Lamb growth trait evaluation of purebred and crossbred Royal Whites in North Dakota

Lauren L. Hulsman Hanna[1], Steven E. Anderson[1], Travis W. Hoffman[1], Pawel P. Borowicz[1], Carl R. Dahlen[1], James D. Kirsch[1], Garry L. Ottmar[2], Wanda Ottmar[2], and Kris A. Ringwall[2]

The purpose of this study was to summarize general production characteristics in weight and growth of Royal White lambs and their crosses with other hair breeds in North Dakota. This paper provides simple means and standard deviations for birth weight, weight after rearing, and average daily gain in Royal White lambs and their crosses produced in North Dakota climates.

Summary

Royal White sheep are an established composite hair breed developed initially using Dorper (DO) (black and white headed) sire lines crossed with St. Croix ewes. There is limited production data readily available on Royal White sheep, particularly in northern climates. This paper provides general summaries of purebred and crossbred Royal White (RW) lamb weights and growth from birth to end of rearing ages. The average birth weight of RW lambs was 7.62 ± 1.71 lb, and the average birthweight of crossbreds was 8.13 ± 1.61 lb overall. Four crosses were made with average birthweights of 8.09 ± 1.62 lb, 8.49 ± 1.53 lb, 8.12 ± 1.71 lb, and 7.67 ± 1.46 lb for F1 DO-RW, ¾ DO ¼ RW, F1 RO-RW, and ½ RO ¼ DO ¼ RW, respectively. Numerically, differences in birthweight based on litter size at birth was only evident in crossbred lambs. Due to study limitations, weights around weaning were inconsistent in ages. Even so, Royal White crossbred lambs averaged 0.64 ± 0.11 lb/d of gain, with similar gains found in purebred Royal White lambs.

Introduction

The Royal White (RW) breed is a composite breed developed by Bill Hoag using Dorper (DO) and St. Croix (SC) hair breeds (Registry Royal White® Sheep Association, 2018). Originally called Dorpcroix, Hoag formally had the name changed in 2003 and trademarked in 2004. A limited number of publications are available on RW sheep. These include publications from studies comparing RW-sired crossbred lambs to Rambouillet lambs for growth given natural prebiotic treatments (Campbell, 2002), pelt and leather quality (Shelly et al., 2009) and genetic resistance to prion diseases (e.g., scrapie polymorphisms; Seabury, 2004). The remainder of RW breed characterizations are based on Mr. Hoag's observations and records (Registry Royal White® Sheep Association, 2018).

The development of the RW breed was focused on arid and tropical regions of the U.S., where Hoag indicated that sheep had to be hardy and cope with unexpected weather changes that occur in West Texas across seasons (Registry Royal White® Sheep Association, 2018). Even so, no characterization has been provided in other climates. North Dakota (N.D.), in general, is described as a continental climate due to extreme shifts in temperatures because of cold winters and warm-to-hot summers (National Weather Service, 2007). The western part of N.D. is characterized as a semi-arid climate due to less precipitation and humidity, while the eastern part of N.D. is characterized as a humid, continental climate due to humid, warm-to-hot summers, and windy, cold winters. The climate of N.D. is distinctly different from the variety of climate types seen in central-to-western regions of Texas. Therefore, the purpose of this study was to summarize general production characteristics in weight and growth of RW lambs and their crosses with other hair breeds in N.D.

Procedures

Animals and Breeding

All procedures involving animals were reviewed and approved by the North Dakota State University (NDSU) Institutional Animal Care and Use committee. A flock of 60 purebred RW ewes (n = 30 spring- and 30 fall-born in 2014) were purchased by the NDSU Dickinson Research Extension Center (DREC) in February of 2015. The spring-born RW ewes were bred prior to purchase, then transported to DREC in Febru-

[1]Department of Animal Sciences, North Dakota State University, Fargo, ND
[2]Dickinson Research Extension Center, North Dakota State University, Dickinson, ND

ary and lambed between late April to late July as approximately one-year-old ewes. Ewe lambs born in 2015 were retained in the flock and males were castrated and sold following weaning (late August). The RW ewes were housed at the DREC ranch located near Manning, ND (47°11′37.3″N, 102°50′20.1″W) and managed as an early summer shed-lambing system. In 2016 and 2017, the ewes were bred to White DO rams and in 2018, ewes were randomly separated into two groups for breeding to DO and Romanov (RO) rams. Some F1 DO-RW ewe lambs (n = 50) produced in 2017 and 2018 were retained for breeding to DO and/or RO rams in 2019 as well. From 2018 to 2019, the flock was downsized due to space limitations at the ranch. In October of 2019, a subset of purebred RW (n = 23) and F_1 DO-RW (n = 17) ewes were sold to the NDSU Sheep Unit located in Fargo, ND (46°54′14.3″N, 96°49′59.3″W) and the remaining ewes were sold by DREC. The ewes retained at the NDSU Sheep Unit were switched to a fall pasture and shed-lambing management system, where they were next bred to a DO ram in late spring of 2020 to produce either F_1 DO-RW or ¾ DO ¼ RW offspring. In 2021 and 2022, remaining purebred RW ewes (n = 13) were used exclusively for laparoscopic artificial insemination (LAI) following the procedure described in Sathe (2018) using semen of purebred, registered RW rams. Any remaining F_1 DO-RW ewes were bred to the White DO ram to produce ¾ DO ¼ RW offspring. A purebred RW ram lamb produced in 2021 was retained and used for natural service breeding with purebred RW ewes in 2022 following LAI.

General Management Practices

At DREC, sheep were fed chopped mix hay and grains produced on DREC lands through winter months. Rotational grazing was used during summer months near ranch headquarters once plant growth was adequate. Sheep Mineral 16-8 (CHS, Inc., Sioux Falls, S.D.) and loose white salt was provided throughout the year as free choice in mineral feeders. Following weaning, lambs were provided mixed hay and a commercial growing feed (Lamb Grower Complete B30; CHS, Inc., Sioux Falls, S.D.) until they were sold or integrated back into the flock.

At the NDSU Sheep Unit, sheep were fed a blend of chopped alfalfa and grass hay or a long-stem native grass round bale hay during winter months. In spring, summer and fall, ewes were rotationally grazed on native pastures. During late gestation and lactation, ewes were fed a 16% protein complete pellet produced at the NDSU feed mill. The Shepherd's Choice Trace Mineral Premix (Premier 1 Supplies, Washington, Iowa) and salt were blended and provided throughout the year as free choice in mineral feeders. Lambs were started on a 20% protein creep pellet and transitioned to a 16% protein complete pellet until sold or retained as replacements. Both diets were produced at the NDSU feed mill.

Production Data

Lambing data were captured on all lambs during the study period. These data included date of birth, litter size at birth (LS_B), litter size based on how they were reared (LS_R), status of lambs (active, died, reasons for death if known), sex, dam, suspected or known sire, expected lamb breed type, and birth weight. Starting in 2017, weights on lambs were captured at least once when lambs were approximately 60 to 90 d old, which was typically weaning but varied based on management needs and location. Average daily gain (ADG) for each lamb was calculated as the difference between the weight captured in the 60 to 90 d timeframe minus birth weight divided by the age of the lamb (in d).

Statistical Analyses

Data was imported into R software version 4.2.3 (R Core Team, 2023) within RStudio version 2023.03.03 (Posit Team, 2023). Basic summaries statistics of lamb data were generated using the *dplyr* R package version 1.1.1 (Wickham et al., 2023) with *group_by* and *summarise* functions. Grouping variables included production year, breed type, lamb sex (male or female), litter type (LS_B and LS_R as single, twin, or triplet), age of dam (in whole years) and their interactions based on available data. Due to the unbalanced nature of available data, no additional statistical models were employed.

Results and Discussion

Royal White Lambs

Purebred RW were only produced in 2015 (n = 21), 2021 (n = 2), and 2022 (n = 11) due to challenges in purchasing purebred rams to support natural service matings. All RW ewes were the same age when producing purebred lambs, such that ewes were one, seven, and eight years old, respectively. The average birth weight of RW lambs was 7.62 ± 1.71 lb across years and 7.14 ± 1.79 lb, 9.10 ± 1.84 lb, and 8.25 ± 1.23 lb for the three years produced, respectively. Given all 2015 born lambs were from one-year old dams, the lower birth weight would be consistent with other sheep breeds (e.g., Gardner et al., 2007). Summary statistics by lamb sex and litter size (Table 1) indicate male lambs were often heavier than ewe lambs, but differences among litter sizes were not as evident.

Weights were generally collected in the 60-to-90 d timeframe, but this was not always consistent with RW lambs and did not always coincide with actual weaning across management location or years. Therefore, the weights and ADG values are described as "after rearing" to be consistent across years data were collected. In terms of RW lambs, there were only two instances that lambs were reared differently than their LSB (one twin raised as a single and one triplet raised as a single) in the two years of available data. Therefore, only LSR

was considered in summary statistics (Table 1). The twin-born LAI lambs born in 2021 consisted of a male and female that averaged 79.0 ± 15.6 lb at 81 d of age with average ADG of 0.86 ± 0.17 lb/d. In 2022, six females and three male lambs were weaned and averaged 63.1 ± 11.5 lb at 100.3 ± 11.1 d of age with average ADG averaged of 0.55 ± 0.13 lb/d.

Crossbred Lambs

Most crossbred lambs were F_1 DO-RW (65.65%) followed by ¾ DO ¼ RW (18.35%), ½ RO ¼ DO ¼ RW (9.18%), and F1 RO-RW (6.82%; Table 2). The majority of crossbred lambs (85.18%), including all RO-influenced lambs, were produced from 2017 to 2019 at the DREC (averaged 121 lambs per year) with the remainder produced at the NDSU Sheep Unit (averaged 21 lambs per year). This was simply due to the larger flock size accommodated at the DREC.

The average birthweight of crossbreds was 8.13 ± 1.61 lb overall and 8.09 ± 1.62 lb, 8.49 ± 1.53 lb, 8.12 ± 1.71 lb, and 7.67 ± 1.46 lb for F_1 DO-RW, ¾ DO ¼ RW, F1 RO-RW, and ½ RO ¼ DO ¼ RW, respectively. Summary statistics by breed type for lamb sex and litter size (Table 3) indicate that when RO was the highest percentage, birth weights of lambs were lower than other crosses, particularly for triplets. Litter size, in general, was particularly impactful for single-born lambs in all crosses compared to twin- and triplet-born lambs (Table

Table 1. Means and standard deviations of Royal White lamb weights and average daily gain from birth to end of rearing grouped by lamb sex, litter size (LS), or their interaction.[1]

		Birth		After Rearing			
Sex	LS	n	BW, lb	n	WT, lb	Age, d	ADG, lb/d
Overall	S	24	7.55 ± 1.75	6	66.7 ± 7.5	96.0 ± 11.3	0.61 ± 0.09
	TW	4	7.55 ± 2.24	2	79.0 ± 15.6	81.0 ± 0.0	0.86 ± 0.17
	TR	6	7.93 ± 1.43	3	56.0 ± 16.5	109.0 ± 0.0	0.45 ± 0.14
Female	Overall	19	7.25 ± 1.78	7	64.0 ± 15.9	102.0 ± 13.2	0.56 ± 0.21
	S	14	7.20 ± 1.72	3	63.3 ± 7.0	101.0 ± 15.1	0.54 ± 0.04
	TW	2	7.70 ± 3.82	1	90.0 ± 0.0	81.0 ± 0.0	0.98 ± 0.00
	TR	3	7.20 ± 1.31	3	56.0 ± 16.5	109.0 ± 0.0	0.45 ± 0.14
Male	Overall	15	8.08 ± 1.55	4	69.5 ± 6.2	88.2 ± 5.2	0.69 ± 0.06
	S	10	8.04 ± 1.76	3	70.0 ± 7.6	90.7 ± 2.3	0.68 ± 0.06
	TW	2	7.40 ± 0.57	1	68.0 ± 0.0	81.0 ± 0.0	0.74 ± 0.00
	TR	3	8.67 ± 1.33	0	--	--	--

[1]Litter size at birth included single-born (S), twin-born (TW), and triplet-born (TR) lambs. Litter size through rearing was based on being reared a single (S), as a twin (TW), or as a triplet (TR). Birth weights were collected over three years, whereas weights after rearing were only collected in two years. Dams were all the same age per year. The n per group level is the total number of lambs with records within that category.

Table 2. Sample sizes of crossbred lambs with birth and rearing age records produced overall as well as by location and year.[1]

		Crossbred type n for birth / rearing records				
Location	Year	F_1 DO-RW	¾ DO ¼ RW	F_1 RO-RW	½ RO ¼ DO ¼ RW	Total
NDSU DREC	2017	116 / 103	--	--	--	116 / 103
	2018	112 / 104	--	--	--	112 / 104
	2019	30 / 26	36 / 31	29 / 26	39 / 35	134 / 118
NDSU Sheep Unit	2020	17 / 17	8 / 7	--	--	25 / 24
	2021	3 / 3	17 / 16	--	--	20 / 19
	2022	1 / 1	17 / 17	--	--	18 / 18
Total		279 / 254	78 / 71	29 / 26	39 / 35	425 / 386

[1]Locations included the North Dakota State University (NDSU) Dickinson Research Extension Center (DREC) ranch near Manning, ND and NDSU Sheep Unit in Fargo, ND. Breeds included in crosses were White Dorper (DO), Romanov (RO), and Royal White (RW), where F_1 (true first crosses) were 50% of each breed.

3). Purebred Romanov lamb birth weight is commonly reported to be about 5.5 lb (e.g., Khattab et al., 2021) due to the prolific nature of the breed. The higher average F_1 RO-RW birth weight in this population would certainly indicate some level of heterosis is present, however a balanced cohort of purebred and crossbred lambs would be needed to determine the exact level. Additional statistical comparisons are warranted to prove litter size differences exist. Furthermore, heavier birthweights of DO x RW crosses compared with purebred RW indicate heterosis still may occur between the two breeds (Table 1 and 3) even though DO influenced RW in breed development.

Weights taken following rearing were more consistent during the 60-to-90 d timeframe for all crossbreds. The overall average was 57.1 ± 11.2 lb at 76.9 ± 10.3 d of age with an ADG of 0.64 ± 0.11 lb/d (Table 4). Given all four types were only present in 2019, Table 5 provides summary statistics by breed type for lamb sex, litter size, and their interaction. Weights and ADG were within the realm of what has been reported in other sheep breeds at the given ages and weights.

Lambs derived from RW genetics, either purebred or crossbred, reached breed comparable weights to medium-framed wool sheep at 53.9 to 66.9 lb after rearing and growth rates of 0.62 to 0.68 lb/d. This early growth meets production expectations indicating that RW-influenced progeny can be effectively marketed after a short backgrounding period for the growing lightweight market. Further research on post-weaning growth and utilizing RW for commercial lambs is warranted.

Table 3. Means and standard deviations of Royal White crossbred lamb birthweights grouped by lamb sex, litter size (LS), or their interaction within breed type.[1]

		Crossbred type			
Sex	**LS**	**F_1 DO-RW**	**¾ DO ¼ RW**	**F_1 RO-RW**	**½ RO ¼ DO ¼ RW**
Overall	S	9.32 ± 1.57	9.19 ± 1.73	9.33 ± 1.04	8.63 ± 0.98
	TW	7.91 ± 1.45	7.90 ± 1.08	8.79 ± 1.48	7.33 ± 1.36
	TR	7.48 ± 1.74	8.13 ± 0.93	7.04 ± 1.56	6.50 ± 2.29
Female	Overall	7.88 ± 1.65	8.21 ± 1.81	7.77 ± 1.82	7.50 ± 1.55
	S	9.25 ± 1.19	8.87 ± 2.14	9.00 ± 0.00	8.08 ± 0.80
	TW	7.55 ± 1.55	7.46 ± 1.08	8.50 ± 1.47	7.44 ± 1.66
	TR	7.47 ± 1.74	9.20 ± 0.00	6.50 ± 1.84	4.50 ± 0.00
Male	Overall	8.26 ± 1.58	8.70 ± 1.26	8.41 ± 1.61	7.77 ± 1.43
	S	9.40 ± 1.91	9.50 ± 1.23	9.50 ± 1.41	9.17 ± 0.88
	TW	8.19 ± 1.31	8.19 ± 1.00	9.07 ± 1.54	7.28 ± 1.24
	TR	7.48 ± 1.77	7.60 ± 0.14	7.43 ± 1.34	7.50 ± 2.12

[1]Litter size at birth included single-born (S), twin-born (TW), and triplet-born (TR) lambs. Breeds included in crosses were White Dorper (DO), Romanov (RO), and Royal White (RW), where F1 (true first crosses) were 50% of each breed.

Table 4. Means and standard deviations of Royal White crossbred lamb weights and growth by end of rearing produced from 2017 to 2022 grouped by breed type.[1]

		Crossbred type			
Trait	**Group**	**F_1 DO-RW**	**¾ DO ¼ RW**	**F_1 RO-RW**	**½ RO ¼ DO ¼ RW**
WT, lb	All	53.9 ± 9.8	62.4 ± 11.2	60.4 ± 8.7	66.9 ± 12.1
	2019-born	54.2 ± 11.5	57.1 ± 12.6	*	*
Age, d	All	72.7 ± 7.3	85.2 ± 13.6	83.4 ± 5.8	86.3 ± 4.0
	2019-born	75.0 ± 9.2	76.9 ± 6.6	*	*
ADG, lb/d	All	0.63 ± 0.11	0.64 ± 0.12	0.62 ± 0.10	0.68 ± 0.13
	2019-born	0.61 ± 0.11	0.63 ± 0.14	*	*

[1]Breeds included in crosses were White Dorper (DO), Romanov (RO), and Royal White (RW), where F1 (true first crosses) were 50% of each breed.
*Values are the same as the All group.

Table 5. Means and standard deviations of 2019-born Royal White crossbred lamb weights by end of rearing grouped by lamb sex, litter size (LS), or their interaction within breed type.[1]

		Crossbred type			
Sex	LS	F_1 DO-RW	¾ DO ¼ RW	F_1 RO-RW	½ RO ¼ DO ¼ RW
Overall	S	66.8 ± 9.2	64.7 ± 10.5	70.0 ± 6.7	76.2 ± 11.7
	TW	54.4 ± 9.7	50.1 ± 8.5	61.6 ± 7.2	63.6 ± 7.1
	TR	45.0 ± 9.9	34.0 ± 0.0	50.8 ± 3.4	51.5 ± 7.7
Female	Overall	52.9 ± 12.1	54.4 ± 8.8	57.9 ± 6.9	61.4 ± 9.8
	S	63.7 ± 8.3	59.3 ± 8.5	69.0 ± 5.7	66.0 ± 7.4
	TW	51.9 ± 10.9	48.9 ± 5.4	56.6 ± 4.2	62.2 ± 7.8
	TR	41.0 ± 11.3	--	51.5 ± 2.1	45.0 ± 1.4
Male	Overall	55.4 ± 11.2	61.4 ± 16.4	62.2 ± 9.6	70.6 ± 12.2
	S	76.0 ± 0.0	73.7 ± 6.6	71.0 ± 9.9	85.0 ± 5.8
	TW	57.0 ± 8.1	52.2 ± 13.0	65.4 ± 6.6	64.2 ± 7.0
	TR	47.0 ± 10.2	34.0 ± 0.0	50.5 ± 4.2	58.0 ± 2.8

[1]Litter size at birth included single-born (S), twin-born (TW), and triplet-born (TR) lambs. Breeds included in crosses were White Dorper (DO), Romanov (RO), and Royal White (RW), where F1 (true first crosses) were 50% of each breed.

Acknowledgement

The authors appreciate the assistance in data collection from many undergraduate and graduate students present during the study period. This project was supported financially by the North Dakota Agricultural Experiment Station, NDSU DREC and NDSU Sheep Unit. Furthermore, this project was supported by labor from sheep management personnel at the NDSU DREC and NDSU Sheep Unit.

Literature cited

Campbell, S. L. 2002. Effects of Amaferm supplementation on growth performance, carcass characteristics, and blood and milk constituents of sheep. Dissertation, Texas Tech University, Lubbock, TX.

Gardner, D. S., P. J. Buttery, Z. Daniel, and M. E. Symonds. 2007. Factors affecting birth weight in sheep: maternal environment. Reproduction. 133:297-307.

Khattab, A. S., S. O. Peters, A. S. Adenaike, A. A. M. Sallam, M. M. Atya, and H. A. Ahmed. 2021. Phenotypic and genetic parameters of productive traits in Rahmani and Romanov sheep and crossbreds. J. Anim. Sci. Tech. 63:1211-1222.

Lenth, R. 2023. *emmeans*: Estimated marginal means, aka Least-Squares Means. R package version 1.8.5, https://CRAN.R-project.org/package=emmeans (Accessed 2 June 2023).

National Weather Service. 2007. Forecast archive: Climate of North Dakota. https://web.archive.org/web/20070926010149/http://www5.ncdc.noaa.gov/climatenormals/clim60/states/Clim_ND_01.pdf (Archived on 27 September 2007).

Posit Team. 2023. RStudio: Integrated development environment for R. Posit Software, PBC, Boston, MA, http://www.posit.co/ (Accessed 2 June 2023).

R Core Team. 2023. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria, https://www.R-project.org/ (Accessed 2 June 2023).

Registry Royal White® Sheep Association. 2018. Royal White®: A genuine pure hair sheep breed booklet. https://royalwhitesheep.biz/index.php/info-links/ (Accessed 18 July 2023).

Sathe, S. R. 2018. Laparoscopic artificial insemination technique in small ruminants – a procedure review. Front. Vet. Sci. 5:266.

Seabury, C. M. 2004. Genetic evaluation of the ovine and bovine prior protein genes (*PRNP*). Dissertation, Texas A&M University, College Station, TX.

Shelly, D. C., D. Pasapulati, P. Thanikaivelan, B. Peng, and C. Hodges. 2009. Performance evaluation of pelts and leather from domestic hair sheep crossbreeds. Journal of American Leather Chemists Association. 104:194-203.

Wickham, H., R. François, L. Henry, K. Müller, and D. Vaughn. 2023. *dplyr*: A grammar of data manipulation. R package version 1.1.1, https://CRAN.R-project.org/package=dplyr (Accessed 2 June 2023).