Fibre requirements for market lambs

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Intro

The cost of raising market lambs in Ontario is largely due to feed costs, approaching nearly 80%, so low-cost feeding strategies should be a priority on sheep farms (Ontario Sheep Farmers 2014). Previous trials we have completed at the University of Guelph Ridgetown Campus have consistently found that 100% concentrate diets have proven to be the most economical. However, in these studies, lambs were purposely bedded on fresh straw to provide lambs with a fibre source and carefully transitioned onto their grain-based diets. The question that remains is exactly how much fibre is needed to keep lambs healthy and growing at a productive rate. While not all fibre behaves the same way in the rumen environment, a trial was set up to generally determine the effect of fibre levels on lamb performance and rumen health. The results will help Ontario sheep producers maximize growth potential in their lambs while maintaining flock health and welfare.

Setting up the trial

The trial was completed at the University of Guelph Ridgetown Campus in an open-sided barn. 43 Dorset x Rideau Arcott crossbred ram lambs (~30 kg initial weight) were used. The experiment was conducted in five "runs" between March 2017 and November 2018 as a maximum of twelve lambs could be kept in the pen at one time. Lambs were kept in a single pen that was bedded with wood shavings to prevent lambs from ingesting forage outside of their test diets. Lambs were randomly assigned to both feeders and diets. Diets were either 0%, 20%, 40%, 60%, 80%, or 100% chopped 2nd cut alfalfa hay, with the remainder of the diet ground corn (64.7% DM), dried distillers' grains and solubles (31.8% DM), and a vitamin/mineral premix that contained lasalocid. Hay was chopped and concentrates were ground to purposely create a "hot" ration to challenge the lambs. Feed costs were approximately $340/tonne for grain and $220/tonne for hay.

Table 1. Chemical composition of feeds used in the trial on a dry matter basis.

	Dietary Treatments					
	100F:0C n=6	80F:20C n=5	60F:40C n=8	40F:60C n=8	20F:80C n=8	0F:100C n=8
Chemical Composition						
DM, %	88.98	88.47	87.96	87.45	86.94	86.43
CP, %	13.22	13.47	13.72	13.98	14.23	14.48
ADF, % DM	37.41	31.44	25.48	19.51	13.54	7.58
NDF, % DM	55.68	48.77	41.85	34.94	28.03	21.11
NEm, % DM	1.30	1.53	1.76	1.98	2.21	2.44
Ash, % DM	9.01	8.21	7.41	6.60	5.82	5.03
NFC, % DM	25.31	32.16	39.00	45.85	52.70	59.55
Fat, % DM	1.62	2.23	2.84	3.45	4.06	4.66
peNDF, % DM	47.81	40.50	33.20	25.90	18.60	11.30
Mean particle size (mm)	5.33	4.67	4.01	3.35	2.69	2.03

CALAN gate feeders were used so each lamb could only eat its assigned diet. Each lamb was fitted with a CALAN lock collar to allow the lamb access to its individual feeder and had at least one week prior to the

commencement of each trial to adapt to the feeders and environment. Each morning, refusals from the previous day were collected and weighed before the daily feeding. Lambs were fed once a day.

Lambs were orally administered a rumen data logger on the 1st and 35th day of the trial in order record rumen pH every five minutes. They were administered using a bolus gun to guide the logger to the back of the lamb's throat to be swallowed. Data loggers allowed us to determine whether acidosis was a problem with certain diets.

Figure 1. Image of a data logger that was used in the trial.

Lambs were weighed weekly. The feeding trial lasted for 70 days and then lambs were slaughtered at an inspected slaughter plant. Loggers were removed from the reticulum or rumen at the time of slaughter with the location noted.

A small tissue sample was collected from the rumen to see microscopic tissue damage. Damage could mean that bacteria from the rumen was able to get into the bloodstream and other body systems. Rumen tissue is five layers thick. The layers, in a descending fashion, are called the stratum corneum, granulosum, spinosum and basale. The final layer, the lamina propria, is the layer with blood vessels that transports volatile fatty acids to the rest of the body via the liver. Figure 2 illustrates this. The rumen wall was assigned a lesion score and health score. Lesion and health scores both ranged from 1 to 3, with 1 being healthy and 3 being very damaged. Figure 3 shows the scoring system used for rumen health scores. Finally, we looked at rumen papillae to see the amount of sloughing that occurred (Figure 4).

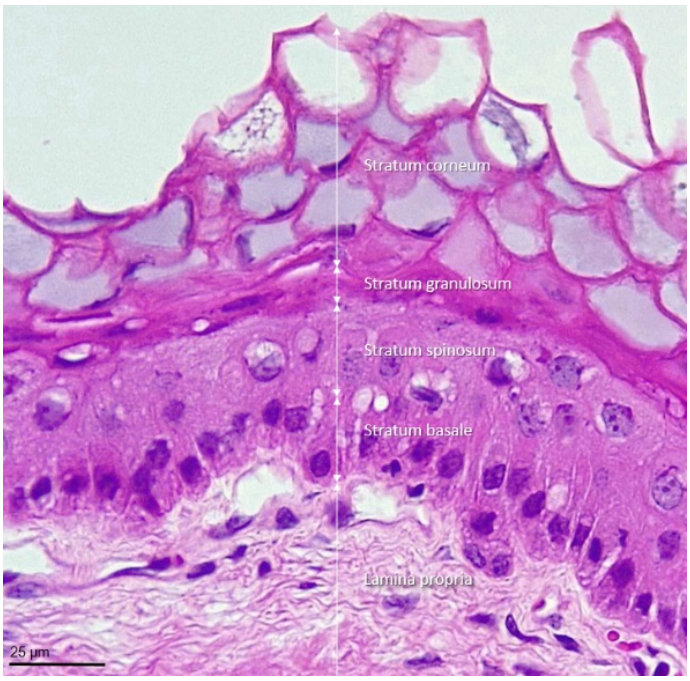

Figure 2. A cross-section of the different layers of the rumen epithelium. This image was taken at 40x magnification. The black line represents 25 micrometres.

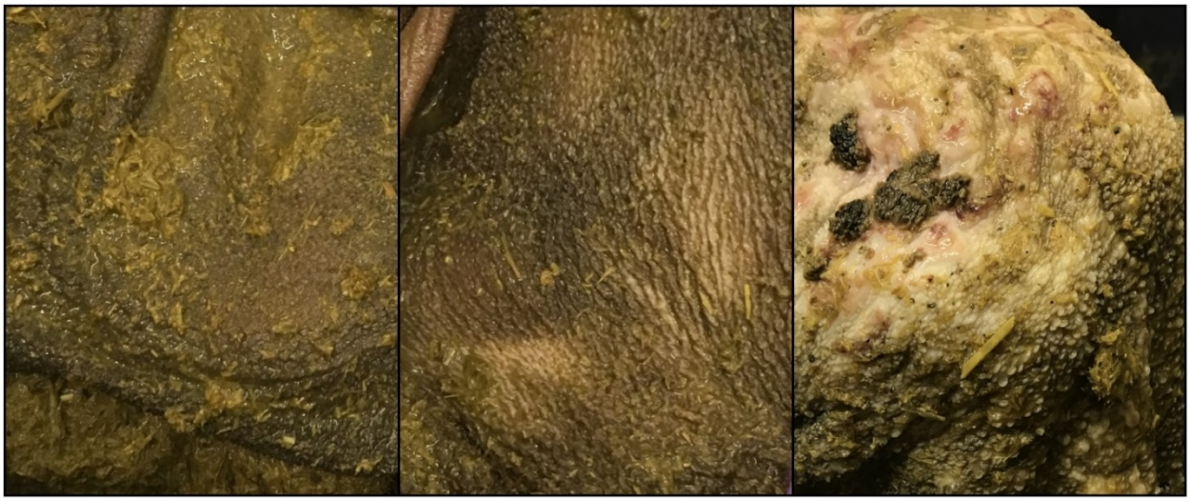

Figure 3. These images are taken of the interior rumen wall and show rumen health scores of 1-3 from left to right. Lightening of the wall means more damage has occurred.

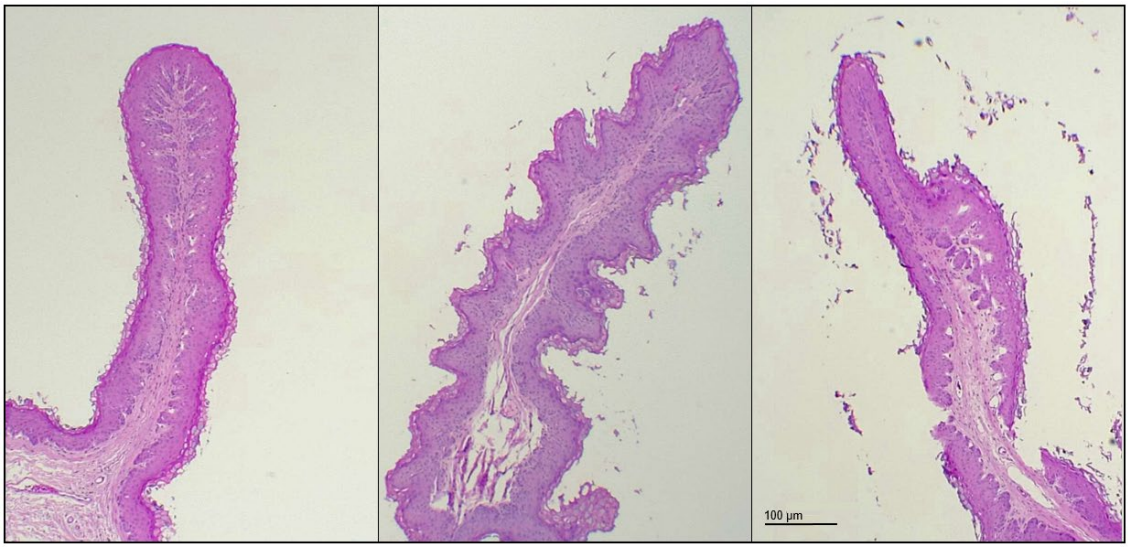

Figure 4. These images show slough scores of 1, 3, and 5 from left to right. Increasing damage is obvious as tissue separates from the papilla. These images were captures at 10x magnification; the black line represents 100 micrometres.

Production results

As Table 1 shows, the weight gained by the lambs was not different across diets once you start offering less than 60% hay (or, in other words, more than 40% grain). There isn't much of a benefit to feeding lambs more than 40% grain because any differences in gain is so small, it's probably not worth it. The feed:gain ratio across all diets wasn't significant by statistical standards, but it does look like there is a tendency for sheep to be more efficient at converting feed once you start offering them grain. Feed intake was also significantly affected by the different diet treatments, but only diets with 100% hay and 60% hay were different from each other.

Table 1. Lamb performance and feed cost (hay/grain)[1]

	100H/0G	80H/20G	60H/40G	40H/60G	20H/80G	0H/100G
Initial bodyweight, kg	29.5^{a}	31.4^{a}	31.3^{a}	30.6^{a}	29.8^{a}	29.1^{a}
Final bodyweight, kg	32^{a}	44.6^{ab}	49.8^{b}	47.4^{b}	45.9^{b}	48.0^{b}
Total weight gain, kg	2.5^{a}	13.2^{ab}	18.6^{b}	16.8^{b}	16.1^{b}	18.9^{b}
Average daily feed intake, kg	0.86^{a}	1.21^{ab}	1.44^{b}	1.34^{ab}	1.14^{ab}	1.18^{ab}
Average daily gain, kg	0.04^{a}	0.19^{ab}	0.27^{b}	0.24^{b}	0.23^{b}	0.27^{b}
Feed:gain, kg	15:1^{a}	8:1^{a}	6:1^{a}	6:1^{a}	6:1^{a}	5:1^{a}
Feed cost per kg of gain	$3.30	$1.95	$1.61	$1.75	$1.90	$1.70

[1]Averages with different superscripts are significantly different from each other.

Acidosis results

Rumen pH was measured through probes we inserted in the sheep's rumen during the finishing period. The ideal rumen pH is between 6.0 and 7.0. Based on the most widely reported values in the current literature, subacute ruminal acidosis (SARA) was reported as a pH between 5.5 and 5.0, and acute

ruminal acidosis (ARA) as being a pH under 5.0. There are often no outward symptoms of SARA but it can be detected through a decrease in production over time. When acute acidosis happens, sheep can get into a downward spiral and have difficulty recovering from it. If the pH is so low, bacteria in the rumen are killed off and feed can't be digested. In extreme cases, death can occur.

Two periods of data collection were used rather than one continuous period. The first sampling period occurred during the dietary transition period (Days 1-14) and the second sampling period occurred when the lambs had adapted to their test diets (Days 35-49).

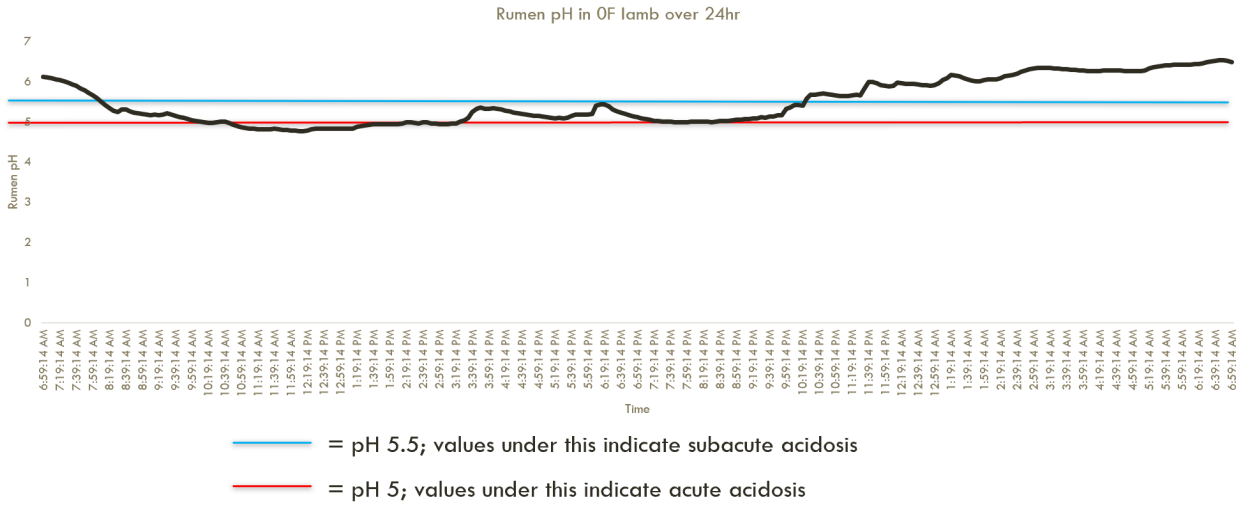

Figure 5. This chart shows a sample of the rumen pH of a lamb receiving a 100% grain diet over a 24hr period.

We used some coding to quantify the data we got from our rumen probes. We measured the extent of SARA and ARA a couple different ways; "Hours in SARA/ARA" means the average number of hours during a 24-hour period that that animal was experiencing SARA or ARA. "Area under the curve" will be best explained by looking at Figure 5. The total area that is under the red or blue lines represents what these numbers mean. The higher the number, the more extreme the acidosis event was.

We can see from Table 2 that the time in both ARA and SARA only significantly increases when animals get less than 40% hay during the finishing period. The sheep didn't have much trouble with acidosis during the transition period (Table 3).

Table 2. Ruminal pH during the finishing period[1]

	100H/0G	80H/20G	60H/40G	40H/60G	20H/80G	0H/100G
Minimum pH	6.2^{a}	5.8^{ab}	5.4^{bc}	5.2^{bc}	4.8^{cd}	4.5^{d}
Maximum pH	7.3^{a}	7.4^{a}	7.0^{a}	7.2^{a}	7.2^{a}	7.2^{a}
Average pH	6.8^{a}	6.6^{a}	6.2^{abc}	6.3^{ab}	5.8^{bc}	5.6^{c}
Hours in SARA[2]	0^{a}	0.5^{a}	1.7^{a}	2.4^{a}	6.4^{b}	9.9^{b}
Hours in ARA[3]	0^{a}	0^{a}	0^{a}	0.4^{a}	4.6^{b}	5.7^{b}
Total time in RA	0^{a}	0.5^{a}	1.7^{a}	2.8^{a}	11.0^{b}	15.6^{b}
AUC for SARA[4]	0	639.9	2161.4	9370.8	29211.0	39048.0
AUC for ARA	0	0	0	657.8	7165.2	17011.0
Total AUC	0	639.0	2161.4	10028.6	36376.2	56050.0

[1]Averages with different superscripts are significantly different from each other.
[2] SARA = subacute ruminal acidosis
[3] ARA = acute ruminal acidosis
[4] AUC = area under the curve

Table 3. Ruminal pH during the transition period[1]

	100H/0G	80H/20G	60H/40G	40H/60G	20H/80G	0H/100G
Minimum pH	6.0[a]	5.7[ab]	5.5[ab]	5.5[ab]	5.2[b]	5.4[a]
Maximum pH	7.3	7.3	7.2	7.4	7.4	7.2
Average pH	6.7	6.5	6.4	6.5	6.4	6.3
Hours in SARA[2]	0	0	0.5	1.0	1.4	5.3
Hours in ARA[3]	0	0	0	0	3.6	1.2
Total time in RA	0	0	0.5	1.0	4.9	6.5
AUC for SARA[4]	0	0	303.4	1825.7	1811.8	8541.3
AUC for ARA	0	0	0	0	3049.1	996.7
Total AUC	0	0	303.4	1825.7	4860.9	9538.0

[1]Only minimum pH values were significant; only this significance is reported through superscripts.
[2] SARA = subacute ruminal acidosis
[3] ARA = acute ruminal acidosis
[4] AUC = area under the curve

Epithelium health results

There didn't seem to be any effect of diet treatment on the health of the rumen epithelium. The layers of the papillae were measured individually but there was no effect on the thickness of the corneum, granulosum, spinosum or basale layers. This was an unexpected finding because there are reported cases of high-grain diets causing thickening of the corneum layer compared to control diets. This can reduce absorption of VFAs which could depress growth potential in lambs. We aren't exactly sure why there was no difference across our diets. Table 4 shows the findings of the rumen health portion of this trial.

Table 4. Rumen health measures during the finishing period.[1]

	100H/0G	80H/20G	60H/40G	40H/60G	20H/80G	0H/100G
Corneum thickness	20.3[a]	22.5[a]	34.1[a]	33.9[a]	32.8[a]	30.9[a]
Granulosum thickness	7.4[a]	8.8[a]	9.4[a]	11.6[a]	8.3[a]	7.7[a]
Spinosum thickness	37.2[a]	39.5[a]	35.2[a]	42.8[a]	33.6[a]	34.0[a]
Basale thickness	47.0[a]	43.2[a]	53.9[a]	54.3[a]	45.6[a]	49.5[a]
Total epithelium thickness	111.9[a]	114.3[a]	132.6[a]	142.6[a]	120.3[a]	122.1[a]
Slough score	1.6	2.0	1.6	1.5	1.8	1.6
Rumen health score	1.3	1.1	1.3	1.6	1.4	1.1

[1]Averages with different superscripts are significantly different from each other.

Summary

Sheep have similar growth rates when they are getting between 40% and 100% grain. However, once you start feeding somewhere between 60% and 80% grain, sheep become significantly more likely to experience acidosis. Based on the way the feeding trial was set up, we don't know exactly what point

this is. There didn't seem to be any sort of pattern associated with diet and rumen health, however. To maximize growth rates while minimizing the risk of acidosis, a good general amount of hay to provide your finishing lambs with is between 40% to 60% of the diet. A little less than this is probably fine.

Determining the most cost-efficient system is a moving target that depends on the current prices for concentrates and hay. There really isn't much benefit to feeding more than 40% grain to your sheep if if current feed costs don't make sense to. You might get a little extra gain, but it's not going to be significant. It also dramatically increases the risk of your sheep getting acidosis. While you might not see a reduction in production from acidosis, it is certainly a welfare and health concern that might be making your flock more vulnerable. To determine exactly what ratio to use for your own flock, take current feed prices into account.

For our trial, the most profitable diet across the board was 60% hay and 40% grain, with a price per kilo of gain of $1.61. The next least expensive diet was 100% grain at $1.70 per kilo of gain; a nine cent price difference. It cost an average of $29.94 to raise 60H/40G lambs and $32.13 to raise 0H/100G lambs for the 70-day duration of our study, which amounts to a difference of $2.20 savings. If you market 1000 lambs a year, that results in *at least* $2200 in savings compared to the next most profitable diet (and likely more because stock are at a much lower risk of acidosis).

For replacement ewe lambs, the ideal growth rate is much slower to favour frame development. Too much fat deposition also decreases the potential of lifetime milk production.

Appendix

	Dietary Treatments												
	100F:0G n=6		80F:20G n=5		60F:40G n=8		40F:60G n=8		20F:80G n=8		0F:100G n=8		*P* value
Variable	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	
Initial BW, kg	29.5	1.46	31.4	1.6	31.3	1.26	30.6	1.26	29.8	1.26	29.1	1.26	0.7721
Final BW, kg	32	3.1	44.6	3.4	49.8	2.7	47.4	2.7	45.9	2.7	48	2.7	0.0023
Total Gain, kg	2.5	2.5	13.2	2.7	18.6	2.1	16.8	2.1	16.1	2.1	18.9	2.1	0.0002
BW change, %	8.1	8.1	41.4	8.9	59.3	7.1	55.6	7.1	54.4	7.1	66.3	7.1	<0.0001
ADG, kg	0.04	0.04	0.19	0.04	0.27	0.03	0.24	0.03	0.23	0.03	0.27	0.03	0.0002
ADI, kg	0.86	0.12	1.21	0.13	1.44	0.11	1.34	0.11	1.14	0.11	1.18	0.11	0.0234
Total Intake, kg	60.1	8.6	85	9.4	101	7.5	94	7.5	80	7.5	82.9	7.5	0.0234
Feed:gain, kg	14.8:1	2.5	7.8:1	2.8	5.5:1	2.2	6.3:1	2.2	6.0:1	2.2	4.5:1	2.2	0.0615

Table 1. Dietary treatment effect on lamb performance.

	Dietary Treatments												
	100F:0C n=6		80F:20C n=5		60F:40C n=8		40F:60C n=8		20F:80C n=8		0F:100 n=8		P value
Variable	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	
Minimum pH	5.98	0.16	5.71	0.20	5.54	0.20	5.50	0.18	5.16	0.18	5.25	0.18	0.03
Maximum pH	7.30	0.10	7.30	0.12	7.22	0.12	7.43	0.11	7.37	0.11	7.21	0.11	0.71
Mean pH	6.66	0.076	6.54	0.009	6.40	0.009	6.48	0.083	6.41	0.083	6.31	0.083	0.07
Subacute RA													
Duration, h/d	0.0	0.0	0.0	0.0	0.47	1.42	0.99	1.27	1.36	1.27	5.29	1.27	0.07
Area, pH*min	0.0	0.0	0.0	0.0	303.37	2875.90	1825.65	2572.28	1811.76	2572.28	8541.32	2572.28	0.16
Acute RA													
Duration, h/d	0.0	0.94	0.0	1.15	0.0	1.15	0.0	1.03	3.57	1.03	1.19	1.03	0.13
Area, pH*min	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3049.09	1497.86	996.69	1497.86	0.36
Total RA													
Duration, h/d	0.0	0.0	0.0	0.0	0.47	2.37	0.99	2.11	4.92	2.11	6.49	2.11	0.18
Area, pH*min	0.0	0.0	0.0	0.0	303.37	3633.90	1825.65	3250.26	4860.85	3250.26	9538.01	3250.26	0.26

Table 2. Dietary treatment effect on ruminal pH during the transition period.

	Dietary Treatments												
	100F:0C n=6		80F:20C n=5		60F:40C n=8		40F:60C n=8		20F:80C n=8		0F:100C n=8		P value
Variable	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	
Minimum pH	6.21	0.17	5.76	0.19	5.38	0.19	5.20	0.16	4.76	0.16	4.45	0.16	<0.01
Maximum pH	7.34	0.18	7.39	0.20	7.01	0.20	7.19	0.17	7.24	0.17	7.13	0.17	0.78
Mean pH	6.77	0.15	6.60	0.17	6.25	0.17	6.28	0.14	5.83	0.14	5.59	0.14	<0.01
Subacute RA													
Duration, h/d	0.0	0.0	0.49	1.09	1.68	1.08	2.44	0.92	6.43	0.92	9.92	0.92	<0.01
Area, pH*min	0.0	0.0	639.90	2279.78	2161.39	2279.78	9370.77	2279.78	29211.0	2279.78	39048.0	2279.78	<0.01
Acute RA													
Duration, h/d	0.0	0.0	0.0	0.0	0.0	0.0	0.36	1.16	4.60	1.16	5.70	1.16	0.01
Area, pH*min	0.0	0.0	0.0	0.0	0.0	0.0	657.83	2680.46	7165.15	2680.46	17011.0	2680.46	<0.01
Total RA													
Duration, h/d	0.0	0.0	0.49	1.79	1.68	1.79	2.80	1.51	11.03	1.51	15.62	1.51	<0.01
Area, pH*min	0.0	0.0	639.90	3306.22	2161.39	3306.22	10028.6	3306.22	36376.2	3306.22	56060.0	3306.22	<0.01

Table 3. Dietary treatment effect on ruminal pH during the finishing period.

	Dietary Treatments												
	100F:0C		80F:20C		60F:40C		40F:60C		20F:80C		0F:100C		P value
	n=6		n=5		n=8		n=8		n=8		n=8		
Variable	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	
Stratum corneum	20.3	5.07	22.5	5.56	34.1	4.39	33.9	4.39	32.81	4.39	30.9	4.39	0.21
Stratum granulosum	7.41	2.45	8.85	2.68	9.35	2.12	11.59	2.12	8.27	2.12	7.75	2.12	0.79
Stratum spinosum	37.2	7.04	39.5	7.72	35.23	6.10	42.8	6.10	33.6	6.10	34.02	6.10	0.89
Stratum basale	47.0	3.07	43.2	3.37	53.9	2.66	54.3	2.66	45.6	2.66	49.5	2.66	0.051
Total thickness	111.5	7.17	117.4	7.66	127.8	8.28	134.3	7.66	133.6	7.66	128.7	7.17	0.21
Mean slough score	1.6		2.0		1.6		1.5		1.8		1.6		
Mean rumen score	1.3		1.1		1.3		1.6		1.4		1.1		

Table 4. Dietary treatment effect on rumen epithelial health.