonja, H. W. R. Raadsma, E. Jonas, G. Thaller, E. Egger Danner, and B. Gredler. 2010. Estimation of individual levels of admixture in crossbred populations from SNP chip data: examples with sheep and cattle populations. In: Proceedings of the Interbull Meeting, Riga, Latvia. p 62-62.

Therneau, T. M., and P. M. Grambsch. 2000. Modeling survival data: extending the Cox model. Springer Science and Business Media. ISBN 0-387-98784-3.

Therneau T. 2021. _A Package for Survival Analysis in R_. R package version 3.2-10, <URL: https://CRAN.R-project.org/package=survival

Thomas, D. L., Y. M. Berger, and B. C. McKusick. 2000. East Friesian germplasm: Effects on milk production, lamb growth, and lamb survival. Journal of Animal Science 77(suppl_E):1-6. doi: doi: https://doi.org/10.2527/jas2000.77E-Suppl1g

Thomas, D. L., and G. F. W. Haenlein. 2017. Sheep Milk. In: Y. W. Park, G. F. W. Haenlein and W. L. Wendorff, editors, Handbook of Milk of Non-Bovine Mammals. John Wiley & Sons, Inc., ProQuest Ebook Central.

Thomas, D. L., Y. M. Berger, B. C. McKusick, and C. M. Mikolayunas. 2014. Dairy sheep production research at the University of Wisconsin-Madison - a review. Journal of Animal Science and Biotechnology 5((1)):1-22. doi: https://doi.org/10.1186/2049-1891-5-22

Tsiplakou, E., K. C. Mountzouris, and G. Zervas. 2006. The effect of breed, stage of lactation and parity on sheep milk fat CLA content under the same feeding practices. Livestock Science 105(1):162-167. doi: https://doi.org/10.1016/j.livsci.2006.06.002

Wojciechowski, K. L., and D. M. Barbano. 2016. Prediction of fatty acid chain length and unsaturation of milk fat by mid-infrared milk analysis. Journal of Dairy Science 99(11):8561-8570. doi: https://doi.org/10.3168/jds.2016-11248

Wood, P. D. P. 1967. Algebraic model of the lactation curve in cattle. Nature 216(5111):164-165. doi: https://doi.org/10.1038/216164a0

Sheep & Goat Research Journal
Volume 37, 2022 - October

Surveying Production and Management Needs of U.S. Sheep and Goat Producers

Jaelyn R. Whaley[1], Kelly A. Froehlich[1], Heidi K. Carroll[1]*

[1] *Department of Animal Science, South Dakota State University, Brookings, SD 57007*

* *Corresponding author: Jaelyn.Whaley@sdstate.edu*

Summary

Resources for sheep and goat production are limited despite expanded interest and rising number of producers in the United States. It is critical for extension professionals, producer organizations, and industry to be attuned to producer needs as educational programming is planned and developed. Therefore, a needs assessment was conducted to identify U.S. producer interests and enhance future extension efforts. The online QuestionPro survey was peer-reviewed by 15 university small ruminant specialists. Close-ended and open-ended questions were utilized to identify important production topics, preferred program delivery methods, production challenges, and participant demographics. Six hundred and seventy-two respondents completed at least half of the survey. Most respondents raise sheep only (46%) followed by goats only (35%) then both (19%). Seventy percent of respondents describe their operation as providing supplemental household income. Fifty-five percent direct market products. The largest percentage of respondents indicated live animals (82%) and meat (63%) were "very important" economically to their operation. Seventy-one percent of respondents have flocks/herds of less than 100 animals and 49% have less than 10 years of experience raising small ruminants. "Very important" topics were parasite management (65%), breeding stock nutrition (61%), and reproductive management (60%). The results of this survey highlighted current needs, interests, and demographics of U.S. sheep and goat producers. These results are important to enhance extension efforts and collectively strengthen the sustainability of the American small ruminant producer. Educational programs and resources should be evaluated to align with the findings of this survey regarding topics of importance for the various groups of sheep and goat producers across the U.S.

Keywords: Extension, Goats, Needs Assessment, Sheep, Small Ruminant, Survey

Introduction

Small ruminants are raised across the U.S. at differing scales and for a multitude of purposes, easily fitting into diversified lifestyles. This adaptability has encouraged new producers, leading to changes in the demographics of sheep and goat producers. The most recent USDA Census data shows the number of small ruminant operations has increased while overall sheep inventory decreased from 2012 to 2017 (USDA NASS, 2012;2017). Growing interest in raising small ruminants is encouraging for industry expansion but highlights the need for extension professionals to identify challenges and topics of importance to support a more diverse producer audience. Previous national needs assessments through USDA National Animal Health Monitoring System (NAHMS) provided insight into goat and sheep management and health priorities (USDA NAHMS, 2019, 2021). While there are some overlaps with the NAHMS study, this survey was written to better understand the producer demographics and true educational programming needs that are not always seen in the Census of Agriculture or NAHMS. Given the diverse production practices and climates across the U.S. this information is separated into regions to better ensure the diversity of needs are addressed by extension professionals. The following survey was distributed nation-wide to assist small ruminant extension professionals in developing programs. The objective of this survey was to better understand operation demographics, production and management topics of importance and challenges to U.S. sheep and goat producers to enhance timely Extension resources and efforts.

Materials and Methods

This project was granted exempt status by South Dakota State University's Institutional Review Board (IRB) office. The survey was created through consideration of previous literature and was peer reviewed by other small ruminant extension professionals across the U.S. The questionnaire included a combination of open-ended, multiple choice, and close-ended questions. The survey was distributed via the Question Pro online survey platform and was open January 27 through July 30, 2021. Fifteen small ruminant specialists from universities across the nation as well as state and national industry groups promoted participation through news releases, email listservs and social media platforms. A printed survey was available and used by one small group of South Dakota respondents.

Responses were collected from 47 states (n = 996). Data was imported into Microsoft Excel® and responses that had less than 50% of questions answered were removed (n = 324). Remaining responses (n = 672) were divided into regions based on the 2018 U.S. cost of sheep production study regions (ASI, 2019). These regions include West (n = 143), Northcentral (n = 246), South Central (n = 62), and East (n = 177; Fig. 1). Respondents that did not indicate where they resided were put into an "unknown" region (n = 44). Responses from open-ended questions were categorized into topic themes. Descriptive statistics were determined using Microsoft Excel®.

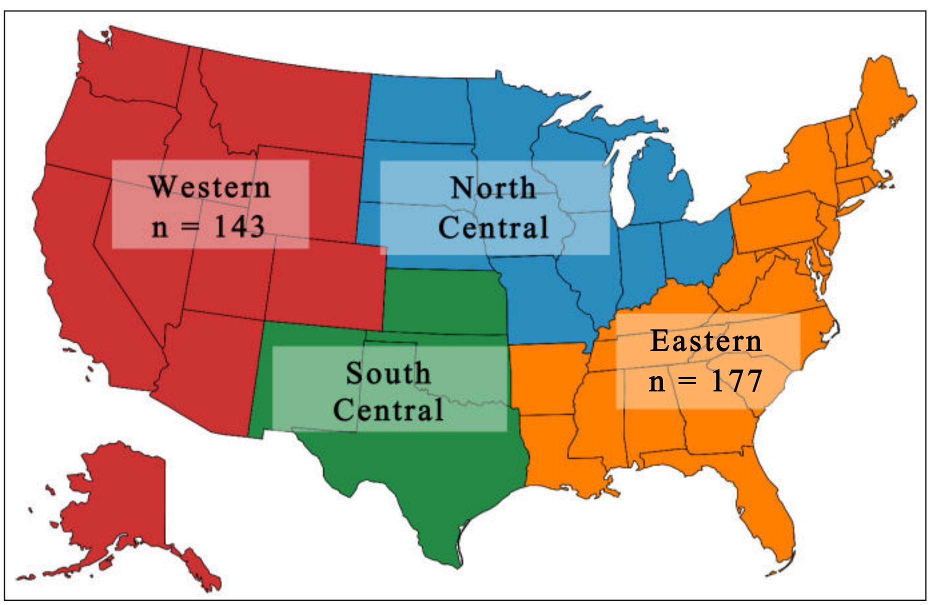
Results and Discussion

Farm and Ranch Demographics

Table 1 outlines overall farm and ranch demographics and key regional demographics are described below. Survey respondents were predominantly comprised of solely sheep producers (46%) with 35% raising only goats and 19% raising both sheep and goats. Higher percentages of solely goat operations were seen in the South Central (52%) and East (42%). Based on aggregated, national results, 70% of sheep and goat operations have flock/herd sizes of 100 head or less. The Western and Northcentral regions had the highest response for large flocks (≥500 head) at 9% and 6%, respectively. Census data from USDA, NASS (2017) indicates that 93% of sheep flocks in the U.S. are 100 head or less, increasing 27% from 2012 to 2017. Goat industry surveys have found that the average U.S. producer owns approximately 20 goats (USDA NASS, 2019) and only 14% of household income came from the producer's goat enterprise (Gillespie et al., 2013). When comparing to USDA, NASS (2017) and Gillespie et al. (2013) findings, questions in the current survey combined sheep and goat numbers instead of asking respondents to provide a response for sheep numbers separate from goats.

The vast majority (70%) of participants indicated that their small ruminant operation provided supplemental income rather than supporting a single spouse (7%) or the whole family (8%).

Figure 1. Geographical distribution within the designated regions of survey respondents (n=628, 44 respondents did not identify their location and were put into an "unknown" region).



©2022, *Sheep & Goat Research Journal*

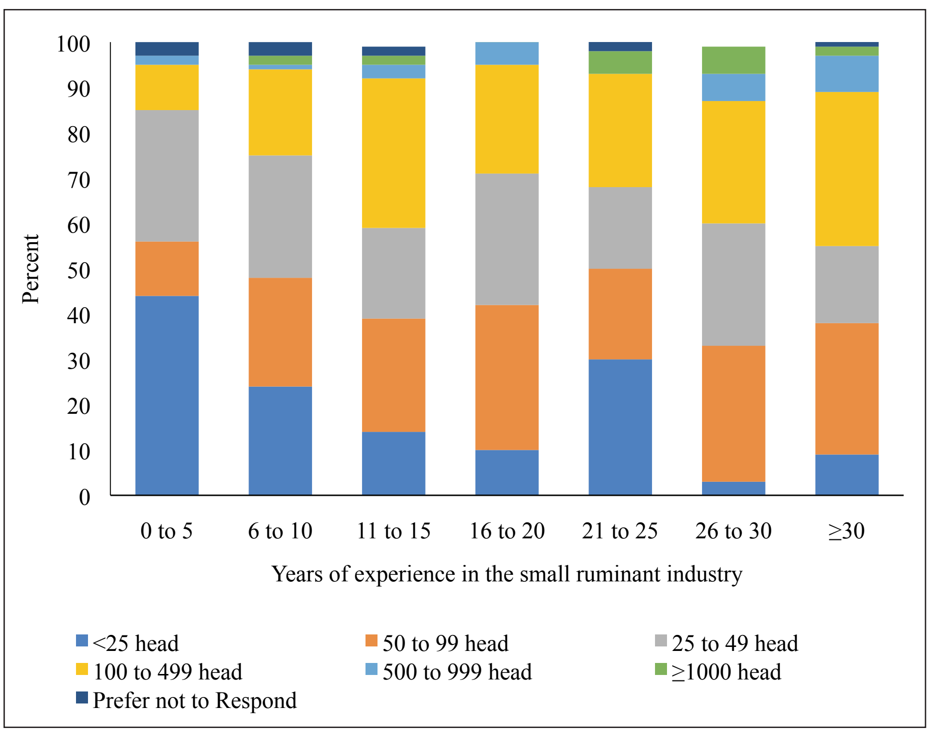
Table 1. Overall demographics of survey respondents

Question	Response Options	Frequency	%
Do you raise sheep, goats, or both? (*n* = 652)	Sheep	302	46.3
	Goats	229	35.1
	Both	121	18.6
Do you direct market your products (meat, fiber, dairy, etc.)? (*n* = 613)	Yes	339	55.3
	No	274	44.7
Which of the following best describes your operation's contribution to your household income? (*n* = 639)	Supplemental Income	449	70.3
	Prefer not to respond	94	14.7
	Whole Family Income	52	8.1
	Single Spouse Income	44	6.9
What is your average flock/herd size annually? (*n* = 648)	≥1000	12	1.9
	500-999	21	3.2
	100-499	145	22.4
	50-99	146	22.5
	25-49	160	24.7
	<25	150	23.1
	Prefer not to respond	14	2.2
Which of the following best describes your operation? Select all that apply. (*n* = 663)	Farm flock/herd	361	38.1
	Registered flock/herd	305	32.2
	Show sheep/goats	146	19.1
	Range flock/herd	82	8.6
	Other	33	5.0
	Feedlot (buy/finish)	28	3.0
How many years have you been working in the sheep and/or goat industry? (*n* = 652)	0-5 years	167	25.6
	6-10 years	152	23.3
	11-15 years	93	14.3
	16-20 years	64	9.8
	21-25 years	41	6.3
	26-30 years	33	5.1
	30+ years	102	15.6
Do you raise your sheep/goats with other livestock species (diversified operation, multi-species grazing)? (*n* = 646)	Yes	310	48.0
	No	336	52.0
Do you utilize your sheep/goats for targeted grazing/weed control? (*n* = 633)	Yes	267	42.2
	No	366	57.8
Do you utilize livestock guardian animals? (*n* = 637)	Yes	345	54.2
	No	292	45.8
Gender (*n* = 636)	Female	399	62.7
	Male	212	33.3
	Prefer not to respond	25	3.9
Age (*n* = 636)	Under 18 years old	8	1.3
	18-29 years old	63	9.9
	30-59 years old	378	59.4
	60 years or older	175	27.5
	Prefer not to respond	12	1.9
Ethnicity (*n* = 629)	Hispanic	8	1.3
	Latino	2	0.3
	Non-Hispanic or Latino	533	84.7
	Prefer not to respond	86	13.7
Race (*n* = 648)	White	561	86.6
	American Indian or Alaska Native	11	1.7
	Asian	1	0.2
	Black or African American	7	1.1
	Native Hawaiian/other Pacific Islander	1	0.2
	Prefer not to respond	67	10.3

Supplemental income was the highest response across each region. Small ruminant production being a supplemental income source could pose a challenge for expanding flock/herd inventories. In an industry survey, 32% of sheep producers indicated that working off the farm was a primary reason for not expanding their operation (ASI, 2016). With this in mind, extension efforts should be made available at times and in formats conducive to producers with off-farm employment. A multi-modal programming approach with both in-person and virtual options could maximize participation, while archiving recorded programs for later use could also increase use and implementation of information. Additionally, given that most respondent's small ruminant enterprise is supplemental income, programs should promote efficient, profitable production to encourage optimal time management for a sustainable operation.

Although respondents could self-identify as multiple types of operations, the most selected answers were "farm flock/herd" (38%) and "registered flock/herd" (32%). These responses were the top two across all regions. A limitation to interpreting operation type data is that no standard description of each category was provided in the questionnaire. Respondents simply self-identified to a category. The greatest number of range flocks (25%) were in the South Central region followed by the Western (10%) and North Central regions (10%). From a broader view of the industry, the 2019 USDA NAHMS goat study found that the predominant goat production uses are meat goats (63.5%), dairy goats (26.1%), and Angora/fiber goats (2.7%) with the greatest percentage of producers also indicated using their goats as pets/companions (11.6%) or seed stock/breed stock (10.7%). Commercial lamb producers comprised most of the 2016 ASI study at 46% followed by seed stock producers (34%). Extension programs should account for the wide range of goals across production types while capitalizing on common areas of interest to reach larger audiences. The diversity of small ruminant operations makes the industry unique. Given the limited number of professionals focused on small ruminants, specialization in one area within production is a challenge, but often encouraged by current extension systems. Sheep and goat specialists are likely to have areas of expertise but should be informed on a wide array of topics. Efforts should include collaboration across regions between specialists as well as industry, government, and non-government organizations to enhance the expertise backgrounds of individuals offering small ruminant producer education in order to meet the diverse management needs of all operation types and scales.

Figure 2. Percentages of flock sizes within years of experience.



An aggregated response indicated that 49% of producers have less than 10 years of experience, thus identifying most respondents as "beginning producers". Meanwhile, 27% of small ruminant producers have worked in the industry for over 21 years. Evaluating responses between demographics, operations of all sizes (number of head) have both experienced (>11 years of experience) and beginning (≤ 10 years of experience) producers (Fig. 2). There were no operations ≥1,000 head in the 0 to 5 years group, confirming the expectation that operations entering the sheep and goat industry would likely not start with such a large number of animals. Beginning operations having smaller flocks/herds is also reflected in the 2019 USDA NAHMS goat study, with producers of smaller herds (5-19 head) having an average of 14 years of experience, medium herds (20-99) having 16 years, and large herds (100+) at 25 years' experience (USDA NAHMS, 2019). The data also show that industry involvement is not connected to the age of producers. Respondents ages 30 through 59 made up the majority of producers surveyed (n=378, 59%) which is consistent with the national U.S. farmer age of 57.5 years (USDA NASS, 2017). This age group was followed by 60 years of age and older (*n* = 175, 28%, Table 1). Data supports the increase in beginning producer programs, and 30 through 60 years of age and older spanned all years of experience indicating that caution should be used in tailoring beginning producer programs to a single adult age group.

Questions were also asked to assess specific production practices. Nationally, 48% of respondents indicated that they raise their sheep and goats with other livestock (predominately cattle), and 42% indicated that they use sheep and goats for targeted grazing and weed control. If "yes" was selected for targeted grazing and weed control, a follow-up multiple-choice question was asked regarding where these practices were being used. The majority of respondents indicated that they target graze on their

 ©2022, *Sheep & Goat Research Journal*

own land (81%). Targeted grazing has been an area of focus by the American Sheep Industry Association for its economic and ecological benefits and is utilized by producers of all sizes (Launchbaugh and Walker, 2006). Multi-species operations open opportunities for stakeholder collaboration outside of sheep or goat industry organizations. Emphasis on the economic and ecological benefits of multi-species grazing can expand target audiences and potentially funding from broader stakeholder groups.

Additionally, most respondents (54%) utilize livestock guardian animals (LGA) with the most common animal being dogs (*n* = 269) followed by donkeys (*n* = 67) and llamas (*n* = 60). Other predator management strategies reported in the USDA APHIS Sheep Death Loss Report (2021) included fencing, night penning, and shed lambing. However, none of these specific strategies were noted by respondents likely due to how this survey question was worded regarding guardian animals instead of general predator control practices. With predator control being a predominant cause of livestock loss (USDA APHIS, 2021) extension programs should include information on predator management and LGA management. Unfortunately, there is limited research on LGA which expands opportunities for on-farm research and producer-panel discussions on efficacy and care of LGA within differing production systems. Wildlife agencies are also another collaborative partner that can inform producers on regulations and control methods unique to each state.

Respondents also indicated that 55% of operations are direct marketing at least one product. Across regions and production scale, small ruminant industries have seen growing interest in small acreage production (Pires et al., 2019), pasture management systems (ASI, 2016), and alternative marketing strategies (Gillespie et al., 2013). Live animals and meat were identified as "very important" economic products to the producer's operation by 82% and 63% of respondents, respectively. Selling offspring contributes the most to operational revenue (ASI, 2018), and the sale of live animals most commonly occurs through auction barns, direct to processor sales, and on-farm sales (USDA NAHMS, 2011; ASI, 2016). However, marketing small ruminants has been identified as a challenge in the current study as well as industry studies (ASI, 2019; USDA APHIS, 2019). According to ASI (2019), the challenge is not unique to a single operation type but is a greater challenge for smaller flocks (1-99 ewes) as most are selling on-farm or through auction barns but have limited availability to sell through larger market outlets (i.e., directly to feedlots, through order buyers, into lamb pools/cooperatives).

Preferences on Production and Management Topics of Importance and Challenges

Respondents were asked to think about the next 6 months and identify the level of importance (1 – "Very Important" through 4 – "Not at all

Table 2. Relative importance to the question "Looking towards the next 6 months, how important are each of the following topics to you?"

	Relative Importance (f)[1]					
Topic area	**1**	**2**	**3**	**4**	**5**	**Mean Score[2]**
Parasite management (*n*=670)	436	186	41	4	3	1.44
General animal health practices (*n*=668)	393	252	20	2	1	1.45
Breeding stock nutrition (*n*=666)	407	212	36	3	8	1.49
Reproductive management (*n*=668)	398	215	43	5	7	1.51
Newborn and maternity health and husbandry (*n*=667)	395	223	32	5	12	1.52
Lamb and kid nutrition (*n*=664)	395	212	42	6	9	1.53
Young stock management (postwean) health & husbandry (*n*=667)	367	244	41	6	9	1.57
Genetics (*n*=665)	325	272	57	4	7	1.64
Grazing systems and pasture management (*n*=668)	340	232	72	16	8	1.68
Business and financial management (*n*=660)	298	254	79	20	9	1.77
Forage production (*n*=666)	284	245	93	23	21	1.88
Direct marketing (food and fiber, *n*= 661)	286	222	95	37	21	1.92
Predator control (*n*=664)	248	240	135	35	6	1.96
Animal behavior and handling (*n*=668)	189	322	141	15	1	1.98
Risk management tools (*n*=661)	196	315	108	19	23	2.03
Livestock protection animals (*n*=667)	213	238	159	41	16	2.11
Working with local processors (*n*=663)	225	203	171	38	26	2.15
Estimated breeding values (EBV) and genetic tools (NSIP, *n*= 661)	198	244	154	40	25	2.17
Cover crop integration (*n*=664)	144	232	189	60	39	2.42
Lamb and goat cuts and fabrication (*n*=660)	157	202	195	68	38	2.44
Fiber quality and marketing (*n*=664)	159	117	153	152	83	2.82
Dairy product quality (*n*=661)	112	101	165	166	117	3.11
Immigrant workers policy and procedures (*n*=661)	44	65	167	233	152	3.58

[1] 1=very important, 2=somewhat important, 3=not very important, 4=not at all important, 5=N/A
[2] A lower mean score indicates a higher relative importance

Important" or 5 – "Not Applicable") of a list of topics to their operation. The top five topics of greatest importance nationally were 1) Parasite Management, 2) General Animal Health, 3) Breeding Stock Management, 4) Reproductive Management, and 5) Newborn and Maternity Health and Husbandry (Table 2). In addition to scoring each listed topic, respondents were asked to share their top three challenges in an open-ended question with the most commonly mentioned topics being "markets" or "marketing: (*n* = 241), "parasites" (*n* = 208), and "feed" or "feedstuffs" (*n* = 148). These topics closely reflect the 2021 USDA NAHMS Sheep Needs Assessment and Gillespie et al. (2013). Although question wording and type were different than the current study, internal parasites rose to the top as flock health priorities (USDA, NAHMS, 2021; ASI, 2016). The sheep death loss report (USDA NAHMS, 2020) also supports producer concerns with general animal health as 15% of nonpredator death loss were attributed to internal parasites.

Production and management topics of importance and challenges for each region can be seen in Table 3. Parasite management was the top concern for all regions except the Western region. This is likely attributed to the west and intermountain west predominately managing sheep on arid rangelands with less rainfall, larger pastures, and lower parasite exposure. Breeding stock nutrition was observed as a top five interest in all regions which further highlights producer challenges surrounding feeds/feedstuffs and ration development across the country. Important topics also varied by flock/herd size. Operations with <100 head prioritized parasite burden. However, operations >100 head did not express parasite management within their top five topics of importance; instead nutrition, reproduction, and generalized health and husbandry topics were emphasized (Table 4). Kelly et al., (2021) also found maternal nutrition to be a predominant concern to sheep producers and highlighted the opportunity for extension engagement on these critical topics to increase producer usage of extension professionals.

Conclusion

The current study supports that the U.S. sheep and goat industries are largely comprised of farm flocks/herds with relatively new producers. Although variable in operational demographics, many regions share the same concerns and challenges including parasite management and nutrition of both young stock and breeding animals. The results of this survey, along with other supporting surveys, are valuable in directing future development of key resources, information, and programming that is tailored toward sheep and goat producers. Current extension efforts should be evaluated and adapted in a way that supports the current structure of the small ruminant industry and builds extensions rep-

Table 3. Top five topic areas indicated as "Very Important" by region.

Region	Topic of Interest	Mean Score[1,2]
Western (*n*=143)	General animal health practices	1.39
	Breeding stock nutrition	1.44
	Reproductive management	1.46
	Newborn and maternity health and husbandry	1.50
	Genetics	1.56
North Central (*n*=246)	Parasite management	1.47
	Reproductive management	1.48
	Lamb and kid nutrition	1.48
	Breeding stock nutrition	1.51
	Young stock management (postweaning) health and husbandry	1.57
South Central (*n*=62)	Parasite management	1.29
	Newborn and maternity health and husbandry	1.40
	Reproductive management	1.40
	General animal health practices	1.42
	Breeding stock nutrition	1.42
Eastern (*n*=177)	Parasite management	1.27
	General animal health practices	1.38
	Grazing systems and pasture management	1.54
	Breeding stock nutrition	1.55
	Newborn and maternity health and husbandry	1.56
Unknown (*n* = 44)	Lamb and kid nutrition	1.27
	Breeding stock nutrition	1.35
	Parasite management	1.37
	Newborn and maternity health and husbandry	1.37
	General animal health practices	1.39

[1] Mean score is based on a Likert scale: 1=very important, 2=somewhat important, 3=not very important, 4=not at all important, 5=N/A

[2] A lower mean score indicates a higher relative importance

 ©2022, *Sheep & Goat Research Journal*

Table 4. Top five topic areas indicated as "Very Important" by flock size.

Flock Size[1]	Topic Area	Mean Score[2,3]
<25 (n = 150)	Parasite management	1.34
	General animal health practices	1.36
	Breeding stock nutrition	1.46
	Newborn and maternity health and husbandry	1.54
	Grazing systems and pasture management	1.54
25-49 (n = 160)	Parasite management	1.34
	General animal health practices	1.42
	Breeding stock nutrition	1.48
	Reproductive management	1.51
	Lamb and kid nutrition	1.52
50-99 (n=146)	Parasite management	1.39
	Reproductive management	1.41
	Breeding stock nutrition	1.49
	Newborn and maternity health and husbandry	1.50
	General animal health practices	1.51
100-499 (n=145)	Reproductive management	1.44
	Young stock management (postweaning) health and husbandry	1.45
	Newborn and maternity health and husbandry	1.49
	General animal health practices	1.49
	Breeding stock nutrition	1.49
500-999 (n=21)	Newborn and maternity health and husbandry	1.45
	Reproductive management	1.52
	Genetics	1.55
	Lamb and kid nutrition	1.57
	General animal health practices	1.65
≥1000 (n=12)	Breeding stock nutrition	1.45
	Genetics	1.50
	Lamb and kid nutrition	1.55
	Predator control	1.58
	Reproductive management	1.58

[1] n=648, 14 respondents answered Prefer not to respond
[2] Mean score is based on a Likert scale: 1=very important, 2=somewhat important, 3=not very important, 4=not at all important, 5=N/A
[3] Lower mean score indicates a higher relative importance

utation as a reliable source of information. The extension model of simply regurgitating non-biased, research-based information in a lecture style is outdated with the increased availability and comfortability of receiving information online. Modern extension and producer partnerships need to be innovative and strive to develop new solutions. Opportunities for cross-collaboration across small ruminant specialists will also further enhance extension programs. Given the diversity of sheep and goat production, extension efforts should be dynamic and relevant. Additionally, there is greater availability for multi-state, regional, and national cooperation given the increased normalcy of online or hybrid programs, opening doors to enhanced influence and accessibility for producers.

Literature Cited

American Sheep Industry (ASI). 2019 U.S. Baseline Lamb Cost of Production Analysis. Denver, Colorado. Available from: www.sheepusa.org/wp-content/uploads/2019/12/2018-ASI-Budget-Project.pdf.

American Sheep Industry (ASI). 2016. U.S. Sheep Industry Research development, and education priorities. Denver, Colorado. Accessed from: https://www.sheepusa.org/resources-publications.

Gillespie J., N. Nyaupane, K. McMillin. 2013. Producer perceptions of important challenges currently facing the United States meat-goat industry. Prof Anim Sci. 29:4. doi: 10.15232/S1080-7446(15)30246-1.

Launchbaugh, K., and J. Walker. 2006. Chapter 1. Targeted grazing-a new paradigm for livestock management. Targeted grazing handbook. American Sheep Industry, Englewood, CO.

Kelly, M. R., A. Halpern, S. A. Reed, S. A. Zinn, and K. E. Govoni. 2021. Understanding gestational and feed management practices of New England sheep producers. Translational Animal Science. 5:234. doi:10.1093/tas/txaa234.

USDA NASS. 2012. Census of Agriculture. (Accessed February 8, 2022). Available from www.nass.usda.gov/AgCensus.

USDA NASS. 2017. Census of Agriculture. (Accessed February 8, 2022). Available from www.nass.usda.gov/AgCensus.

USDA NAHMS. 2019. Goat Study. (Accessed February 15, 2022). Available from https://www.aphis.usda.gov/aphis/ourfocus/animalhealth/monitoring-and-surveillance/nahms/NAHMS_Goat_Studies.

USDA NAHMS. 2020. Sheep Death Loss in the United States. (Accessed February 20, 2022). Available from https://www.aphis.usda.gov/aphis/ourfocus/animalhealth/monitoring-and-surveillance/nahms/nahms_sheep_studies.

USDA NAHMS. 2021. Sheep Needs Assessment: (Accessed February 23, 2022). Available from https://www.aphis.usda.gov/aphis/ourfocus/animalhealth/monitoring-and-surveillance/nahms/nahms_sheep_studies.

©2022, *Sheep & Goat Research Journal*