Proceedings of the 15th Annual

GREAT LAKES DAIRY SHEEP SYMPOSIUM

November 12 – 14, 2009
Albany, New York, USA
Proceedings of the 15th Annual

GREAT LAKES DAIRY SHEEP
SYMPOSIUM

November 12 – 14, 2009

Albany Marriott
Albany, New York, USA

Organized by:
Dairy Sheep Association of North America, 1675 Observatory Dr.,
Madison, Wisconsin 53706, USA (http://www.dsana.org/)

Assisted by:
Cornell University, College of Agriculture and Life Sciences, Department of
Animal Science, (http://www.ansci.cornell.edu/ansci) and Cooperative
Extension (http://www.ansci.cornell.edu/sheep/index.html) Ithaca, New York,
USA
University of Wisconsin-Madison, College of Agricultural and Life Sciences,
Department of Animal Sciences, Madison, Wisconsin, USA
(http://www.ansci.wisc.edu/)
University of Wisconsin-Extension, Cooperative Extension, Madison, Wisconsin,
USA (http://www.uwex.edu/ces/animalscience/sheep/)
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Terri MacKenzie, Fort Plain, New York, USA
David Thomas, Madison, Wisconsin, USA
Michael Thonney, Ithaca, New York, USA

Proceedings Edited and Compiled by:

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Clockwise from top right:

Dairy ewes with lambs, Garden Variety Cheese, Royal Oaks, California, USA
– photo provided by Rebecca King

East Friesian dairy ewe, Hidden Springs Farm, Westby, Wisconsin, USA
– photo provided by Brenda Jensen

Milking dairy ewes, Green Dirt Farm, Weston, Missouri, USA
– photo provided by Sarah Hoffmann

Processing sheep milk, Old Chatham Shepherding Company, Old Chatham, New
York, USA
– photo provided by Nancy Clark

Curing of farmstead sheep milk cheeses, Garden Variety Cheese, Royal Oaks,
California, USA
– photo provided by Rebecca King
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Program of Events

Thursday, November 12, 2009

8:30 a.m. Registration, Albany Marriott, Albany, New York, USA

9:15 a.m. Welcome, Claire Mikolayunas, President, Dairy Sheep Association of North America, Madison, Wisconsin, USA

9:30 a.m. Getting Started in Sheep Dairying
Rebecca King, Dairy Sheep Producer and Farmstead Cheesemaker, Royal Oaks, California, USA

10:15 a.m. Farmer Grant Opportunities
Carol L. Delaney, Northeast Sustainable Agriculture Research and Education, University of Vermont, Burlington, Vermont, USA
Perry Ells, Dairy Sheep Producer, Ellsfarm, Union, Maine, USA

11:00 a.m. Cheesemaking with Sheep Milk
Dr. Stephanie Clark, Department of Food Science and Human Nutrition, Iowa State University, Ames, Iowa, USA

Noon Lunch

1:00 p.m. Cheese Plant Design
Jim McFadden, Dairy Incubator, Morrisville State College, State University of New York, Morrisville, New York, USA

1:45 p.m. Experience with Plant Design – Artisan Cheesemaker Panel
Sarah Hoffmann, Dairy Sheep Producer and Cheesemaker, Green Dirt Farm, Weston, Missouri, USA
Brenda Jensen, Dairy Sheep Producer and Cheesemaker, Hidden Springs Creamery, Westby, Wisconsin, USA
Nancy Clark, Dairy Sheep Producer and Cheesemaker, Old Chatham Shepherding Company, Old Chatham, New York, USA

2:45 p.m. Visit Sponsors and Break

3:15 p.m. Intake on Pasture I
Dr. Darrell Emmick, State Grazing Land Management Specialist, USDA-NRCS (Natural Resources Conservation Service), Cortland, NY, USA

4:00 p.m. Protein Utilization in Lactating Dairy Ewes
Claire Mikolayunas, Graduate Research Assistant, Department of Animal Sciences, University of Wisconsin-Madison, Madison, Wisconsin, USA

4:45 p.m. General Annual Meeting – Dairy Sheep Association of North America

5:45 p.m. Sheep Milk Cheese Reception
Program of Events (cont.)

Friday, November 13, 2009
8:30 a.m.  Prepubertal Lamb Nutrition
Dr. David L. Thomas, Department of Animal Sciences, University of Wisconsin-Madison, Madison, Wisconsin, USA

9:00 a.m.  Genetic Markers for Milk Production
Dr. Raluca G. Mateescu, Department of Animal Science, Oklahoma State University, Stillwater, Oklahoma, USA

10:00 a.m.  Visit Sponsors and Break

10:30 a.m.  Intake on Pasture I
Dr. Darrell Emmick, State Grazing Land Management Specialist, USDA-NRCS (Natural Resources Conservation Service), Cortland, NY, USA

11:15 a.m.  Hormonal Control of Ewe Reproduction
Dr. E. Keith Inskeep, Division of Animal and Veterinary Sciences, West Virginia University, Morgantown, West Virginia, USA

12:15 p.m.  Lunch

1:15 p.m.  Fermentable Fiber and Dairy Sheep Nutrition
Dr. Douglas E. Hogue, Department of Animal Science, Cornell University, Ithaca, New York, USA

2:15 p.m.  Insights into Dairy Sheep Production in Sardinia, Italy
Carol L. Delaney, Northeast Sustainable Agriculture Research and Education, University of Vermont, Burlington, Vermont, USA

3:15 p.m.  Visit Sponsors and Break

3:30 p.m.  Economic Evaluation of Sheep Milk Production
Yves M. Berger, Spooner Agricultural Research Station, University of Wisconsin-Madison, Spooner, Wisconsin, USA

4:15 p.m.  Updates from the Interstate Milk Shipments Conference
J. Thomas Clark, Dairy Sheep Producer and Sheep Milk Processor, Old Chatham Shepherding Company, Old Chatham, New York, USA

7:00 p.m.  Banquet – Pre-registration required

Saturday, November 14, 2009
8:15 a.m.  Board Buses for Farm Tours, Albany Marriott
Ovinshire Farm, Fort Plain, NY – Scott Burrington and Dr. Terri MacKenzie
Old Chatham Shepherding Company, Old Chatham, NY – Tom and Nancy Clark

4:00 p.m.  Buses return to Albany Marriott and symposium concludes
Speakers and Farm Tour Hosts

Yves M. Berger, Sheep Researcher, Spooner Agricultural Research Station, University of Wisconsin-Madison, Spooner, Wisconsin

Scott Burrington, Dairy Sheep Producer, Ovinshire Farm, Fort Plain, New York

J. Thomas Clark, Dairy Sheep Producer and Sheep Milk Processor, Old Chatham Sheepherding Company, Old Chatham, New York

Nancy Clark, Dairy Sheep Producer and Cheesemaker, Old Chatham Sheepherding Company, Old Chatham, New York

Dr. Stephanie Clark, Associate Professor, Department of Food Science and Human Nutrition, Iowa State University, Ames, Iowa

Carol L. Delaney, Farmer Grant Specialist, Northeast Sustainable Agriculture Research and Education, University of Vermont, Burlington, Vermont

Perry Ells, Dairy Sheep Producer, Ellsfarm, Union, Maine

Dr. Darrell Emmick, State Grazing Land Management Specialist, USDA-NRCS (Natural Resources Conservation Service), Cortland, New York

Sarah Hoffmann, Dairy Sheep Producer and Cheesemaker, Green Dirt Farm, Weston, Missouri

Dr. Douglas E. Hogue, Professor Emeritus, Department of Animal Science, Cornell University, Ithaca, New York

Dr. E. Keith Inskeep, Professor, Division of Animal and Veterinary Sciences, West Virginia University, Morgantown, West Virginia

Brenda Jensen, Dairy Sheep Producer and Cheesemaker, Hidden Springs Creamery, Westby, Wisconsin

Rebecca King, Dairy Sheep Producer and Cheesemaker, Garden Variety Cheese, Royal Oaks, California

Dr. Terri MacKenzie, Veterinarian and Dairy Sheep Producer, Ovinshire Farm, Fort Plain, New York

Dr. Raluca G. Mateescu, Assistant Professor, Department of Animal Science, Oklahoma State University, Stillwater, Oklahoma

Jim McFadden, Facilities Director, Dairy Incubator, Morrisville State College, State University of New York, Morrisville, New York

Claire Mikolayunas, President, Dairy Sheep Association of North America and Director, Dairy Sheep Initiative, Dairy Business Innovation Center, Madison, Wisconsin

Dr. David L. Thomas, Professor, Department of Animal Sciences, University of Wisconsin-Madison, Madison, Wisconsin
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**Old Chatham Sheepherding Company**, 155 Shaker Museum Road, Old Chatham, NY 12136, USA; [http://www.blacksheepcheese.com/](http://www.blacksheepcheese.com/)

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Sydell, Inc., 46935 SD Hwy. 50, Burbank, SD 57010, USA; http://www.sydell.com

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Please support these sponsors as you purchase equipment, supplies, and services for your dairy sheep farm or sheep milk processing facility.
GETTING STARTED IN SHEEP DAIRYING

Rebecca King
Garden Variety Cheese
Royal Oaks, California, USA

Planning

Beginning a new enterprise, whether it be a dairy sheep operation or any other type of business, requires a significant amount of planning and research to be successful. Because sheep dairying is still rather uncommon in this country and there is a limited amount of available reference material, it is particularly challenging to develop a working plan and make projections about a new operation. I have spent the past three years researching, planning and then starting a small-scale farmstead sheep cheese business on the Central Coast of California. While any particular farm or enterprise is going to be unique and have its own set of circumstances and parameters, there is a basic set of questions to be answered and decisions to be made that are common to every sheep dairy. This process is basically just the development of a business plan which you can use to guide the creation of your operation. What follows is a description of the points to be considered and some of the information necessary to make key decisions.

Overview

The first decision to make about your operation is what type of business you plan to develop. Look at the marketing opportunities in your area, the relative costs of farmland and operating expenses such as labor, utilities, and feed. What resources do you already have that can be utilized in a sheep dairy enterprise? While the possibilities for sheep dairying are quite wide open and unexplored, there are a few distinct strategies that have been successfully employed by existing operations, varying by their particular circumstances.

Farmstead Cheese. For a sheep dairy located near a major urban market, with relatively high costs of operation, there is more incentive to develop a smaller operation based on value-added products and direct marketing. This type of farm would be milking around 100 ewes or less, most likely using a bucket-milker and specialty small-scale processing equipment. The product needs to be unique and of high quality to be marketed to upscale restaurants, specialty stores and farmers markets.

Processing Co-op. Another option for a small to mid-sized sheep dairy is to join a co-op of other similar sized operations to pool milk for processing into fresh and aged cheeses, yogurt, ice cream and other products. The co-op would then be responsible for the development of products and marketing. This type of operation needs to be located reasonably near to other sheep dairies in an area with access to specialty markets and consumers. A mid-sized sheep dairy would be milking around 100 to 500 sheep, 12 to 24 at a time, in a pit-style dairy with a low-line or high-line.

Bulk Milk. The largest type of sheep dairy is usually focused entirely on the production of fluid milk which is sold in bulk to processors. The milk can also be frozen prior to sale which
means this type of enterprise does not need to be located near a potential market. While the return on milk is much lower than on cheese and specialty products, the larger producer can take advantage of economies of scale and the lower operation costs associated with rural areas. The largest sheep dairies milk 500 to 1000s of sheep, 24 to 48 or more at a time, with automated milking systems that allow two or three workers to milk hundreds of ewes an hour.

**Farmland, Feed and Flock**

**Farmland.** What type of sheep dairying operation you develop will be in large part determined by your farm property. Whether you have an existing farm or are looking to rent or purchase property to start a sheep dairy, there are many points to take into account. Location, as described above, is very important in shaping expenses and marketing options. Land for pasture or hay, ability to irrigate and access to other feed sources also need to be considered. Existing buildings that can be remodeled for use as a milking parlor or processing facility can also be useful assets.

**Feed.** High quality feed is of utmost importance to a dairy sheep operation. Dairy sheep are producing much more milk than a typical meat flock and their nutritional needs are therefore much higher. Because of the limited volume of their gut, dairy ewes must be given feed of high nutritional value, not just higher quantities of low value feed, if they are expected to produce well. Quality and flavor in sheep milk cheese and other products is also closely related to the feed that the ewes are consuming. A well-managed pasture, with a grain supplement in the milking parlor, is the basis for many high quality dairy products. There are however, many other feed options to be considered based upon availability, cost and nutritional value. By-products of other agricultural and food processing operations can provide valuable supplements at a low cost. Access to hay, silage or other stored feedstuff is an important consideration for those times of the year when fresh pasture may not be available.

**Flock.** Breed of sheep can play an important role in any sheep dairy, in terms of quantity, quality, seasonality, and length of milk production. The value of additional farm products such as meat lamb and wool can also vary depending on the breed of the flock. Any breed of sheep potentially can be milked. The yields of non-dairy breeds on average do not reach the levels of the typical dairy sheep, but the percentage of milk solids, which is important in cheese production, tends to be higher. Many producers with existing meat or wool flocks may choose to introduce a dairy breed ram to their non-dairy ewes to develop a milking flock. In regions, such as the Southeast, with high parasite pressure or other intense environmental stress, it may be advantageous to crossbreed a locally adapted flock with a ram from a dairy bloodline.

The two sheep dairy breeds that are readily available in the U.S. are the East Friesian and the Lacaune. The East Friesian is commonly milked in this country because it produces a high volume of milk over a long (220 to 240 days) lactation, with a high prolificacy. The drawback of the East Friesian is that purebreds have a reputation for being susceptible to pneumonia and have a reduced lamb survival rate. The Lacaune breed was introduced to the U.S. from the Roquefort producing region of France in 1998 by Spooner Agricultural Research Station. The Lacaune breed has been systematically improved by the French to produce a high volume of milk with a high percentage of solids and to be adapted to the modern milking parlor, as well as to be an
overall healthy animal. Because of this it is a highly desirable breed for the establishment of any sheep dairy.

Facilities and Equipment

Whether your facility will be handling fresh cheeses or yogurt versus aged raw cheeses and milk destined for processing will determine whether your dairy needs to meet Grade A or Grade B standards. This can have a significant impact on the design of your facility as Grade B dairies may use wood in the milking parlor and do not need a pasteurizer, for example. All Grade A dairies in the U.S. are subject to the PMO, or Pasteurized Milk Ordinance, which is put out by the Food and Drug Administration. Each state has its own individual regulations regarding milk and dairy production, and both the federal and state regulations are enforced at the state level. Some cities or counties may also have additional regulations for milk products. Before purchasing any equipment or beginning any work on a dairy facility it is very important to contact your state dairy inspection office and review the design of your dairy with them. You should also carefully review the state and federal regulations for dairy production so you are aware which stipulations your inspector makes are actual legal requirements and which are his personal interpretations of the law.

The scale of the milking operation on a dairy sheep farm is going to have a significant influence on the design of the milking and processing facilities. A larger-scale operation will often custom build a milking parlor to meet their needs and work with a dairy equipment manufacturer on design and construction. Small sheep dairies are more likely to adapt their milking system to what buildings and facilities are pre-existing on-site and to what equipment they are able to locate. Cow and goat-milking equipment can be converted to use in sheep dairying, but sheep-specific equipment can be hard to find and expensive. Most dairy equipment manufacturers and consultants are also not well-informed about the development of very small farmstead operations. The dairy sheep farmer with mechanical skills such as welding, plumbing and fabrication will be at a distinct advantage when it comes to building a dairy. However, with work, a functional small-scale sheep dairy can be built to fit any operation.

Much of the new equipment available for small dairies and creameries is imported from Europe, made by specialty purveyors, or custom built. This means that it is often relatively expensive. This also means that you will rarely be purchasing a whole, integrated system from one source, but rather piecing together equipment from various vendors. Some of the problems that can arise are that different components are not pre-designed to work together, equipment does not come with instructions or specifications, and parts need to be special ordered or fabricated. Your local dairy inspector may also want to inspect each piece of equipment before it is purchased or installed. Used equipment appropriate for a small-scale operation can also be found through food processing and brewery suppliers. While some of the equipment, such as clamps and heat-exchangers, are interchangeable between dairy and other processing applications, others may need to be adapted to function in dairy processing. This is also a case where you dairy inspector may have significant input.

When researching dairy equipment it is important not to be afraid of asking stupid questions, and to try to get as much information about the equipment and how it works as possible. [i.e.
What type of electricity does it need? What size and type are the inlets and outlets and what type of hosing, clamps, etc. does it connect to? Does it come with its own motor, compressor, heater, etc., or do I need to supply this separately?] This may help you to identify potential problems or challenges before you have equipment in hand and are trying to connect part A with part B.

<table>
<thead>
<tr>
<th>Table 1. Recommended Milking Settings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height of Milking Platform</td>
</tr>
<tr>
<td>Pulsation Rate</td>
</tr>
<tr>
<td>Pulsation Ratio</td>
</tr>
<tr>
<td>Vacuum Level</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 2. Useful Estimates for Calculating Equipment Needs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daily Yield of Milk per Ewe</td>
</tr>
<tr>
<td>Length of Lactation</td>
</tr>
<tr>
<td>Cheese Conversion Yield</td>
</tr>
<tr>
<td>Aging Room Temperature</td>
</tr>
<tr>
<td>Aging Room Humidity</td>
</tr>
</tbody>
</table>

**Staffing**

Only the very smallest of dairy operations can be run completely by one person, and these are very susceptible to catastrophe if the sole operator is incapacitated for some reason. There are many varied labor demands on a dairy in addition to the animal tending, twice-daily milking, and pasture maintenance. If the dairy is also a farmstead processing facility, there will need to be a cheesemaker or other person responsible for product production, as well as labor for marketing and sales. There is also general farm management and upkeep, equipment maintenance, plus bookkeeping, taxes and office management.

A small-scale farmstead sheep dairy can be well-managed with two or three full-time adults and some part-time help, whether this is all family or some hired workers. It is important for the dairy farmer to recognize that they most likely cannot do every task on the farm themselves and that it is often a better use of time and resources to pay someone else to do some of the work. The farmer needs to decide what realm of the operation they are most crucial to and focus their efforts there, while delegating some of the simpler labor tasks. In some operations, the owner/farmer may choose to prioritize pasture management and animal tending and hire a cheesemaker to oversee the production phase of the business. Others may concentrate on the creamery and on marketing value-added products, hiring lesser-skilled labor to handle the daily milking and feeding chores. Regardless of what role the owner may play in the daily operation, it is important that they determine that position early on in the planning process and make allowances for finding individuals to be responsible for the other aspects of the farm. The need for skilled, experienced workers such as cheesemakers must be considered when making budgets and marketing plans.
Budgeting

Making a budget with projections for initial start-up expenditures, as well as annual operating costs and estimated income, is likely the most crucial step in planning a new business enterprise like a sheep dairy operation. Because of the scarcity of sheep dairies in the U.S. and of data compiled on them it can be very difficult to make estimates of the costs to start and run a sheep dairy. The best process is to start with a rough budget outline, and refine it as your business plan takes shape and you have access to more accurate calculations. I have included here my initial start-up costs, annual operating expenses and projected income to provide a starting point for other operators.

Table 3. Initial Fixed Costs for Garden Variety Cheese

<table>
<thead>
<tr>
<th>Category</th>
<th>Item Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Animals</td>
<td>sheep (50 ewes, 2 rams)</td>
<td>$13,000</td>
</tr>
<tr>
<td></td>
<td>dogs and supplies</td>
<td>$1,000</td>
</tr>
<tr>
<td>Sheep Equipment</td>
<td>shed and movable shelter</td>
<td>$9,000</td>
</tr>
<tr>
<td></td>
<td>waterers, feeders</td>
<td>$2,500</td>
</tr>
<tr>
<td></td>
<td>portable electric fencing</td>
<td>$3,500</td>
</tr>
<tr>
<td></td>
<td>handling facilities</td>
<td>$3,000</td>
</tr>
<tr>
<td>Milking Parlor</td>
<td>stanchions, gates, ramps</td>
<td>$6,000</td>
</tr>
<tr>
<td></td>
<td>milking equipment</td>
<td>$3,000</td>
</tr>
<tr>
<td>Cheese Factory</td>
<td>bulk tank</td>
<td>$6,000</td>
</tr>
<tr>
<td></td>
<td>cheese vat</td>
<td>$9,500</td>
</tr>
<tr>
<td></td>
<td>press</td>
<td>$5,000</td>
</tr>
<tr>
<td></td>
<td>sink, tables, water heater etc.</td>
<td>$3,000</td>
</tr>
<tr>
<td></td>
<td>molds/forms, etc.</td>
<td>$2,000</td>
</tr>
<tr>
<td></td>
<td>heat exchanger, pump, tubing</td>
<td>$2,000</td>
</tr>
<tr>
<td>Aging Room</td>
<td>fan/vent etc.</td>
<td>$500</td>
</tr>
<tr>
<td></td>
<td>shelving, etc.</td>
<td>$1,000</td>
</tr>
<tr>
<td>Farmers Market Supplies</td>
<td></td>
<td>$800</td>
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<tr>
<td>F-250 Truck</td>
<td></td>
<td>$8,500</td>
</tr>
<tr>
<td>Livestock Trailer</td>
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<td>$5,800</td>
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<tr>
<td>Tractor &amp; Implements</td>
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<td>$20,000</td>
</tr>
<tr>
<td>Irrigation Equipment</td>
<td></td>
<td>$4,000</td>
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<tr>
<td>Dairy Building Remodel</td>
<td></td>
<td>$85,000</td>
</tr>
<tr>
<td>Cheese Cave Remodel</td>
<td></td>
<td>$5,000</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td>$199,100</td>
</tr>
</tbody>
</table>

Financing

The initial start-up costs for a sheep dairy can be very expensive, as the dairy facility must be completed entirely and the milking flock must be bred and lamb before any product can be produced and sold. As with any new enterprise, it can also take significantly longer to begin production on a commercial scale than planned due to a number of factors. This can greatly increase the expenses incurred prior to receiving any income from the operation. On the bright side, there is a large and growing demand for sheep dairy products and a successful sheep dairy
can see a substantial return on their initial investment. The key is to begin with adequate financing, and personal savings or an outside farm income in the family to cover living expenses while the dairy is in the early stages. Farm start-up loans are available through ag lenders, Farm Services Agency and some non-profits. Some funding for livestock operations is also available through the Natural Resource Conservation Service EQUIP program, which reimburses farmers for improving pasture and rangeland, reducing erosion and composting manure. The reimbursement rate is higher for new farmers and those using organic practices.

<table>
<thead>
<tr>
<th>Table 4. Projected Annual Expenses for Garden Variety Cheese</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advertising</td>
</tr>
<tr>
<td>Car &amp; Truck</td>
</tr>
<tr>
<td>Computer &amp; Internet</td>
</tr>
<tr>
<td>Custom Hire</td>
</tr>
<tr>
<td>Dogs</td>
</tr>
<tr>
<td>Feed</td>
</tr>
<tr>
<td>Gasoline</td>
</tr>
<tr>
<td>Business &amp; Liability Insurance</td>
</tr>
<tr>
<td>Truck Insurance</td>
</tr>
<tr>
<td>Workers Comp</td>
</tr>
<tr>
<td>Office Supplies</td>
</tr>
<tr>
<td>Repairs &amp; Maintenance</td>
</tr>
<tr>
<td>Small Tools &amp; Equipment</td>
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<tr>
<td>Cheesemaking Supplies</td>
</tr>
<tr>
<td>Pest Control Supplies</td>
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<tr>
<td>Salt</td>
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<tr>
<td>Straw</td>
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<tr>
<td>Other Supplies</td>
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<tr>
<td>Telephone</td>
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<tr>
<td>Garbage</td>
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<tr>
<td>Water</td>
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<tr>
<td>Propane</td>
</tr>
<tr>
<td>Electricity</td>
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<tr>
<td>Veterinary</td>
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<tr>
<td>Loan Payments</td>
</tr>
<tr>
<td>Payroll</td>
</tr>
<tr>
<td>Rent</td>
</tr>
<tr>
<td>TOTAL EXPENSE</td>
</tr>
</tbody>
</table>
Table 5. Projected Income for Garden Variety Cheese

<table>
<thead>
<tr>
<th>PROJECTED INCOME</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
</tr>
</thead>
<tbody>
<tr>
<td># of ewes milked</td>
<td>40</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>lbs of milk per day</td>
<td>2.25</td>
<td>2.75</td>
<td>3</td>
<td>3.25</td>
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<tr>
<td>days of lactation</td>
<td>90</td>
<td>180</td>
<td>180</td>
<td>180</td>
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<tr>
<td>total lbs of milk/lactation</td>
<td>8100</td>
<td>49500</td>
<td>54000</td>
<td>58500</td>
</tr>
<tr>
<td>lbs of cheese/milk</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td>lbs of cheese/yr</td>
<td>1620</td>
<td>9900</td>
<td>10800</td>
<td>11700</td>
</tr>
<tr>
<td>$ per lbs of cheese</td>
<td>$25</td>
<td>$25</td>
<td>$27</td>
<td>$27</td>
</tr>
<tr>
<td>CHEESE INCOME</td>
<td>$40,500</td>
<td>$247,500</td>
<td>$291,600</td>
<td>$315,900</td>
</tr>
<tr>
<td>rent of cheesemaking facility</td>
<td>$5,000</td>
<td>$10,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>cheesemaking (for hire)</td>
<td>$5,000</td>
<td>$6,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CHEESEMAKING INCOME</td>
<td>$10,000</td>
<td>$16,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td># of meat lambs</td>
<td>20</td>
<td>50</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>income/lamb</td>
<td>$300</td>
<td>$300</td>
<td>$300</td>
<td>$300</td>
</tr>
<tr>
<td>MEAT LAMB INCOME</td>
<td>$6,000</td>
<td>$15,000</td>
<td>$15,000</td>
<td>$15,000</td>
</tr>
<tr>
<td># of other lambs</td>
<td>100</td>
<td>130</td>
<td>130</td>
<td>130</td>
</tr>
<tr>
<td>income/lamb</td>
<td>$50</td>
<td>$60</td>
<td>$75</td>
<td>$75</td>
</tr>
<tr>
<td>LIVESTOCK INCOME</td>
<td>$5,000</td>
<td>$7800</td>
<td>$9,750</td>
<td>$9,750</td>
</tr>
<tr>
<td>cull ewes</td>
<td>6</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>income/cull ewe</td>
<td>$300</td>
<td>$300</td>
<td>$300</td>
<td>$300</td>
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<tr>
<td>CULL EWE INCOME</td>
<td>$1,800</td>
<td>$3,000</td>
<td>$3,000</td>
<td>$3,000</td>
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<tr>
<td>TOTAL INCOME</td>
<td>$63,300</td>
<td>$289,300</td>
<td>$319,350</td>
<td>$343,650</td>
</tr>
</tbody>
</table>
Background

Since 1998, the USDA has supported a competitive grant and education program targeting applied on-farm research. The Sustainable Agriculture Research and Education (SARE) program is spread across four regions (Northeast, Southern, North Central, Western) in the country and includes the U.S. Territories of Guam, Northern Mariana Islands, Micronesia-FSM, American Samoa, Puerto Rico and the Virgin Islands. The twenty year summary of all the grants and monies funded to each state and territory may be found at http://www.sare.org/highlights/state_summaries.shtml.

When we take a look at New York state we see that it has received over $10.8 million in funding from 1998-2008 for following 296 grant projects.

<table>
<thead>
<tr>
<th>Number of grants</th>
<th>Category of Grant</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td>Sustainable Community Grants</td>
</tr>
<tr>
<td>26</td>
<td>Professional Development Grants</td>
</tr>
<tr>
<td>33</td>
<td>Partnership Grants</td>
</tr>
<tr>
<td>72</td>
<td>Research &amp; Education Grants</td>
</tr>
<tr>
<td>152</td>
<td>Farmer Grants</td>
</tr>
</tbody>
</table>

Why should any dairy sheep farmer care about SARE?

In the Northeast, it has the following resources:

- Speaker fund for sponsoring presentations that pertain to sustainable agriculture
- Program staff located in each state to provide education and support
- Searchable database to find results of past funded
- Competitive grant program for running on-farm trials ($2.9 million in 2009)

How does a farmer or researcher get these funds?

First, look at any mission or outcome statements in your region’s SARE webpage. Northeast SARE includes the states of Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont, West Virginia, and Washington, D.C.

Northeast SARE assigns its funds and support based on its own outcome statement. An outcome statement, like a mission statement, expresses a long-term vision of the results we are working to achieve. The Northeast SARE outcome statement is:
Agriculture in the Northeast will be diversified and profitable, providing healthful products to its customers; it will be conducted by farmers who manage resources wisely, who are satisfied with their lifestyles, and have a positive influence on their communities and the environment.

This outcome statement bears directly on what kinds of projects we fund, how we set priorities, and what grants are offered.

Who qualifies to apply for a farmer grant?

You must be a commercial farmer selling some type of agricultural product. You need not be farming full time, but your operation must have an established crop or product that you sell seasonally or on a regular basis.

How much money is awarded?

We award up to $15,000 per applicant on projects that last from 1-3 years, including the outreach component. Outreach means workshops, field days, articles in newsletters, etc.

How are the applications evaluated?

All proposals must contain three essential elements, which are:

1. **A direct link to agricultural sustainability.** Sustainability is defined as farming practices that are profitable, good for the environment, and beneficial to farm communities, and all projects must have a direct link to key themes in sustainable agriculture. These themes are incorporated into the Northeast SARE outcome statement and listed below:

   - the reduction of environmental and health risks in agriculture
   - the prevention of agricultural pollution
   - improved productivity, the reduction of costs, and the increase of net farm income
   - the conservation of soil, the improvement of water quality, and the protection of natural resources
   - the enhancement of employment in rural areas
   - the improvement of quality of life for farmers, their employees, and the farm community

2. **Innovative content and approach.** Proposals should advance or explore new paths to sustainable agriculture and they should avoid merely verifying that a common practice really works. The purpose of SARE is to test new ideas or to promote the adoption of new techniques.

3. **Involvement from the technical advisor.** Technical advisors are typically Natural Resources Conservation Service staff, Cooperative Extension staff, certified crop advisors, farmers who have specific knowledge, veterinarians, or other agricultural service providers with
expertise they can bring to the project. Your advisor should review your proposal for feasibility and good design.

**In addition to the above, proposals will be evaluated using these criteria:**

1. **Innovation and significance.** Your project should develop new information and explore innovative approaches that address a demonstrated need on the part of other farmers or the wider agricultural community.

2. **Clear objectives, sound methods, and measurable results.** Proposals should specifically describe the goal of the project, the details of what will be done to achieve the goal, and how tangible, measurable results will be collected.

3. **Outreach.** Proposals should describe how other farmers and service providers will learn from the project, continue the research, and perhaps replicate or adopt your findings. Develop a thoughtful plan for sharing project results, including unexpected results, to people who can make use of the information.

4. **Capacity for success.** Experience is a key element in any project, as is access to the basic tools that will make it work. Proposals should describe the farm or farms hosting this project and introduce the key people, describing the skill, time, and commitment they will bring to see the work through to its conclusion.

5. **Familiarity with related work.** Your proposal should describe previous efforts to address similar problems and how this project would build on it. Your proposal should make it clear that you have done your homework, investigating what has been done before and consulting with experts in the field.

6. **Sensible budget.** Be clear how money will be spent, why the budget items are needed, and that all expenses are allowed by SARE.

**When are the applications due?**

December 8, 2009 for a 2010 award. Just send in one original copy by mail, postmarked by that date.

**Past Sheep Dairy Farmer Grants in the Northeast**

To give some examples of past farmer grants awarded in the Northeast, it is easy to search for them on the nation SARE project database found at [http://www.sare.org/projects/](http://www.sare.org/projects/). After using the word “sheep” as a search word, 48 projects come up on the list. Of those that pertain directly to sheep dairying, we find the following:
Mrs. Major makes cheese from the milk of her own sheep, which she sells under the label "Vermont Shepherd." She has found a healthy demand for her product, and would like to expand production to meet it. Rather than investing to increase her own production, however, and incurring the headaches that would go along with managing a larger operation, she preferred to create a consortium of sheep dairies, each producing its own cheese to a common standard, but curing and marketing their product collectively.

In 1996 Mrs. Major recruited four farmers, and put them through an apprenticeship cheese-making program at her farm. She wished to continue and expand the program in 1997, with the involvement of more technical expertise, and applied for a SARE grant to help her do so. Mrs. Major recruited various experts in sheep, pasturing, and cheese-making and marketing. These experts made frequent visits to the participating farms, providing instruction and advice on sanitation, record-keeping, equipment, technique, quality control, and other subjects. They conducted taste tests, took samples for laboratory analysis, gave feedback, and discussed various untoward problems as they arose. While this was going on, Mrs. Major and her associates compiled a resource list for would-be cheese makers, and wrote a guide, which they copyrighted, entitled "The Joy of Cheese-Making." The project ended with a workshop for other interested sheep farmers.

Suzanne Sankow and her husband raise sheep. They market the wool and meat themselves, and make cheeses and yogurt from the milk. They wanted to learn how to make higher quality cheeses, which command a better price, and for which the market is strong, so Ms. Sankow applied for a SARE grant to bring Alfred Michiels, an expert on sheep's milk cheeses, from Belgium.

Mr. Michiels conducted a five-day workshop at the Sankow's farm, attended by Ms. Sankow and three others. Mr. Michiels discussed and demonstrated various facets of cheese-making, e.g. the use of starters and rennet, sanitation, equipment, pasteurization, brining, aging, and pressing. Together they made several cheeses, including Brindamour, Belgium Abbey, Manchego, and Pyrénées.

Ms. Sankow has taken some of the cheese made at the workshop to her local farmers' market. She found that the Brindamour sold for $16/lb, twice the price of the Feta that she had been making. She intends to continue to use her newly acquired skills, and to expand her operation by infusing high milk-producing East Frisian stock into her herd, and by increasing the size of her cheese-making facility. She has sent samples of her cheeses to three experts, whose feedback will provide a check on quality.

Neil is a dairy farmer. He had been milking cows for many years, but had become discouraged at the prospects, because of the low and variable prices for cow’s milk. He decided
to get out of cows, but not out of dairying. He applied for a SARE grant to help switch to milking sheep.

Neil built what he calls a “greenhouse” parlor in which to milk the sheep. He calls it that because the design would serve as well for a greenhouse—it is high, airy, and, as the metal frame is covered with plastic sheeting, admits ample light. The sheep enter this area twelve at a time from a holding area, formerly used to house heifers, but now modified for sheep. The sheep feed from a grain trough while they are machine-milked.

The milk is pumped overhead to another newly constructed building, and into a stainless steel tank, mounted on wheels. The tank is hitched to a tractor, and pulled to yet another new building, where it is drained into a basin, and here conversion of the milk into cheese begins. Neil belongs to the Vermont Shepherd Cooperative, and consequently does not complete the process on his farm. After a preliminary curing the cheese is shipped to the Majors’ cave in Putney where the process is finished. Another conversion that Neil made was to pull the stalls out of his cow barn, so that it could serve as winter quarters for his sheep. Neil has about 300 sheep now, of which almost 200 are milkers. He no longer has any cows. He does rotational grazing with the sheep, and puts away much of his own winter feed.


Summary of proposal:

To improve the quality, consistency and efficiency of production of a cooperatively produced cheese with the help of an experienced technical advisor. Vermont Shepherd Cheese is a high quality aged sheep’s’ milk cheese made on individual farms is marketed around the country and available in gourmet food shops and restaurants. The seven producers of this cheese hope to examine the problems involved in creating a cheese of consistent high quality which can be sold under a common name.

Cheeses are graded each month at the aging cave by a panel of 3 - a producer, an ager from the cave, and a retailer. At this point approximately 80% of cheeses are of 1st quality and remaining 20% of lower quality. About 1-2% of the total production is rejected as gassy or 'bad' tasting.

Summary of study:

Jacky Mege, a technical advisor to sheep cheese producers in France (from the agency CREOM) visited Vermont Shepherd producers from July 23 to August 8, 2000. The focus of his visit was to improve the quality and uniformity of the cheese produced on six different farms. Those participating in the visits were:

Ellen and Bruce Clement
Gari and Mark Fischer
Cindy and David Major
Margo Tucker and Mike Ghia
Neil Urie
Ann and Bob Works  
The cheese cave at Major Farm  
(Rich and Jason Huck did not participate as planned because they were not able to begin milking this year.)

Jacky Mege, with his companion Carole and their two children lived with four of the producer families as he traveled from farm to farm and made cheese with each of the farms twice. M. Mege’s mastery of English was sufficient for social occasions but translators were employed for cheese making and technical conversations.

He looked at all aspects of production: pasture management, milking, milk storage, cleaning and sanitizing, and cheese making. In addition to various social events, M. Mege had a final meeting with producers to review his ideas on ways to improve production:

Use of MA400 Starter. Exact measuring of the culture that producers have been doing is counter-productive. Cheese making facilities are very humid, and as soon as culture is exposed to air it begins to activate—and die if it has nothing to feed on. M. Mege felt that volume of culture was as precise as weight. Also, the amount of culture determines the speed of acidification. Higher dose quickens acidification, weaker dose allows for slower acidification. He also suggested that starter culture rehydrate in one pound of milk, rather than in the vat to inhibit growth of unfavorable bacteria present in the milk. After the culture has rehydrated, 30-60 minutes, it should be added to the vat. Vat temperature should be higher than culture solution.

Use of Rennet and “Curding”. Vermont Shepherd producers have been using a time schedule for cutting the curd. M. Mege suggested we change to a formula of 2-4 times the moment of flocculation – the precise moment when the milk changes from liquid to a gel. The flocculation time varied greatly from farm to farm.

Reheating or Cooking the Curd. M. Mege suggested that the time of reheating could be made shorter, and that there was no danger of killing the culture if the optimum temperature was exceeded by 2-3 degrees.

Moulding. Even though Vermont Shepherd molds are very distinctive, the shape requires a great deal of hand pressing which has caused hand problems for a few of the producers. He suggested the Majors consider trying to find a mold with up-right sides that would require less hand pressing.

The changes suggested by M. Mege reduce production time by approximately 20 percent.

Vermont Shepherd producers followed M. Mege’s suggestions for changes in production for those batches produced with him. These twelve batches of cheese from six farms aging in the cave at Major Farm will begin to be evaluated at the end of September. By spring 2001 Major Farm will decide which of the changes suggested by M. Mege will be used in the production of Vermont Shepherd Cheese.
Proposal Summary:

The Cornell Net Carbohydrate and Protein System (CNCPS) is a nutritional model developed for cattle, and the farmer will explore adopting it to dairy sheep and to the environmental conditions of the Northeast. Ewe weight, body score condition, wool depth, milk production and composition, forage and concentrate characteristics, and environmental factors will all be collected and entered into a CNCPS spreadsheet, and the CNCPS predictions for animal changes will be compared to actual ones. This will lay the groundwork for adapting the CNCPS to dairy sheep.

Summary of Study:

Estimation of intake by measuring sward available dry matter before and after grazing was not accurate in reflecting pasture intake of dairy ewes. Use of intake prediction models from Sardinian researchers (Cannas and Pulina) is what is currently available to balance rations with concentrate.

The data collected over the summer was entered into the CNCPS program to see what diet adjustments should be made for next year. The results of this project suggest supplementing half as much energy supplement in late lactation (>9 weeks). Assuming a 16-week lactation, and a whole corn cost of $7 per hundred weight, this would save approximately $37 per head over the course of the lactation. However, the increased protein supplement in early lactation would increase costs by approximately $60 per head over the course of the lactation based on whole corn and soybean meal supplementation.

The goal of this project was to produce a high value crop - pasture based sheep milk - through grazing of underutilized pasture. The project was based around a portable sheep parlor, allowing ewes to be milked in the field, on borrowed land. For two seasons, dairy and domestic ewes grazed hillsides of a nearby educational farm. The milking system included a 9 x 14 portable parlor, allowing 6 ewes to enter the parlor at a time. The milk was frozen and delivered once per week to a local cheese maker.

The project spanned two milking seasons, with Suffolk and East Friesian ewes and ewe lambs milked each year. Ewe lambs that were more than 50% Friesian averaged much greater milk production and longer lactation length.

Claire found that income was less than projected for both years due to lower milk production than she expected and the number of ewes. She feels that it is important to milk at least 24 ewes in the first year, getting more milk for equipment prep and cleanup time investment. The portable parlor worked very well but Claire would make some modifications in the future. She would
increase the size of the holding pen and have the holding pen on a concrete pad. She would also work on developing an efficient milk transport system.

2009 Pressing Spent Brewers Grains to improve its use as alternative feed: A Study of its effect on Dairy Sheep and Meat lambs - Perry Ells, Maine $9,992

Proposal Summary:

In 2007 and 2008, US agriculture was hit with a double shot - high fuel prices and rising grain costs. This has tested the sustainability of all types of farming, but especially those operations with grain fed animals. Feed expenses represent approximately 60% of the cost of a livestock operation. Finding a high quality alternative feed or protein source that is more cost effective can mean the difference between success and failure in farming. This project attempts to improve the current practice of collecting and storing spent microbrewery grain for use as a livestock feed on small farms.

Conclusion

Farmer grants are very useful in testing specific questions that are practical to farmers. The application process is straightforward but the advice of a technical advisor is essential to help make the proposal more competitive. Many grants have been awarded in the last 12 years to farmers on the topic of dairy sheep from Northeast SARE. Contact Carol Delaney, Farmer Grant specialist, 802-656-0697, carol.delaney@uvm.edu or go to www.nesare.org for more information.

Deadline for Farmer Grant proposals this year is December 8, 2009.
PROJECT TITLE: Pressing Spent Brewers Grains to improve its use as an alternative feed: A Study of its effect on Dairy Sheep and Meat lambs

PROJECT LEADER: Perry Ells, Owner/Operator, Ellsfarm

ADDRESS: 1244 Clary Hill Road, Union, Maine 04862

TELEPHONE: H 207-785-2118  Cell 207-542-3941
Best Time to call: Cell phone, anytime

EMAIL ADDRESS:  ellsfarm@aol.com

SARE REQUEST: $9992

PROJECT DURATION: March 2009 to January 2010

HOW DID YOU HEAR ABOUT SARE?
I heard about SARE from a farmer friend who was a recipient in 2003

SUMMARY:
In 2007 and 2008, US agriculture was hit with a double shot - high fuel prices and rising grain costs. This has tested the sustainability of all types of farming, but especially those operations with grain fed animals. Feed expenses represent approximately 60% of the cost of a livestock operation. Finding a high quality alternative feed or protein source that is more cost effect can mean the difference between success and failure in farming. This project attempts to improve the current practice of collecting and storing spent microbrewery grain for use as a livestock feed on small farms. The project will test portable dewatering equipment and its ability to reduce air pollution, conserve fuel, decrease farm costs and improve farm efficiency and production. The project will also produce valuable data on comparing the nutritional value of brewers grains versus conventional grain and their effect on milk volume and components in a sheep dairy and it use as a feed for fattening meat lambs. Of the 30 microbreweries in Maine having farmers pick-up their spent grain, not a single one uses a press before or after transport to improve efficiency – this project will bring this technology to Maine. The results will be useful to any small farmer in the US looking at spent grain from microbreweries as a possible alternative feed.
1. What is the problem and why is it important?

Profitability of livestock operations relies heavily on controlling feed costs. In today’s environment, dairies and meat operations are faced with price increases in purchased grain and harvested forages due to unstable fuel prices and competition for other uses (i.e. ethanol, biodiesel, etc.) Discovering and trying alternative feeding systems is imperative for farm sustainability. Because of the economies of scale, this is especially true for small farms in the northeast. In Maine, as in other states, one of these alternative feeds is spent brewery grains (BG). A waste product of the beer brewing process, “brewers grains are considered to be good sources of un-degradable protein and Water Soluble Vitamins. They have been used in feeding both ruminant and monogastric animals. BG is the material that is remaining after the grains have been fermented during the beer making process. The materials can be fed in the un-dried form or dried and fed. The nutritional content of the material will vary from plant to plant and depending upon the type of substrate being used (barley, wheat, corn, etc.), proportions being fermented and fermentative process being used.” (Animal Feed Resources Information System, reference 53). In 2008, the state of Maine had approximately 30 breweries, all of them considered micro-breweries. Spent BG from all these Maine breweries is picked up by various farmers and used in livestock feeding operations, few if any of the farmers have done analysis on the particular brewery grains they are feeding out and all are trucking them as wet grain, or up to 80% - 85% moisture content. Many blend the BG with corn, barley or pelleted grain or simply use the BG as a bulking agent. The greatest difficulty facing the farmer, who picks up the spent grain for free, is the moisture content of the BG. Wet brewer's grain is an excellent media for microbial growth and has been shown to support the growth of yeast and mold. Feed mixtures containing brewer’s grain spoil rapidly and the palatability declines with increasing storage time. It is also heavy to haul and drips while being transported. In Maine, in some cases the BG is picked up as frequently as once or twice a day. Transportation costs, air pollution, and grain odors are other issues. Therefore, dewatering the spent grain might help alleviate these problems and make it more cost effective.

Farms with dairy sheep and meat lambs feel the same financial pressures as other livestock producers. Grain is necessary in the parlor at milking time and raising meat lambs with a grain supplement is the norm. Nutritional analysis on the BG and its effect on sheep milk production vs. conventional grain is information the farmer lacks at this time. Rate of gain on fattening meat lambs on BG vs. conventional grain is also deficient. How cost effective is feeding BG when you take into account transport and storage needs? This project hopes to gather enough information to answer that question and qualify this alternative feed as it is used in the Northeast.

2. What efforts have been made by others to solve the problem?

Finding quality alternative feeds is an option depending on the farm’s proximity to the source. Many farmers across the US use BG to feed a large variety of livestock. Every source of alternative feed, like BG has its own characteristics and challenges. It might be storage issues, odors, or grinding or processing requirements. In this case, microbreweries pose an extra challenge. Each microbrewery has its own secret recipes for beer production that sets it apart, carves a niche and secures the market as opposed to mass produced beer.
Microbreweries can be very creative in their production systems and currently there is no information on the spent BG produced in Maine. Spent brewers grains have been tested in the past and there are numerous articles in general which prove that it has nutritional value, especially protein. But in Maine, after having contacted one half of the 30 breweries, data does not exist on their spent BG. Nutritional analysis would aid the farmer in balancing rations and being more cost effective. In addition, after having done internet searches (www.ofrf.org, www.sare.org, www.nal.usda.gov, www.dsna.org, www.atra.org, www.google.com) no article was available on spent brewers as it applies to sheep dairies and its affect on milk volume and nutrition. There are numerous sheep dairy operations in the US, the greatest number in Wisconsin, Minnesota, New York and Vermont. BG have not been fed to any dairy sheep and the milk collected from the sheep studied for the length of a lactation, 5 months, and compared with milk from sheep consuming conventional grain. A comparison of the two different grain systems and comparative milk analysis to determine whether brewers grain is a cost effective and nutritional feed alternative would provide the data necessary to make a decision.

Brewery grains have been fed to meat lambs and there are articles on the subject, but every brewery has a different recipe and fermentation process. Having an analysis performed on the brewery grains produced at Maine microbreweries is another tool for providing a balanced diet for both the dairy sheep and the meat lambs. Also, a rate of gain on the market lambs fed brewery grains versus market lambs fed conventional grain in the northeast would further help the farmer determine whether the brewers grain is a cost-effective feed alternative.

It is known that transporting the wet grain uses relatively large amount of fuel and storage is a challenge. Dewatering spent grain, or the practice of running it through a press is normally performed in very large breweries, such as Coors and Anheuser-Busch. A screw press reduces the moisture content into the range of 64 % - 70%. At this point the weight will have been reduced to one half or a third, and the shelf-life will have been extended. For many years it was common practice to use a rotating drum dryer to reduce the moisture content down to 10 % - 2 %. In this condition the spent grain could be stored and marketed as a commodity. With the increase in energy costs, the value of the end product, thus far, has not justified this final drying step. Right now, farmers are making frequent trips to the breweries and feed the wet BG as quickly as possible to avoid spoilage, acidosis and decreased palatability. Screw presses for use on BG are not being used at Maine microbreweries today, but portable screw presses are readily available for rent. Why not bring this technology to Maine farmers and test its applicability, effectiveness?

3. How will your project fit in with your farm operation?

Ellsfarm is primarily a sheep dairy and meat lamb operation. Located on 63 acres on thin upland soil, the farm has been in operation since 1999. Before setting up in Union, Maine, skills were acquired working on a sheep and cattle ranch in Idaho and a multi-species farm in Lincolnville, Maine. As the full-time primary operator of Ellsfarm, Perry Ells attends educational conferences every year in order to improve her farming skills and keep up on improvements in the industry. Her husband Nate works off the farm full-time and helps with certain farm tasks as needed. The Ells family is not complete without mentioning Emery and
Evelyn Ells, ages 11 and 6 who enjoy growing up on a farm and actually help out daily, especially during lambing.

The production year begins at Ellsfarm at lambing time, usually in February and March. Milking the approximately 70 ewes begins April 1 and finishes at the end of September. Our dairy was first inspected in 2004. The milk is all sold in liquid form to two nearby cheesemakers. We raise lambs for sale to local restaurants and retail stores, we have a logo and branded products. Lambs are raised on pasture and fattened with grain in-the-field. The fresh lamb season runs from June thru November. Frozen lamb is available year round. Minor revenue is earned selling sheepskins and wool.

Currently we have both a milk and meat supply problem and are thinking of expanding to satisfy the current market demand and increase our lamb and milk production. The biggest hurdle to accomplish these goals is the farm’s feed costs. Every year the grain prices increase and we try to pass that cost on to the buyers of both the milk and meat, but the market for these products is competitive and margins are tight. Bulk grain supply is not stable and precarious in Maine. In 2004, Maine farmers could choose between 6 different feed companies selling sheep grain in bulk and the prices ranged from 7 – 9 cents/lb. In 2008, there are now two providers, Blue Seal in Augusta and Auburn and Sawyerville Mills in Quebec. They both sell sheep grain for 18 – 22 cents/lb. We lost 4 suppliers and the price almost tripled in the span of 4 years. In the past Agway was a supplier, but their bulk operations were purchased by Feed Commodities, who no longer sells sheep grain in bulk. New England Feed, a past supplier, was consolidated and purchased by a competitor, Blue Seal. P.A. Lesard sold their bulk grain operations to Sawyerville Mills. Morrison’s Feed in Vermont, no longer sells feed in Maine, “transport costs are too expensive.” Sheep farmers have the least options and most expensive conventional livestock feed in the state. In contrast, spent brewery grain is free of charge at the brewery dock. Cost of transport varies and can be decreased if grain is altered, pressed and/or dried at the brewery.

In addition, in 2007 and 2008, like many other farmers we were hit with both high transport (diesel and gasoline) costs and skyrocketing feed prices due to competition for other uses (alternative fuels).

We rotationally graze our pastures and measure all grain fed to each group or individual on a daily basis. We also record pounds of milk and meat sold. We can sort and treat animals with a handling system and scales we have on site. We do not have the acreage or equipment to harvest hay or grow grain. We use or “Free Lease” pasture from two other property owners in town for grazing the meat lambs. All the milkers stay on site and graze on our farm when they are not being milked.

Finding a more cost effective, protein/grain alternative would help our farm in becoming more sustainable. However, the feed alternative must be incorporated very carefully as it can effect the products we produce and the long term health of the animals.

4. What will your methods be?

The project has 3 main research areas: Milking operation, Market lambs, Using the Screw Press. The project also has data collection areas: milk testing at Dairy One, Weighing lambs/calculating rate of gain, microbrewery spent grain testing at Dairy One, recording grain weights, storage observations, fuel usage/transport costs - wet vs. pressed grain.
**Milking operation**: Beginning April 1, using the farm’s handling system, we will divide the milking group in half randomly. Ewes will also be weighed and condition scored. One half will be fed conventional grain, one half fed brewers grain. Based on nutritional analysis of the brewery grain, a custom supplement or pellet may or may not be supplied by Blue Seal Feed for a balanced dairy ration.* Before each milking the ewes will be sorted, and fed their assigned grain at milking. Once a month, for a total of 5 months, milk will be sampled from each ewe, volume recorded and sent to Dairy One for analysis. Ewes will also be weighed and condition scored at mid-lactation by a veterinarian. End of June, and at drying up, mid-September for additional data. Between milkings the ewes will rotationally graze pasture, together.

**Market lambs**: There will be a rolling weaning, beginning April 1 (30 – 50 days depending on when they reach 30 lbs, standard for sheep dairies), wean weights of lambs will be gathered using the farm scale. They sex will be recorded, and then they will be divided in half randomly and put in two separate pastures. Lambs pastures will be managed using the rotational grazing method. Before weaning, lambs were consuming conventional grain in their creep rations, along with hay. After weaning each group will be fed the same amount of grain per head, one group the conventional grain, one group the brewery grain. For the lambs being fed brewery grain there will be a one week gradual change - blending of conventional and brewery grains. This will be to minimize digestive upsets. Based on nutritional analysis of the brewery grain, a custom supplement or pellet may or may not be supplied by Blue Seal Feed for a balanced grower ration, the farmer will consult with the Technical advisor on ration analysis. When lambs reach market weight – approximately 100 - 110 lbs live weight – the rate of gain will be calculated- (Market weight – wean weight) / # days from weaning to market weight. At the end of the season we will compare lbs gained on conventional grain vs. brewery grain.

**The Screw Press, Transport and Storage**: At the end of March, a Vincent KP 6 Screw Press, (most economical model) will be shipped from Florida, and brought to Gritty’s Brew Pub in Freeport, Maine, the closest microbrewery with enough supply to conduct the project. The Brewery is roughly one hour, 55 miles south of the farm. It is known that wet brewers grain should not be stored for more than a week due to fermentation and mold growth. At a maximum, trips will be made once/week using the farm truck. (With the use of the screw press, we hope to be able to reduce the frequency of trips by lengthening storage time.) Other brewery options are Andrews in Lincolnville, Three Tides in Belfast and Sheepscot in Whitefield. These breweries may become available sources of spent grain if they expand. On pick-up day, the spent grain will be weighed wet, and then a batch loaded into the screw press at the brewery. Afterwards, a pressed sample will be taken and then the rest of the batch will be placed in 55 gallon drums and lifted into the farm truck. The once a month sample will be sent to Dairy One in NY. Daily internal temperatures using a Probe thermometer will be recorded at the farm to watch for spoilage and observe storage conditions and length. Weather details will also be recorded to see how this affects grain spoilage. The farm’s tractor will be used to unload the grain from the truck. All grain fed will be measured, both conventional and BG using the farm’s scale. The farm currently feeds out 15 tons of conventional grain a year. This will be halved and it is estimated that between 500 – 700 lbs of brewers grain will be fed out each week to one half the milkers and
one half of the meat lambs. The lambs being fed conventional grain will be kept separate at an additional pasture “Free leased” in town. For baseline data, one pick-up will be done with un-pressed grain to determine transport costs of unpressed grain. The press will be returned 7 months later in November.

5. How will you measure your results?

Grain analysis - We will measure nutritional value of the spent grain by means of grain analysis done at Dairy One. One time a month for 7 months we will send a pressed grain sample to Dairy One. We will also send one, un-pressed sample for baseline information. The results at Dairy One and by consulting with the technical advisor Rick Kersbergen, Waldo County Cooperative Extension will help the farmer develop a balanced ration using the BG and whether a supplement will need to be purchased.

Milk analysis – We will measure the effect of BG on milk production by sampling milk from all milkers 1x/mo for 5 months and sending samples to Dairy One. We will compare production from sheep consuming brewers grains vs. conventional grain and compare volumes as well.

Condition scoring and weighing the ewes - performed on 60 – 70 milkers by Dr. Eleanor Kollmar, DVM at weaning, mid-lactation and at drying up will help us observe how the BG physically affects a dairy animal. Condition score will standard method for sheep - from poor, 1 to obese, 5. Average weight for Friesian Dairy ewe is 150 – 175lbs

Calculating rate of gain of meat lambs – Recording weights for two different groups of 40 – 50 lambs each, randomly selected will give us part of the information needed to determine which is a more cost effective feed for meat production. We will record birth weights, weaning weights and market weight or finish weight 3 times in the lifetime of the lambs. We will calculate rate of gain by subtracting wean weight and finish weights dividing by days between the two dates.

Testing the screw press - Recording weights of BG before and after pressing.

Transport costs – recording fuel and labor expense making trips to the brewery will provide us with data needed to compare direct costs of acquiring BG vs. conventional grain.

Collecting data on grain storage - Recording internal and external temperatures of the BG using a compost thermometer and weather thermometer including humidity, will help us identify potential handling, storing and spoilage issues and efficacy of using the screw press.

6. How will the results of your project help farmers in the Northeast?

The Northeast is not the bread basket or the grain growing center of our nation. We do grow many grains, but not enough to be self sufficient in our livestock feeding systems. Northeast farms rely on importing grain using traditional methods, rail and roads. This means we pay high transport costs on top of high grain prices. This threatens the viability of
many small farms in the Northeast and uses tremendous amounts of fuel. If farmers can be creative in finding alternative feeds, markets, and production methods closer to home they have more choices and a better chance at being sustainable, while conserving natural resources.

Microbreweries are growing in number all over the Northeast. They provide a waste product – spent brewers grains, or BG – that is already being used as a source of feed for livestock. But what is in the BG from a local microbrewery is about as varied as types of specialty coffees these days. Quantitative data on feeding BG to sheep, how it affects their health, the sheep milk, and growth rates on lambs is not readily available. This project hopes to gather this information and make it available to farmers. The project will also show farmers the process by which he or she can test the BG from a local brewery. With this information farmers can determine its usefulness and nutritional value as a feedstuff as well as effect on production/output.

With the data collected on the screw press we hope to make recommendations that will help farmers decide whether to consider purchasing the equipment – whether it will affect their bottom line. By renting a screw press and bringing the technology to Maine for a pilot or test project – we can try to reduce the problems many farmers are facing now with spoilage and transport costs when they use BG in any state. Hopefully we will learn that by dewatering the grain, a farmer can increase net farm income by decreasing fuel /transport costs and lengthening storage time. Farmers who are currently using BG as a livestock feed might be able to make fewer trips with lighter loads. Fewer trips will also reduce air pollution, automobile exhaust. Odors would also decrease by dewatering, and this makes the neighbors happy! Less time spent hauling wet grain will free up more time to do other farms tasks.

Today, BG is given away free of charge. This is a huge savings for the farmer as compared to conventional grain, but only if the farmer is close to the brewery. If this project discovers that it is more cost effective to use the screw press, then more farmers can consider using BG as an alternative feed.

7. What is the outreach plan for your project results?

Preliminary results of the project, both farm data and equipment research will be presented at the Common Ground Fair in September, 2009. A demonstration day inviting farmers to view the grain press in action will be held at the Brewery in October 2009. The final results in printed form will be available at the annual Dairy Sheep Association of North America conference in November 2009, then the Maine Agricultural Trades Show in January of 2010. An article will be written and sent to the following publications: American Agriculturist, Journal of Northeast Farming, The Shepherd magazine, Sheep! Magazine, Maine Cheese Guild’s “Parings”, Maine Sheep Breeders Association newsletter “The Producer”, Vermont Sheep and Goat Association newsletter, Vermont Center for Sustainable Agriculture, Dairy Sheep Association of North America newsletter. Results will also be sent to the Small Farm Institute in Massachusetts. At the farm’s annual Open Farm Day we will talk about the project to the 200 – 500 visitors on that day.
BUDGET

Personnel

Perry Ells
Sorting pre-milking, 1 hr x 150 days (5 mo. Lactation), 150hr x $10/hr = $1500
Time handling grain each week + Road time roundtrip to Brewery including operation of the
crack press, 4hrs x 34 = 136hr x $10/hr = $1360
Weighing Lambs, 2 groups, 3 times = 20.2 hr x $9/hr = $182
Weighing/Scoring ewes, {((70 ewes x 10 mins) / 60) x 3 = 40hr x $10/hr = $400

Hired Labour
Storage data, .25 hrs x 210 days (7 mo.) = 53hr x $9/hr = $477
Weighing lambs, 18hr x $9/hr = $182

Materials and supplies
4 cattle/hog panels for use a portable weighing pen in the field, $28/ea = $112
3 Livestock paint quick ID for sorting ewes pre-milking, $5/ea = $15
14 used 55 Gallon drums for use as wet grain storage, $25/ea = $350
Grain Temperature Probe for recording daily stored grain temps, $20/ea = $20

Travel
Round Trip to Brewery, 110 miles round trip x 34 trips x $.505 = $1888
Round trip to Cooperative Extension Office, 54 mi x $.505 = $28

Printing & Publications
N/A

Other Direct costs
Screw Press/KP 6”, Rental $150/mo x 7 mo = $1050
Shipping round Trip (from FL) = $1000
Tractor usage, Loading & unloading grain each trip, 30 trips x 1hr x $20/hr = $600
Telephone, Current phone package allows for unlimited usage = $0
Milk Samples, Perform these tests already each season = $0
Grain Samples, 1/mo x 7mo. x $35 = $245
Postage of grain samples, 7 x $5 = $35
Photocopying, N/A = $0
Consultants:
    Rick Kersbergen, Cooperative Extension, Tech Advisor, 10 hrs performed gratis
    Eleanor Kollmar, 17 hours x $20/hr = $350
    Billy/Gritty’s Brewery Owner, 10 hours x $20/hr = $200

Total Grant Funds Requested = $9992
I. Introduction

Goats and sheep were among the first animals to be domesticated, and it is arguable which species’ milk yielded the first cheese more than 5,000 years ago. Although cow milk cheeses dominate the market, due to the higher milk yield of cows, sheep milk cheeses, in particular, yield a higher price per pound of product. For those who are just starting to investigate the potential to make cheese with sheep milk, and for those who have made cheese for some time, understanding some dairy chemistry and microbiology is a must. This paper will provide some information on the chemistry and microbiology of cheesemaking, explain the general steps in cheesemaking, and then focus in on sheep milk and cheesemaking with sheep milk, including some make procedures.

II. Chemistry and microbiology of cheese milk

Regardless of the type of cheese or species from which the milk is derived to make a given cheese, without question, the production of high quality cheese requires a high quality starting material: milk.

Some of the primary considerations that go into defining high quality milk include, but are not limited to the following:

- Good health of animals from which the milk is collected
- Normal somatic cell counts (SCC)
- Low bacteria levels
- Lack of inhibitory substances (antibiotics)
- Milk cooled to less than 45°F (7°C) within two hours of collection
- Fresh milk (stored less than 48 hours)
- Pasteurized milk (required if one plans to sell fresh cheese) but not homogenized
- Use of sanitary stainless steel equipment, pipes and fittings (no copper)

Animal health, and udder health in particular, is of critical importance in the production of high quality milk and cheese. Factors such as weather, season, stage of lactation, parity, udder condition and nutrition not only affect the amount of milk an animal produces but also the quality of milk she produces. In times of highest production, cheese yield will be the lowest due to an inverse relationship between solids content (fat and protein, in particular) and milk production. While the yield of cheese per pound of milk will be higher during times of low production, overall yield (total amount of cheese) will be low.

Somatic cell counts (SCC) are an accepted parameter for the evaluation of milk quality and as a management tool in dairies worldwide (Paape et al. 2007). In the U.S., the legal SCC, established by the Food and Drug Administration for cows is 750,000 per mL and for goats and
sheep is 1,000,000 per mL because somatic cells are typically associated with abnormal milk. In a recent study by Paape and colleagues (2007), the SCC of milk from over 26,000 goats, 5 million cows and 2,000 sheep were studied. For goats and cows, SCC increased with stage of lactation and parity. For sheep, SCC for the first parity were higher than for later parities. Sheep SCC were similar to those of cow milk, which were lower than those of goat milk. Increases in SCC due to stage of lactation and parity for cows and sheep are mainly the result of intramammary infections, while non-infectious factors such as estrus, season and milk yield, also affect goat milk SCC.

Although Grade ‘A’ milk is not required for cheese, it is good to cover some of the regulations for Grade ‘A’ milk production. Grade ‘A’ farms are not only licensed, but also permitted with a Grade ‘A’ permit, and must comply with the regulations set forth by the Grade ‘A’ Pasteurized Milk Ordinance (PMO) and state regulations (USDHHS 2007). The Grade ‘A’ requirement is only necessary if the milk is being processed into a Grade ‘A’ product, specifically: fluid milk, yogurt, sour cream, cream, half and half, buttermilk, and any variation of these products. The Grade ‘A’ quality standards for milk are:

- Milk cooled to less than 45°F (7°C) within two hours of collection
- Standard Plate Count (SPC) for total aerobic bacteria less than 100,000 per mL
- SCC less than 750,000 (1,000,000 for goats and sheep) cells per mL
- Antibiotic (beta-lactam drug residue) tests negative

There are three types of cheese-milk that may be used to make cheese: raw, heat-treated, and pasteurized. Raw milk cheeses must be aged at least 60 days at greater than 35°F. The time-temperature combination is important because the microbial metabolism must be active so that pathogens (if present) go through life cycle into death phase. Any heat treatment less than legally pasteurized is called heat-treated, but it is treated as if made from raw milk. Any microorganisms that remain in milk will influence flavor, body and texture (sometimes positively, sometimes negatively).

In the U.S., most fermented dairy products are made from pasteurized milk. Pasteurization (145°F/62.8°C for 30 min or 161°F/71.6°C for 15 sec) kills all pathogens but not all microorganisms (some thermoduric microorganisms survive). Some psychrotrophs and or their enzymes are thermoduric (bad for quality). When a high number of psychrotrophs are present before pasteurization, milk and cheese quality will suffer, which is why only fresh milk should be used for dairy products. Cheeses made from pasteurized milk can be sold fresh or aged. Excessive heating of milk (higher than the legal pasteurization temperature) should be avoided, because over-heating causes the whey protein, β-lactoglobulin, to bind to κ-CN across the chymosin-sensitive bond, which results in softer curds and lower yields. Further, homogenization of milk intended for cheese is not recommended because fat is lost in the whey and cheese yield is reduced.

Although it is legal to leave milk in a bulk tank for up to 72 hours prior to processing, it is not advisable to do so. Cold-loving bacteria (called psychrophiles and psychrotrophs) continue to multiply at in the refrigerated bulk tank and produce off flavors in milk and flavor, body and texture defects in cheese. It is strongly advised to utilize only fresh milk (held for less than 48 hours) for any dairy product.
Only high quality, sanitary stainless steel equipment, pipes and fittings are recommended in a dairy plant. Any stray oxidizing metals can induce oxidation and off flavors in the milk and cheese.

In addition to animal and udder care, safe, high quality milk and cheese require proper hygiene and sanitation, including but not limited to:
- Properly trained employees
- Hair nets and beard nets
- Clean and sanitized hands (gloves)
- Foot baths
- Appropriate chemicals and usage
- Chlorinated alkaline cleansers
- Acid cleansers
- Sanitizers (sodium hypochlorite)
- Time, temperature, concentration and agitation

It is beyond the scope of this paper to elaborate on the details of cleaning, hygiene and sanitation, but utmost care must be taken in these areas to ensure safety and quality of milk and cheese.

Cheesemaking proceeds with high quality ingredients and supplies, including but not limited to:
- Viable and appropriate starter cultures
- Functional coagulating enzyme
- Viable and appropriate molds (microbial)
- Appropriate cheesecloth, molds or hoops (for pressing)
- Salt (non-iodized)
- Other inclusions (herbs, fruits, nuts)
- Good record-keeping

Starter cultures are lactic acid bacteria that “start” the fermentation process and contribute to the flavor, body and texture of the resulting cheese. When selecting cultures, cheesemakers may choose mesophilic and/or thermophilic cultures. Mesophilic cultures like warm temperatures (68-111°F/22-44°C) and are typically used for Cheddar, Monterey Jack, Cottage, Gouda, and Blue cheeses. Thermophilic cultures like hot temperatures (111-140°F/44-60°C) and are typically used for Italian style cheeses. Culture houses are available to help you select the appropriate combination of cultures for a given cheese. They can also assist with selecting the style of culturing you may use. For instance, for farmstead and artisan cheesemakers, direct vat set (DVS) cultures are usually recommended because the convenient freeze-dried cultures can be easily measured and added to small vats of cheese milk without the need for large reserves of media to be held on site.

Other ingredients and supplies will be discussed in more detail in the next section.
III. The Steps in Cheesemaking

As mentioned earlier in this manuscript, all high quality cheeses share one common feature: high quality milk. From that point on, any modification in the processing can yield a different cheese. Different cheeses are made based upon source of milk, type of culture used, temperature of ripening, cooking regime, temperature of aging, size of curd cutting, use of coagulating enzyme and type, style of curd handling, style of salting, etc.

The basic nine steps in cheesemaking are listed below and are elaborated upon in subsequent pages.

**General steps in Cheesemaking**

1. Place high quality milk into recently cleaned and sanitized vat (avoid foaming)
   a. Gradually raise the temperature of the milk to target temperature for culture
2. Agitate milk and add culture (note time and pH or TA)
   a. Allow to ripen for the recommended period of time
3. Addition of coagulating enzyme
   a. Stop agitation (note time)
4. Check curd
   a. Look for sharp cut in curd and clear whey to fill cut
   b. Cut curd (note time)
   c. Heal (rest curd for 5 – 15 minutes, depending on cheese)
5. Begin gentle agitation of curd (note time and pH/TA)
   a. Begin heating/cooking/stirring of curd to target temperature (some types require no cooking)
   b. Increase agitation along with temperature incrementally (note time and pH/TA)
   c. Turn off heat at target temperature and agitate until target time (note time and pH/TA)
6. Drain whey
   a. This part may be incremental, and may include addition of water, depending on cheese type
7. Subsequent steps vary according to cheese type
   a. Cheddar and Jack types
      i. Cheddar (flip and stack loaves of curd) or stir curds
      ii. Mill (if cheddared)
      iii. Salt
      iv. Mold/hoop
      v. Press
   b. Mozzarella and Provolone styles
      i. Stretch
      ii. Brine
   c. Feta
      i. Mold/hoop
      ii. Salt/Brine
   d. Blue-veined mold-ripened varieties
      i. Inoculate with mold spores
ii. Mold/hoop
iii. Aerate with needles
e. Camembert-style mold-ripened varieties
   i. Mold/hoop
   ii. Spray surfaces with mold spores

8. Package
   a. May include plastic, wax, etc.

9. Age/ripen
   a. All raw milk cheeses must be aged at least 60 days at 35°F/2°C or greater
   b. Fresh cheese (pasteurized milk) may be sold right away
   c. Mold-ripened cheeses require oxygen and high relative humidity for formation

The most important milk component for cheesemaking is the protein generally referred to as casein (CN). It is generally accepted that native milk casein (pH of about 6.7) is in the form of casein micelles, which are composed of the sub-classes of caseins (αS₁, αS₂, κ-, and β-CN). The micelles are between 40 – 300 nm in diameter (smaller than fat). Submicelles are thought to be 10 – 20 nm in diameter. The hydrophobic caseins (αS₁, αS₂, and β-CN) orient themselves to the inside of the micelles. Hydrophilic caseins (κ-CN or hydrophilic parts of proteins) extend beyond the micelles into the surrounding milk serum. Since κ-CN is not susceptible to Ca²⁺ precipitation, it stabilizes the micelle against precipitation. There is a net negative charge on the surface of the micelles at the pH of milk, so the κ-CN hairs stretch out. Micelles repel each other and are very stable to dessication, heat and cold. At low pH, fewer negative charges exist, therefore the hairs curl up, and coagulation occurs.

When milk is acidified, as in the case of fermentation by mesophilic and/or thermophilic starter cultures, lactose is converted to lactic acid. This results in several important features, including:
1. Neutralization of charges on proteins, which leads to coagulation of proteins
2. The acid protease enzyme (chymosin/rennet) becomes more active at acidic pH, which speeds coagulation
3. Some minerals go into solution (the amount of Ca²⁺ in final cheese dictates texture)
4. Syneresis (water is squeezed out), the form of the product changes, and shelf life is increased

Some cheeses (cottage cheese, chevre) are made by the process of acidification, but it is a slow process. We can wait for lactic acid to form and coagulate the milk, but we can speed up the process with the enzyme chymosin (commonly called rennet). The enzyme is specifically active on the κ-CN in milk. It essentially cuts the negatively charged “hairs” off of the casein micelle, which allows the micelles to come together and coagulate. The chymosin cleaves specifically at the phenylalanine-methionine amino acids bond in κ-CN. Part of the κ-CN, the glycomacropeptide, remains soluble and ends up in whey, while another part of it, the parakappa-casein, stays with the curd.

When using chymosin, there are several important issues to keep in mind, which are listed below:
• Dilution (1 part enzyme to 40 parts water) is necessary so localized coagulation does not occur
• The enzyme degrades over time and in heat. Keep refrigerated until use.
  • Mix enzyme with cold water immediately before use. Don’t pre-mix & let sit.
• Distribute the enzyme as evenly as possible in the vat
• Coagulating efficiency increases approx 1.5% per °F between approx 68-100°F.
  • Maximum temperature for chymosin is 106°F (in activated at high cooking temperature).
• Hard water, chlorine and heat will destroy enzyme activity
  • If mix-water contains high chlorine levels, mix drops of pasteurized milk in to neutralize chlorine before adding the coagulant (organics inactivate chlorine).

When the caseins coagulate, most of the fat is trapped in the matrix. For most cheeses, about 90% of the casein and fat are retained in the cheese. The remaining material that is not trapped in the curd matrix is called whey. Whey is primarily composed of water, but it also contains most of the lactose, almost all of the whey proteins, as well as some fat, vitamins and minerals. Whey can be used to make ricotta cheese, but it is a good idea to supplement the whey with milk to increase the yield of ricotta.

Other considerations in cheesemaking include use of molds, calcium chloride (CaCl_2), salt and color. Molds include the microbiological kind and physical kind. Different molds can produce great flavors and attractive appearance to products. CaCl_2 promotes ionic cross-bridging of caseins, gives a stronger coagulum with the same amount of chymosin, may also give greater yield, but does not increase calcium in curd. Color is added to some cheeses to identify them, but does not provide flavor or other attributes. The most typical color, annatto (natural extract from Lipstick tree) binds to caseins. Salt is added to most cheeses. It assists in syneresis, serves as a preservative (slows microbial growth), and provides flavor.

IV. Sheep milk chemistry

 Compared to the milk of goats and cows, sheep milk can be described as more rich in solid nutrients (Table 1). Like goat milk, sheep milk contains a higher proportion of short and medium-chain fatty acids than cow milk (Table 2). This feature makes goat and sheep milk and cheese have characteristic flavors that are more piquant and rancid than cow milk products.

In summary, compared to cow milk, sheep milk:
• Has lower water content
• Has higher lactose, fat, protein and ash
• Has higher normal titratable acidity (TA)
• Has more overall flavor
  • Higher proportion of short chain volatile fatty acids
• Yields more cheese per pound of milk
  • Yields less whey
• Cheese is more white
  • Beta-carotene converted to Vitamin A
The normal pH of cow milk is approximately 6.6 to 6.7. Sheep milk pH is approximately 6.5 to 6.9. The pH value is a measure of the concentration of hydronium ions in the solution, and an indication of acidity. For Cottage and Mozzarella cheeses, processors use pH to guide decisions during cheesemaking. However, for most cheeses, processors use titratable acidity (TA) to guide decisions because it measures the amount of acid in the volume measured (generally 9 mL).

The normal TA of cow milk is from about 0.14 to 0.18% as lactic acid. Fresh milk does not contain lactic acid, but contains citrates, phosphates and proteins that accept protons during the titration process. Thus, the 0.14 – 0.18% as lactic acid is really “apparent acidity”. Fresh sheep milk naturally has a TA of 0.22 to 0.25% as lactic acid. The reason the value is so high for sheep milk is because of the high level of caseins in the milk, which have negative charges and buffering capacity (apparent acidity). Developed acidity, on the other hand, indicates the progression of fermentation, which is not desired in fresh milk, but is desired during cheesemaking. Measuring TA during cheesemaking can serve as a measure of progress. It is good to keep track of TA and or pH in a log book or on make sheets. An example make sheet is included at the end of this manuscript, Appendix 1, which can be modified to fit the needs of your plant.

Sevi et al. (2000) studied milk yield, composition, bacteria count, SCC and renneting parameters of Comisana sheep milk in Italy. They reported that milk yield was not affected by number of lactations, but that the milk from higher parity ewes had higher protein, casein and fat and better renneting ability than first parity ewes. The microbial quality of third parity ewes was also better than first of second parity ewes. Further, they noted that ewes in first of second lactation had a lower milk secretion status than ewes with a higher number of lactations. The authors suggested that milk yield and quality of younger ewes may be improved by offering feed rations that take into account the reduced capacity of young ewes to mobilize body reserves for milk production. The authors also stressed the need for scrupulous control of sanitation of housing, equipment and personnel.

Since sheep milk production is highly seasonal, sheep milk processors have an interest in the potential for freezing the milk during peak season, for use in the dry season. Research has demonstrated that sheep milk can be skimmed, ultrafiltered (UF; to increase solids), recombined with cream, frozen, stored up to six months, and used for cheesemaking (Voutsinas et al. 1995a, Voutsinas et al. 1995b). After storage at -20°C for 6 months, insignificant increases in lipolysis (production of rancid flavor), fat oxidation (production of oxidized flavor) and good protein stability were exhibited. Feta-like cheeses made from the UF concentrates had similar pH, higher protein and calcium, but lower fat, moisture and yield than the control cheese made without concentration and freezing (Voutsinas et al. 1995b). The UF cheeses also had a sandy texture, were harder and more acidic in flavor and ranked lower in overall quality than the control cheese. The authors did not recommend the UF process for production of sheep milk cheese.

V. Cheesemaking with sheep milk

Just about any cheese that can be made from cow milk can also be made of sheep milk. However, a greater yield per pound of milk can be expected and the resulting cheese will have
some different flavor characteristics than cow milk cheeses. Traditional cheeses made from sheep milk include, but are not limited to:

- Beyaz peynir (Turkey; salty white raw milk sheep cheese similar to feta)
- Caciocavallo (Italy; protected designation of origin (PDO) status raw sheep milk; hard, tear-drop-shaped cheese with nutty flavor; similar to Provolone)
- Feta (Greece; sheep and/or goat milk; salty, crumbly)
- Halloumi (Greece; sheep and/or goat milk; not cultured, mild flavor; good for frying)
- Idiazabal (Spain; PDO status raw sheep milk; nutty flavor; similar to Manchego)
- Kasseri (Greece; PDO status raw sheep milk; soft textured, stringy, pasta filata cheese)
- Manchego (Spain; PDO status sheep milk cheese; hard, piquant, herringbone rind design)
- Mizithra (Greece; sheep and/or goat milk and/or whey; mild)
- Pecorino (Italy; including P. Romano, P. Sardo, and P. Siciliano; hard grating sheep milk cheese, similar to but more flavorful than Parmesan)
- Roncal (Spain; PDO status; sheep milk; hard)
- Roquefort (France; PDO status; sheep milk blue cheese from Lacaune sheep, aged in caves of Roquefort-sur-Soulzon)
- Teleme (Romania; sheep and/or cow milk; creamy texture, tangy aftertaste)
- Zamorano (Spain; PDO status sheep milk cheese; hard, similar to Manchego)

To get you started in the practice of making a variety of cheeses, the make procedures for several cheeses are included in the form of figures at the end of this document, including Feta (Fig 1), Romano (Fig 2), and Roquefort-style (Fig 3).

Cheesemaking involves both science and art. Because so many things influence the product, careful record-keeping is a must if you are to prevent recurring disasters and, more importantly, reproduce a fabulous cheese. A make sheet for the production of stirred curd Monterey Jack cheese from sheep milk is included in Appendix 1. Try following the steps as written, then modify the make sheet to meet your needs as you improve the recipe according to your starting material and taste.

### Table 1. Cow, Goat and Sheep Milk Production and Composition Compared.

<table>
<thead>
<tr>
<th>Component (%)</th>
<th>Cow</th>
<th>Goat</th>
<th>Sheep</th>
<th>Human</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Mean</td>
<td>Mean</td>
<td>Mean</td>
</tr>
<tr>
<td>Water</td>
<td>87.5</td>
<td>87.5</td>
<td>80.9</td>
<td>87.7</td>
</tr>
<tr>
<td>Protein</td>
<td>3.4</td>
<td>3.6</td>
<td>5.9</td>
<td>1.8</td>
</tr>
<tr>
<td>Casein</td>
<td>2.7</td>
<td>2.9</td>
<td>4.7</td>
<td>-</td>
</tr>
<tr>
<td>Whey</td>
<td>0.7</td>
<td>0.9</td>
<td>1.2</td>
<td>-</td>
</tr>
<tr>
<td>Fat</td>
<td>3.6</td>
<td>4.1</td>
<td>7.0</td>
<td>3.6</td>
</tr>
<tr>
<td>Lactose</td>
<td>4.8</td>
<td>4.5</td>
<td>5.3</td>
<td>6.8</td>
</tr>
<tr>
<td>Ash*</td>
<td>0.7</td>
<td>0.8</td>
<td>0.9</td>
<td>0.1</td>
</tr>
<tr>
<td>Production (kg/day/animal)</td>
<td>18-23</td>
<td>1-5</td>
<td>0.5-2.0</td>
<td>-</td>
</tr>
<tr>
<td>Cheddar cheese yield (%)</td>
<td>9.9</td>
<td>9.8</td>
<td>14.8</td>
<td>-</td>
</tr>
</tbody>
</table>
Table 2. **Fatty acid profiles of milk from different species** (USDA, 2009).

<table>
<thead>
<tr>
<th></th>
<th>Cow</th>
<th>Goat</th>
<th>Sheep</th>
<th>Buffalo</th>
<th>Human</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saturated total</td>
<td>2.08</td>
<td>2.67</td>
<td>4.60</td>
<td>4.60</td>
<td>2.01</td>
</tr>
<tr>
<td>4:0</td>
<td>0.11</td>
<td>0.13</td>
<td>0.20</td>
<td>0.28</td>
<td>-</td>
</tr>
<tr>
<td>6:0</td>
<td>0.06</td>
<td>0.09</td>
<td>0.14</td>
<td>0.15</td>
<td>-</td>
</tr>
<tr>
<td>8:0</td>
<td>0.04</td>
<td>0.10</td>
<td>0.14</td>
<td>0.07</td>
<td>-</td>
</tr>
<tr>
<td>10:0</td>
<td>0.08</td>
<td>0.26</td>
<td>0.40</td>
<td>0.14</td>
<td>0.06</td>
</tr>
<tr>
<td>12:0</td>
<td>0.09</td>
<td>0.12</td>
<td>0.24</td>
<td>0.17</td>
<td>0.26</td>
</tr>
<tr>
<td>14:0</td>
<td>0.34</td>
<td>0.32</td>
<td>0.66</td>
<td>0.70</td>
<td>0.32</td>
</tr>
<tr>
<td>16:0</td>
<td>0.88</td>
<td>0.91</td>
<td>1.62</td>
<td>2.00</td>
<td>0.92</td>
</tr>
<tr>
<td>18:0</td>
<td>0.40</td>
<td>0.44</td>
<td>0.90</td>
<td>0.68</td>
<td>0.29</td>
</tr>
<tr>
<td>Monounsaturated total</td>
<td>0.96</td>
<td>1.11</td>
<td>1.72</td>
<td>1.79</td>
<td>1.66</td>
</tr>
<tr>
<td>16:1</td>
<td>0.08</td>
<td>0.08</td>
<td>0.13</td>
<td>0.14</td>
<td>0.13</td>
</tr>
<tr>
<td>18:1</td>
<td>0.84</td>
<td>0.98</td>
<td>1.56</td>
<td>1.57</td>
<td>1.48</td>
</tr>
<tr>
<td>20:1</td>
<td>trace</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.04</td>
</tr>
<tr>
<td>22:1</td>
<td>trace</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>trace</td>
</tr>
<tr>
<td>Polyunsaturated total</td>
<td>0.12</td>
<td>0.15</td>
<td>0.31</td>
<td>0.15</td>
<td>0.50</td>
</tr>
<tr>
<td>18:2</td>
<td>0.08</td>
<td>0.11</td>
<td>0.18</td>
<td>0.07</td>
<td>0.37</td>
</tr>
<tr>
<td>18:3</td>
<td>0.05</td>
<td>0.04</td>
<td>0.13</td>
<td>0.08</td>
<td>0.05</td>
</tr>
<tr>
<td>18:4</td>
<td>trace</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>20:4</td>
<td>trace</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.03</td>
</tr>
<tr>
<td>20:5</td>
<td>trace</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>trace</td>
</tr>
<tr>
<td>22:5</td>
<td>trace</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>trace</td>
</tr>
<tr>
<td>22:6</td>
<td>trace</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>trace</td>
</tr>
</tbody>
</table>

Table 3. **Composition of a variety of sheep, goat and cow milk cheeses, compared** (Fox et al. 2000).

<table>
<thead>
<tr>
<th>Cheese</th>
<th>Fat (%)</th>
<th>Total solids (%)</th>
<th>Salt (%)</th>
<th>pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Camembert</td>
<td>23.0</td>
<td>47.5</td>
<td>2.5</td>
<td>6.9</td>
</tr>
<tr>
<td>Cheddar</td>
<td>32.0</td>
<td>63.0</td>
<td>1.5</td>
<td>5.5</td>
</tr>
<tr>
<td>Feta</td>
<td>20.3</td>
<td>40.3</td>
<td>2.2</td>
<td>4.2</td>
</tr>
<tr>
<td>Gouda</td>
<td>28.5</td>
<td>59.0</td>
<td>2.0</td>
<td>5.8</td>
</tr>
<tr>
<td>Manchego</td>
<td>25.9</td>
<td>62.1</td>
<td>1.5</td>
<td>5.8</td>
</tr>
<tr>
<td>Mizithra</td>
<td>25.0</td>
<td>56.3</td>
<td>1.6</td>
<td>5.0</td>
</tr>
<tr>
<td>Mozzarella</td>
<td>18.0</td>
<td>46.0</td>
<td>0.7</td>
<td>5.2</td>
</tr>
<tr>
<td>Ricotta</td>
<td>12.7</td>
<td>28.0</td>
<td>&lt;0.5</td>
<td>5.9</td>
</tr>
<tr>
<td>Romano</td>
<td>24.0</td>
<td>77.0</td>
<td>5.5</td>
<td>5.4</td>
</tr>
<tr>
<td>Roquefort</td>
<td>31.0</td>
<td>60.0</td>
<td>3.5</td>
<td>6.4</td>
</tr>
</tbody>
</table>
Fresh, High Quality Sheep Milk
or
Sheep/Goat Milk

Standardize (0.7 – 0.8 : 1 casein : fat; ~ 6% fat)
Pasteurize (not necessary if aged > 60 days)

Add chymosin  Add thermophilic and/or mesophilic
Add CaCl₂ (optional) starter culture (~38°C)

Coagulum

Check curd, Cut (2 – 3 cm cubes; no cooking), Heal (10 min)

Fill molds/allow to freely drain
Invert molds
Curd cut into blocks (after 2-3 hr)
Dry salt surfaces

Place curds in container (~14% NaCl)
~7 days

Fill container with brine
pH 4.5
14 – 16°C
3 – 4°C
> 2 months

Feta Cheese

Figure 1. Manufacturing protocol for Feta cheese (Fox et al. 2000; Kosikowski & Mistry 1997; ARS:USDA 1978).
Fresh, High Quality Sheep Milk

- Standardize (~2% fat)
- Pasteurize (not necessary if aged > 60 days)

Add chymosin
Add CaCl$_2$ (optional)
Add thermophilic starter culture (~38°C)

Coagulum

Check curd, Cut (rice sized; cook to >45°C)

Hoop & Press

Invert hoops

Whey

(after 2-3 hr)

Brine (>14% NaCl; > 4 hours)

Dry salt surfaces

Place wheels in room on shelves

~10-18°C

> 5 months

Cure (oil and/or clean rind regularly)

Romano Cheese

Figure 2. Manufacturing protocol for Romano cheese (Fox et al. 2000; Kosikowski & Mistry 1997; ARS:USDA 1978).
Fresh, High Quality Sheep Milk

Pasteurize (not necessary if aged > 60 days)

Add rennet (dilute) → Mesophilic starter culture (~27°C) → Coagulum

Check curd, Cut (1 cm sized curds; no cooking), Heal (10 min)

Drain whey & Inoculate with Penicillium roqueforti

Hoop (no pressing)
Invert hoops (every 6 hours; 5 days; 22°C; 85% relative humidity)

Brine (>12% NaCl; > 24 hours) or
Dry salt surfaces
Wax surface of wheels
Penetrate wheels with needles

Place wheels in room on shelves
~10-15°C; 95% humidity
> 2 months

Cure

Roquefort-style Blue Cheese

Figure 3. Manufacturing protocol for Roquefort-style blue cheese (Fox et al. 2000; Kosikowski & Mistry 1997; ARS:USDA 1978).
References


Appendix 1. Make Sheet for the Production of Stirred Curd Monterey Jack Cheese from Sheep Milk

Date: _________________________ Amount of milk (10 gallons): _________________________

Culture (lot #): ____________ Amount (1/2 pint): ____________

Coagulant (lot #): ____________ Amount (3 tsp ss): (dilute, 5 oz water):

Salt (lot #): ____________ Amount (~1/3 lb): ____________

<table>
<thead>
<tr>
<th>Operation</th>
<th>Target time/temp</th>
<th>Target pH/TA</th>
<th>Actual time/temp</th>
<th>Actual pH/TA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Add raw or past. milk</td>
<td>Warm gradually</td>
<td>6.7/0.20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Add culture</td>
<td>0:00/90˚F</td>
<td>6.7/0.20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Add chymosin, stir, then stop agitation</td>
<td>0:45/90˚F</td>
<td>6.6/0.25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cut curd</td>
<td>1:15/88˚F</td>
<td>6.5/0.18</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heat on (slow rise)</td>
<td>1:30/88˚F</td>
<td>6.5/0.19</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heat (increase agitation)</td>
<td>1:45/94˚F</td>
<td>6.3/0.20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heat off</td>
<td>2:00/100˚F</td>
<td>6.3/0.22</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Continue stirring (once every 5 min)</td>
<td>2:15/100˚F</td>
<td>6.1/0.24</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Do not go above 100˚F (can add cold water)</td>
<td>2:30/100˚F</td>
<td>5.9/0.26</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drain whey (allow curds to settle)</td>
<td>2:40/</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stir curds (every 5 min)</td>
<td>2:45/</td>
<td>5.8/0.28</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Measure/record pH/TA (every 15 min)</td>
<td>3:45/</td>
<td>5.3/0.32</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Salt (1/3)</td>
<td>4:00/</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Salt (1/3)</td>
<td>4:05/</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Salt (1/3)</td>
<td>4:10/</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fill hoops, molds or cheesecloth</td>
<td>4:15/</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Press or hang</td>
<td>4:30/70˚F</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Remove from hoop or cloth, wax or wrap</td>
<td>12:30/40˚F</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ripen</td>
<td>60 d – 6 mo</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Weight of cheese after pressed: yield:

Form updated: 09/30/09
There is no one perfect plant design

You have to design the plant for your operation
Every design is made up of trade-offs
   Money
   Space
   Time
Best if you can work at a plant first

Start with great milk

Milk at best when leaving animal, goes downhill from there
Milk the animal clean
Store it clean and cold
You want the milk to have your culture, not what is in barn

Raw / Pasteurized

Raw – cash flow, has to age, have to make everyday, don’t know how it tastes
Pasteurized – fresh cheese, sell right away, flavors

Big enough

Can’t build too big, can spend too much
Leave room for expansion
Most build too small

Utilities

Water, clean, potable, volume, does it dry up
   Will you need chilled water?
Septic, systems don’t like a lot of milk waste
   Needs to be large enough to handle
Located so no contamination
   Has to handle waste, soap, and sanitizer
Electrical, right voltage and phase
Much commercial equipment is 3 phase
Watch how they charge you
Residential / Agricultural
Commercial
Demand

Heating source for building heat, hot water, steam
Boiler fuel
Electric, Natural gas, Fuel oil, Propane, Wood
Steam
Clean
Culinary
Watch your boiler chemicals – are they food grade
Hot water
Will need enough
Fast recovery or large storage tank

**Size equipment to output**

Leave room for expansion, but you must fill at least half
Too small and you are doing many batches
Too big and will not properly work, inefficient
Best full, but will work between half and 2 third

**New or Used equipment**

New is great, every thing matches but expensive
Probably installed
Warranty
Watch for a salesperson that will sell you too much

Used is less expensive but you could be looking for the right piece
Internet searches
Word of mouth
Going out of business

Be careful buying used sight unseen
Not always like the picture
Flash on the camera will hide imperfections
Buckling, pinholes, valves, all parts
Usually no warranty
Ask for provision to send it back if won’t pass inspection
Pay shipping to get it here
Usually have to pay before you get it
You probably have to pay to send back
Make sure it will work with your utilities
May have to take what is available
Regulatory help
Local inspector may have knowledge of equipment model
Ag & Mkts has equipment specialist
3A marking
  National standard
  Not needed to be legal
  Just because it has it doesn’t mean it meets regulations

Separate building for plant
  50 feet separation is standard
  Site where contaminants won’t interfere
    Barnyard
    Manure pit
    Leach / septic fields
    Dusty road

Building

  Solid
  Secure

Parking lot

  Especially if you are going to have sales at plant

Plant design

  Layout on paper to scale, including equipment
  Make a person to scale and see how much room to move around
  Layout where the drains and hoses will be
  Easier to move equipment with a pencil
  Show the design to other people
    Regulatory
    Codes officer in local area
    Others in industry
  Are you right or left handed?
  Think about how you will work and how product flows
  Make sure you leave room all the way around equipment
  Look to have room for expansion
  Storage for small tools, you will want shelving close
    Knives, Moulds, Paddles, Screens, Rake, Scoops, Pails
  Where will you use water, you want hoses
    Use a dairy hose (food grade) not a garden hose
  Where will your drains be, slope floor to help you
    Don’t put equipment on top of drains
    Have enough so you are not chasing across plant
Other areas to think about

Bathroom
- When it is time to go, it is time to go
- Will always happen when you are about to do next step
- Make sure it won’t contaminate plant
- Ventilated, but not into plant
- Sink individual towels
- Usually have to go through 2 doors
- Door will be self closing

Office
- Nice to be separate room so it won’t get wet
- Desk and file cabinets, records will be your best friend
- Inspector will like to have a space not in your way
- Copy of the regulations
- Computer, telephone

Lab
- Need to do antibiotic testing
- Some may do more tests
- Storage for scales, PH meters, other equipment
- Nice to be away from plant
- Could be with office

Storage rooms
- Dry for paper products
- Chemicals
- Food related – cultures, flavors
  - Refrigerated / Frozen / Dry
- Packaging supplies
- Spare parts, spare equipment

Aging room
- Large enough to rotate stock
- Shelving to find individual batches
- Has to hold temperature and humidity

Equipment

Pasteurizer – unless you are going raw
- Batch - smaller, less expensive, lower temperature, many used
  - Steam
  - Electric
- HTST – continuous, larger, more expensive, auto controls

Cheese vat
- Size to your production, don’t get too big or small
- Manual or mechanical cutting and agitation
- Make sure you have room all the way around
Draining tables
Get them close to vat
Move them out of the way
Can they go right into the cooler?

Wash vat
Some thing that has wash water very easy to use
Clean equipment is happy equipment and good cheese

Raw milk receiving room
Separate room
Able to get truck in
Ability to wash truck
Sink individual towels

Raw milk storage
How many days will you make?
How many days do you need to store?

Packaging, cutting, wrapping, labeling
Equipment to wrap or package
Tables
Shelves
Boxes

Cooler
Big enough for stock
Shelving so that you can find product
Keep product off floor
Good lighting
Constant temperature

Other equipment depending on product
Brine tank
Salting table
Chilled water tank
Stretching machine (Pasta Filita)
Press

Sales area
Will you sell from the plant?
How much do you want people to see?
What don’t you want them to see?
Coolers
Shelving
Sales counter

Changing room
Keep plant clothes and boots separate
Have a separation between work and home
   Mostly for contamination
Entrance / Reception area
If no sales area, where will you meet with people?
Don’t want them in your plant
Good impression

Break room
Will you have employees?
Can’t be eating in plant

Plant interiors

Walls / Ceilings – washable, cleanable, smooth, impervious
No bare wood!
Paint will work, keep it in good condition
Tile, nice expensive
FRP – fiberglass reinforced plastic, nice

Lighting
Enough, make it bright
Sealed or at least covered
Natural or Artificial
Windows
Not operating (can’t open)

Floors – washable cleanable, smooth, impervious
Dairy tile with acid resistant grout, expensive
Epoxy, nice
Cement/concrete, keep it in good shape
Acid will pit it easily

Heating / Cooling / Ventilation
Make your plant comfortable
Constant temperature and humidity makes good cheese
Watch for drafts, will carry contaminants

Put pride in your plant

People will notice
Will make it easy to put pride in your product
Remember it has your name on it
Green Dirt Farm, LLC is a grass-based sheep dairy and cheese making operation owned by Sarah Hoffmann and Jacqueline Smith. The business was started in 2002. We started almost totally from scratch. That is, all that we had was the land and an idea- no sheep, no barns, no fences, no equipment, and no know-how. Our intention from the outset was to milk sheep and make cheese with the milk; however, we did not have enough experience or money to build the facilities. So, initially, we sold lamb at a local farmers’ market, selected our flock, built fences, improved our pastures, milked a bit and practiced making cheese.

Our first milking facility was in a tent, with a single wooden head gate, a generator and a portable vacuum pump. We eventually graduated to a barn and a six-headgate platform that we bought from Major Farms, using the portable pump and making cheese in our home kitchen. These facilities did not pass muster with our State Milk Board, so we were still unable to sell our cheese. Starting slowly like this allowed us to make mistakes without disastrous consequences. It also gave us time to gain knowledge, figure out how we would finance the project and reflect on the design. We visited many different dairies and cheese facilities, took classes, enlisted the help of experts and did lots of thinking.

In 2008 we built a new milking parlor and separate cheese kitchen. Our new milking facility is a single twelve low line parlor. It was built to accommodate expansion to double twelve in the future. The cheese kitchen was built immediately adjacent to the parlor (11 feet apart) and downhill (the cheese kitchen is built below grade like a house basement) to allow the milk to be gravity fed from the bulk tank to the cheese kitchen where it can be directed to the pasteurizer, to a vat or to bags for freezing.

The cheese kitchen is a 2000 square foot building that houses our office, a small (250 sq ft) entry space with a viewing window into the make room, (the space was designed to be used for retail sales and tours), a bathroom, 4 walk-in cold rooms (a conventional freezer, a refrigerator, and 2 aging rooms), a mechanical room, and the make room itself (600 square feet).

The make room contains a 100-gallon vat pasteurizer (from Dairy Technology, USA), two stainless steel drain tables (from Glengarry Cheesemaking Supply), three 22-gallon plastic coagulation vats, a rolling cart, a three compartment sink, a commercial dishwasher, a hot and cold water mixing valve hose bib, a thirty foot hose, a whey drain and sump pump (to pump the whey to a holding tank), shelves for holding small equipment, packaging materials and cheese making records, and a small stainless table for laboratory equipment (Delvo testing and pH meter.) Most of the stainless equipment was bought used from a restaurant salvage business.

Sarah designed both buildings with lots of help from DeLaval, Neville McNaughton, and The Dairy Practices Council publications. The primary considerations in the design were: 1. Ease of cleaning, 2. Process efficiency 3. Energy efficiency and 4. Economics. To finance the project we
used Sarah and her husband’s retirement savings and Jacque was able to secure low-interest FSA loans for her side of the business.

Both buildings are metal on concrete foundations, with blown on closed cell insulation or rigid foam board insulation. We used 6in of rigid foam board on the outside of the cheese kitchen foundation walls, 2 in on outside of parlor concrete stem walls, 4in under the slab in cheese kitchen, and 6in under the cold room floors- we used metal faced bubble wrap under the slab in the parlor (since we did not think this building needed tight insulation.) Interior walls are either sealed concrete or plastic wallboard (Extrutech Plastics) mounted on metal studs. We used only concrete, metal, and plastic materials to minimize the rot and deterioration that is inevitable in such a high humidity environment and to maximize our ease of cleaning. Both buildings utilize radiant floor hot water heat provided by Takagi tankless propane hot water heaters. Separate tankless propane hot water heaters also provide hot water for cleaning and for the process equipment in the buildings. We use an old 250-gallon milk bulk tank to chill water for cooling the milk after pasteurization.

Figure 1. Design of Green Dirt Farm milking facilities (upper left) and cheese processing and curing building (lower right).

The building progression had the usual delays, mostly weather related, which set us back 6 months in 2008. We were very fortunate in that we had good experiences with nearly all of our
subcontractors. We had an excellent electrician and plumber. For the most part, the design works well and we are very satisfied with it. There are a few minor things we would change- (Such as enclosing the whey drain, and not using radiant floor heat in the cheese kitchen itself.) There are a few pieces of equipment that we bought but didn’t really need (like a steam kettle and a milk pump.) If we had to do it all over again our strategy would be to buy only the bare minimum of equipment to get started and add things slowly only when it proves to be truly necessary.

We also had some unexpected good fortune with regard to the building design. We found that because of the placement of our refrigerator and freezer in the bank of cold rooms, we can achieve ideal aging conditions without having to provide mechanical refrigeration to the aging rooms. The cold rooms are all adjacent to one another separated by metal and foam sandwich walls (from Advanced Insulation Concepts). The refrigerator is on one end, next to it is an aging room, next to that is a -20deg freezer, and next to that is the second aging room. The aging room that is between the freezer and refrigerator maintains about 50 deg and close to 100% humidity. The aging room on the end next to the freezer maintains temp at about 55 deg and 95% humidity.

This is our first full year in operation. We’ve made some mistakes and had many challenges but overall it’s been a really great year for us. The experience has been quite extraordinary; often gratifying, occasionally frustrating and/or terrifying, but never a dull moment.
HIDDEN SPRINGS EXPERINCE WITH PLANT DESIGN

Brenda Jensen
Hidden Springs Farm and Creamery
Westby, Wisconsin, USA

Hidden Springs Farm is located in Westby, WI. Our farm consist of 76 acres, milk parlor, 2 large hay storage buildings, a machine shed, creamery and many 3-sided lean-twos to provide shelter. We have fresh water to every paddock, and most paddocks have shade available. We have been milking dairy sheep for 8 years and making cheese for 3 years. Last year we milked 145 East Friesian and Lacaune dairy sheep. We will be doubling our milking flock next year. We also buy all of our Amish neighbor’s milk next door, and he will be increasing his milk production next year.

We first began our cheese making quest making cheese at other plants. We would highly recommend this for costs purposes. Cheese plants in Wisconsin are generally very busy and short of employees. (Due to hard labor) This being said it can be very difficult to have your cheese made at these facilities. After the 3rd plant and getting over 60 miles away, we decided to build our own farmstead creamery.

We hired a consultant who was very knowledgeable about cheese. We on the other hand were not really sure who we wanted to be, how big we wanted to be, what cheeses we wanted to make, how much we were going to sell, how often do we plan on making cheese, will we have employees?. After completing a business plan, looking at cheese processing costs, and deciding to use a current foundation structure on the farm, we began our remolding and building project.

We have a current structure of over 1325 square feet. We 2 - 8x 10 underground man-made caves with a hallway in between them with a stairway, storage area for supplies and an area for a lift or dumbwaiter (one day). We currently do have additional cooling and heating units in these caves. They have 8 inches of concrete, 3 inches of installation, and 3 feet of dirt, 2 rubber membranes, 3 and feet of dirt. We could not consistently hold the temperature, so we have built a retaining wall and added dirt and insulation. We age our raw milk washed rind in these caves.

The make room has pitched ceilings for great ventilation. The creamery is underground built in a basement and stays very cool in the summer, and is easy to heat in the winter. We have a 200 gallon vat pasteurizer, a 200 gallon vat and a 40 gallon vat. We have a press, stainless steel 3 compartment sink, hand wash station, a long stainless steel work table, and a hanging rack for the soft fresh cheese.

We have 2 walk in coolers, where we store and age our other cheeses in these coolers. The receiving area is currently for the canned milk. Milk comes in cans from our Amish neighbor, we also had been transporting from our bulk tank to the receiving area in cans. This next season we will use a very controversial transport tank. To do this we will need to remodel our existing receiving area to accommodate for the transport tank.
The state of Wisconsin has very little requirements for cans. Reasons being not many cans are used any more, and they are mostly used by the Amish. Our small transport tank will be regulated just like the big over the road tankers and must meet the state requirements. Before attempting to get a transport tank made, consult your state regulations, just because you see a tanker being used, does not mean that you can legally use this style of tank, the tanker may be grandfathered in.

We processed over 84,000 pounds of milk this last season and purchased milk from the WSDC. We made 4 different styles of cheese with various flavors. We also have a blue cheese made with ours and WSDC’s milk at an outside plant. We sell 30% at Dane County Farmers Market at retail price, 30% at distributor’s price in CA, NY, and the Chicago area, and 40% at wholesale price in WI, Ill, and MN. I do the wholesale sales and distribution to all wholesale customers.

Our biggest challenge in building our cheese plant was the state of Wisconsin requirements. We had our inspector visit with us right at the start and asked for recommendations. His first recommendation was to visit the other farmstead plants. He also recommended not building because it’s a big head ache with a lot of requirements. Our inspectors argued with each other, changed their minds on things as we were building, did not provide good clear information, and literally many times sent us down the wrong path. This was very costly and time consuming.

We are very happy with our current design of the plant, the space we have is conducive for growth. We have plenty of work space, room for much more equipment, and space around the plant to build more caves or add packaging facilities, or store front. We have built dry storage in the attic and can grow that very easy when needed. We have a lot of room for parking and semi load and unload areas. HSC will add 2 new employees this next season, and double our milk availability. We will be making some trials of yogurt at an outside facility and internally developing a mixed milk cow sheep blend.

Hidden Springs Creamery is excited about a profitable and exciting year in 2010.
• The creamery is situated where the old mechanic shop was but only the left hand door as shown above is the original building.
• The main floor of the creamery and the aging rooms and an office are in the old mechanic shop with no basement.
• The new section out front is the blue cheese-make room on a slab.
• The new section to the left is 2 additional aging rooms on a slab.
• The 2 new sections to the right are the receiving spaces for the milk, the bulk tank room, the clean room, the clean in place room, the lab, the wrapping room, refrigerator, freezer, employee space and bathroom, and the wrapping and shipping spaces.
• YES YOU NEED ALL THESE SPACES AND LOTS MORE FOR STORAGE.
Great things about our creamery……….  
• The main section of the creamery, the creamery floor and the aging rooms are designed very well for the purpose of making cheese.  
• The temperature and humidity controls of the whole creamery make for consistency in product. EXTREMELY IMPORTANT!!!  
• Aging rooms are all adjacent to the main creamery floor.  
• Floor drains work well  
• Filtered HVAC separates filtered intake air  
• BRILLIANT IDEA…An exterior Ice bank which runs off- peak at night and stores the ice until the day to be used to chill the coolers, pasteurizers and incubators.  

ICE BANK  

AGING ROOMS  

• The aging rooms are all adjacent to the make room.  
• BUT we have learned from our mistakes  
  o The hall in the aging area should be much wider so two persons with carts can pass.  
  o Wider doorways
- Might be using frozen milk and need space for storage and thawing
- Oversize a little more when you begin your design
- When you go from one style of cheese to another, you may need completely different set of make spaces and aging rooms.
- When you try to add the yogurt production and a larger yogurt filler, you just are too crowded.
And more packing space…..

And more trash space

More space for the SEPTIC SYSTEM
And don’t forget SPACE for storing boxes, shipping supplies, cups, stickers, labels, wrapping papers, salt, maple syrup, other flavorings, hairnets, milk samples, and empty milk sample units, refrigerators and the rest of the kitchen sink that goes along with the operation of milking and cheese and yogurt making.

If we did it all over again, we would start with a huge warehouse type building and infill with what you need as you need it.
Introduction

Ever wonder why your animals eat the things they do, and sometimes do not eat what you think they should? Or worse yet, they do not eat what your fancy computer-based ration balancing program tells you they require? Well, I have some bad news. Your animal is probably not wrong. Rumor has it they were one of the original lie detectors. For hundreds of thousands of years before we came along to show them the error of their ways, the ancestors of our modern herbivores foraged, lips to leaves, in and among a vast array of plants in their environments seeking out the foods that most closely met their ever-changing nutritional requirements and leaving behind those that did not. As it is today, some plants were higher in nutrients and lower in toxins, others were higher in toxins but lower in nutrients, and some plants varied in nutrient to toxin ratio by location, time of day, season, and environmental conditions. Selecting what to eat and where was, and still is, dangerous. Consuming the wrong plant at the wrong time or eating too much of one plant and not enough of another can cause sickness, malnutrition, and even death. The question is how do animals select diets that are higher in nutrients and lower in toxins? Is it the luck of the bite, or is there more?

While some folks view the foraging activities and diets selected by grazing animals as little more than the aimless wanderings of animals looking for something to eat, and eating whatever is available, a closer look at these activities reveals that this is far from the truth. Herbivores, both wild and domestic have evolved a very sophisticated strategy for evaluating foods and selecting diets that closely match their ever-changing nutritional requirements. And despite an occasional glitch now and then, modern livestock remain well-adapted for coping with foraging for a living in a world that is constantly undergoing change, very complex, and inherently unpredictable.

Behavior-Based Grazing Management

Behavior-based grazing management, which I define as the incorporation of behavioral principles in grazing management planning to enhance animal well-being, ecosystem health, and enterprise sustainability, represents a divergence from contemporary livestock production systems (including most organic and pasture-based systems) in that it replaces “animal = machine” with the understanding that “animal ≠ machine.” Rather, animals are living, breathing, social creatures that have likes and dislikes, feel pain, discomfort, and stress. They prefer familiar foods to novel foods, mixed diets to monotonous diets, familiar environments to unfamiliar environments, and prefer to be with companions rather than strangers. Unlike on modern factory farms where these attributes and characteristics are often viewed as impediments
to efficient production, in behavior-based management, they are accepted as part of the natural behavior of animals to be understood, embraced, and incorporated into production systems. The more we recognize and accommodate the nutritional and behavioral needs of our animals, rather than dictate what they are going to get and under what circumstances, the more contented and productive they and we will be, and the more efficient our production will be from grass-based production systems.

**Diet Selection is a Learned Behavior**

One of the very first things that need to be recognized in order to effectively adopt a behavior-based management strategy is that most all behaviors are a combination of genetic and environmental influences. Genes provide the blueprint that makes a sheep different from a bird. But life experiences acting on the genes create the individual. For example, birds have wings and feathers, thus they fly. However, upon taking that first plunge out of the nest, where do most young birds end up? The neighbor’s cat never seems to lack food during spring and early summer. Flying is something birds can do based on their genetic blueprint, but getting good at it requires practice. Sheep are herbivores; they have rumens, and are thus genetically programmed for eating forage. However, a ewe that has been raised and fed in confinement it’s entire life, never setting hoof in a pasture, will not recognize pasture as food or have a clue as to how to actually eat the stuff. Grazing is a learned behavior, and like most learned behaviors, it is best to start when young and with the animal’s own mother serving as a social model.

**Individuals Versus the Group**

It is common practice on most farms today to not feed individual animals but rather to feed groups of animals. This is an industrial agricultural practice based on cheap, readily available, and abundant fossil fuels, and it has led to an almost complete disregard for the uniqueness of the individual. Unfortunately, for the animals, no two in a herd, flock, or group look the same, act the same, or eat the same things in quality or quantity. Why should they? They are as unique as each and every one of us. This is especially true in dietary preferences and food requirements. Animals vary in, among other things, age, general health and condition, stage of lactation, milk production level, ability to cope with environmental stress factors such as heat, humidity, and you. Nutritional requirements are specific to each animal and are influenced, along with the above, by their life experiences (what they have learned to eat) and the influence of the nutrients and toxins consumed in their previous meals. Thus, when we use computer-based ration balancing programs to create group rations, how many of the animals in the group are being fed to their actual nutritional requirements? I suggest, not many. The take home message here is that nutritional requirements, foraging behavior, and diet selection varies with the individual, and in grass-based systems it behooves us to ensure that pastures consist of a wide variety of plants so that individual animals may be nourished to their own specific needs.

**Grazing as a Mechanical Process**

From a behavioral perspective, dry matter intake is a function of three variables. The number of bites an animal takes per unit of time (bite rate), the amount of food taken in with each bite (bite size), and the amount of time an animal spends grazing (time). Although rather simplistic
in nature, anything that interferes with or impedes this process will lower dry matter intake, and thus animal performance will be reduced. Keep in mind, each animal is an individual, and there is great variability in the above factors. Some animals will take more bites per minute, but take smaller bites. Some animals will take larger bites, but fewer bites per minute. Some animals will take fewer bites per minute and smaller bite sizes, but will graze longer to achieve nutritional satiety. Generally, animals take 50-70 bites per minute, ingest .02 of an ounce or less of forage with each bite, and will graze about 8 hours a day (generally about 4 hours in the morning and 4 hours in the evening). However, depending on forage availability and quality, and the animals experience with the forage, this can range between 5 and 13 hours.

Forage Availability and Quality

Forage availability is correlated with pasture height and density. The taller and denser the forages are in a pasture, the greater the forage availability. However, there is more to high animal intake than just forage availability. We must also consider the quality of the plants. Generally speaking, pastures managed for high intake should be very dense grass-legume combinations grazed from a 6-8 inch starting height to no closer to the ground than about 2 to 2.5 inches. From a behavioral perspective, when pasture plants are taller than 8 inches, the fiber values increase to the point where leaf shear and tensile strength begin to slow bite rate. In addition, the longer leaves must be chewed and manipulated more before they can be swallowed. Collectively, these two factors slow bite rate. When pasture plants are in the 4 to 6 inch range, bite size is typically reduced. However, animals can adapt to this by taking more bites per minute and grazing longer to maintain intake. When pastures are less than 4 inches, dry matter intake drops because they cannot adapt any further. In addition, animals prefer legumes over grasses by a 70 to 30 ratio. Legumes are higher in protein and energy, are more digestible, and animals can eat legumes faster than they can eat grasses.

Food Neophobia

Neo- means early, and a phobia is a fear. Thus, food neophobia is an early fear of food. In other words, at first exposure to a new or novel food, most animals are likely not going to eat much of it. Familiar foods with desirable nutritional qualities are readily consumed. Unfamiliar foods are viewed as potentially dangerous and are avoided. Because all foods are toxic at some level (some more than others) it does not pay an animal to be the first to eat the most toxic plant in the pasture. So when animals are introduced to new foods, intake generally drops until enough of the food has been eaten that it can be evaluated postingestively. Thus, if you have a need to introduce a new plant species into your pasture, it is best to interseed it into a pasture with species known and readily accepted by your animals; otherwise, at first exposure, intake will likely drop, along with animal performance.

Conditioned Taste Aversion

While familiarity with a food item that meets a particular nutritional requirement is a precursor to high initial intake, animals, over time, can develop what are known as “conditioned taste aversions”. Conditioned taste aversions are believed to have evolved as a survival mechanism that inhibits animals from over-ingesting foods that may be nutritionally adequate
but contain toxins, or foods that are inadequate (excessive or inadequate) in nutrients that, perhaps, taste good.

For example, some of us hold the fresh, hot-out-of-the-oven cookie in extreme high esteem. I, personally, can eat at least three and maybe even four of my wife’s chocolate chip cookies and do so without breaking a sweat! However, by the time I get to the third cookie, somehow it does not taste quite as good as the first one. While the last cookie is exactly the same in content, texture and delightful gooiness as the first, the last is just not as palatable as the first and, thus, my preference changes. However, after drinking a glass of milk, my aversion to the flavor of the last cookie subsides and that fourth cookie goes down just fine. Just like me and chocolate chip cookies, grazing animals can over-eat even their most preferred or favorite foods, and end up wanting to eat something else.

**Total Ration Factors**

What an animal chooses to eat at its next meal is strongly influenced by the chemical composition of its previous meal. Thus what is fed in the form of concentrates or additional forages in a feed bunk or in the barn strongly influences what an animal will select to eat from pasture. While forages generally substitute for pasture on a 1 to 1 basis, concentrates substitute on ratios of .4 to .6 to 1. However, because there is more to a food than just its volume, these ratios tend to be not overly accurate. All foods can be viewed as part nutrient and part toxin. As a result, animals have to evaluate not just the nutrient-nutrient interactions, but also the nutrient-toxin, and toxin-toxin interactions. Feeding a concentrate high in protein to animals on high protein pasture is guaranteed to lower the intake of pasture. Protein in excess of animal requirements converts to ammonia in the rumen, and this shuts down intake. In addition, energy is diverted away from milk production to detoxify and eliminate the ammonia. The short of it is, do not over-feed nutrients in barns or bunks if you want your animals to consume as much pasture as is possible. This is especially true concerning the feeding of supplemental protein.

**Summary**

Grazing behavior and diet selection are learned behaviors. They are best started when young and with its own mother serving as a social model.

Each animal has its own unique dietary requirements. To meet these varying requirements it is best to graze pastures with high plant diversity.

Grazing is a mechanical process based on bite rate, amount of food taken in with each bite, and the number of hours a day an animal spends grazing. Anything that gets in the way of this process will reduce intake and animal performance.

To ensure high dry matter intake, pasture should be dense and grazed from a height of no taller than 8 inches down to a residual of not less than 2 inches.

Animals are neophobic. They have a natural fear of novel or new foods. Make sure your animals know what they are eating.
Animals do not like to eat the same foods day after day any better than you do. To reduce the influence of conditioned taste aversions, make sure your pasture consists of many different plants, especially a high percentage of legumes.

Total ration factors play an important role in what an animal is willing to eat from pasture. Be careful of how much and what kind of supplemental concentrates you feed. You could be reducing pasture intake and costing you both production and money.

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Background

Protein Requirements for Lactating Sheep

Dietary protein recommendations for lactating sheep include amino acid requirements for maintenance, tissue and wool growth, and milk production (NRC, 2007). These requirements are met by a combination of feed, microbial, and endogenous protein. Rumen microbes utilize energy from fermentable carbohydrates and nitrogen (N) from peptides, amino acids (AA), and ammonia to grow and multiply (NRC, 2001). After leaving the rumen, feed, endogenous and microbial proteins are exposed to acid-pepsin digestion in the abomasum and pancreatic and intestinal proteases in the small intestine. The amino acid products are absorbed in the small intestine, transported to the liver, and may reach the mammary gland to contribute to milk protein production. The utilization of amino acids for milk protein depends on the quality and quantity of the amino acids leaving the rumen and their degree of intestinal absorption. The dynamic process of rumen fermentation creates challenges to balancing diets for ruminants to optimize nitrogen utilization for milk production.

Rumen Degradable Protein

Rumen degradable protein (RDP) is composed of non-protein N and true protein N. Non-protein N is present in the form of AA, peptides, nucleic acids, and ammonia. Rumen microbes utilize N from ammonia, amino acids and peptides to support microbial protein growth (Argyle and Baldwin, 1989; NRC, 2007). Through the fermentation of feedstuffs, rumen microbes alter the profile of amino acids reaching the small intestine. Rumen microbial protein (MCP) is the primary source of protein for ruminants and may constitute 60 to 75% of the AA flow to the small intestine (Agricultural Research Council, 1980; Clark et al., 1992). In dairy cows, Hristov et al. (2004) reported 61% of milk protein N originated from MCP. Therefore, diet formulation must incorporate adequate RDP to support microbial growth. Inadequate RDP compromises microbial growth, leading to a reduction in DM digestibility and nutrient availability to the host (Stokes et al., 1991; Clark et al., 1992).

Since microbial growth is dependant on the utilization of fermentable carbohydrates, RDP recommendations for sheep in the NRC (2007) are based on the concentration of dietary total digestible nutrients (TDN), with a correction for physically effective fiber levels below 20% of dry matter (DM). Recent guidelines (NRC, 2007) indicate that a 100 kg (220 lb.) dairy ewe producing 2.37 to 3.97 kg (5.2 to 8.7 lb.) milk/day requires 8.6% RDP, as a percentage of DM intake, to maximize microbial protein production in the rumen.

Excess RDP can have negative consequences on animal performance and the environment. Ammonia-N appearing in the rumen may be absorbed across the rumen wall, captured in the
blood, transported to the liver and detoxified to urea. There is an energetic cost to the host to
detoxify and excrete this excess urea (Cannas, 2002). Excess RDP reduces embryo quality in
sheep, possibly related to ovarian steroid concentrations affecting embryo development and
transport (Berardinelli et al., 2001; Fahey et al., 2001). While 10 to 80% of urea (reported 58%
in sheep; Lobley et al., 2000) is recycled back to the rumen through saliva or blood, the excess is
excreted via urine (Clark et al., 1992; Castillo et al., 2001). Urinary urea readily volatilizes and
contributes to environmental pollutants such as atmospheric ammonia and fine particulate matter.

**Rumen Undegradable Protein**

Rumen undegradable protein (RUP) bypasses rumen degradation and reaches the small
intestine unaltered. Since this protein source does not rely on rumen fermentation, feeding
dietary RUP can increase the flow of AA above MCP supply. However, intestinal absorption of
these proteins depends on their post-ruminal digestibility, which varies between and among
protein sources. In an evaluation of various animal feed products, Stern et al. (1997) reported
that intestinal absorption of RUP sources ranged from 22 to 67%. Santos et al. (1998) reported
that while RUP supplementation increased the flow of essential amino acids to the small
intestine, the flow of the first limiting AA were not consistently increased. Therefore, both
source and quality of protein must be considered when evaluating results from trials with RUP
supplementation and may explain the inconsistent effects of RUP on milk production in
published literature.

Heat treatment of soybean meal (SBM) is an effective way to decrease rumen degradability
(Broderick, 1986), with higher temperatures and longer holding time decreasing rumen
degradability (Faldet et al., 1991). Expeller SBM (ExSBM) is created by a process of heat-
treating SBM to high temperature (> 160°C). Broderick (1986) reported that ExSBM increased
RUP by 64% compared to solvent SBM, resulting in decreased rumen ammonia and blood urea
levels for cows fed ExSBM. Other trials report that supplementation with RUP from ExSBM
increased the flow of non-ammonia, non-microbial N to the small intestine and increased milk
production by 7 (Cunningham et al., 1996) to 10% (Broderick et al., 2002). When alfalfa silage
(high in RDP) was the primary forage source, ExSBM increased milk yield by 3% compared to
solvent SBM (Broderick et al., 1990) and increased N efficiency by 4% (Titgemeyer and Shirley,
1997).

There is no specific requirement for RUP in lactating ewe diets. The NRC (2007) guidelines
present dietary recommendations for diets containing 20 to 60% RUP as a % of crude protein
(CP). For a 100 kg dairy ewe producing 2.37 to 3.97 kg milk/day, as RUP increases from 20%
of CP to 60% of CP, dietary CP requirements decrease from 17% to 15.5% of DM.

**RUP Feeding Trials**

In dairy sheep, there is an established milk yield response to increasing dietary CP. In mid-
lactation ewes fed diets with CP ranging from 14 to 21%, milk production reached a plateau with
the diet containing 18.8% CP, regardless of dietary energy level (Cannas et al., 1998). Purroy
and Jaime (1995) also report a 14% increase in milk production and no effect on milk protein
percentage with dietary CP increasing from 13 to 16%, regardless of protein source. Gonzalez et
al. (1984) fed diets containing 12.8, 15.5 and 18.6 % CP and three levels of energy. In ewes fed the highest energy level, milk (+23%) and milk protein (+9%) yield increased linearly with increasing dietary CP. However, many trials provide no indication of protein degradability of the diets, making isolation of the effect of RUP difficult to determine.

Among the trials conducted on lactating sheep, many include non-dairy breeds, which have lower potential for milk production and lower protein requirements than dairy ewes. In addition, many trials were conducted using milk production and milk measurement techniques which may compromise the potential for peak milk production. Considering trials from dairy and non-dairy sheep breeds, five of eight trials reported increased milk yield due to protein source. Among these trials, there are none conducted on dairy ewes machine milked from lambing, the common management technique for dairy ewes in North America. However, considering only trials with hand milking from lambing or oxytocin-induced milk yield from ewes suckling lambs, five of seven trials report increased milk yield with RUP supplementation.

Fish meal (FM) is the most common source of RUP in these trials. Trials reported an increase in 13 to 27% when supplementing FM and blood meal compared to soybean meal (SBM), ground nut meal (GNM), and meat and bone meal (Robinson et al., 1979; Loerch at al., 1984). Robinson et al. (1979) reported that milk yield responded within 3 days to FM withdrawal or reintroduction in ewes in early lactation (week 2 to 5). In most of the trials reporting milk composition, milk protein percentage was not affected by protein source. However, due to increased milk yield, milk protein yield did increase. Of the trials reviewed, only Robinson et al. (1979) reported increased milk protein percentage from the feeding of RUP sources (7.9, 7.4 and 7.5% increased protein with the FM, SBM and GNM diets, respectively).

Grazing Dairy Ewes

The majority of dairy sheep production in North America is based in areas well suited to pasture production, such as southeastern Canada, the Upper Midwest and New England. During the grazing season, sheep milk producers utilize improved pasture as the primary source of forage and provide supplemental grain (generally corn) in the parlor.

While temperate grass or mixed grass-legume pastures may be high in CP, this protein source is also highly degradable (>70%; Bargo et al., 2003). Fresh grass and legume forages contain the highest and most variable non-protein N (30 to 65%; Schwab, 2003) compared to silages (15 to 25%; NRC, 2001) and greater RDP than hay (Broderick et al., 1992; Messman et al., 1994). Høngerholt and Muller (1998) found an average of 84% protein degradability in cows grazing primarily orchardgrass and Kentucky bluegrass pastures. Extensive rumen proteolysis may lead to the formation of ammonia in excess of microbial utilization (Beever et al., 1986). These ruminal N losses may lead to a shortage of absorbable AA in the small intestine. Therefore, RUP supplementation may be particularly relevant to grazing, lactating livestock.

Trials in dairy cattle with supplementing RUP offer mixed results. In dairy cattle grazing grass pastures, supplementing RUP from an animal protein blend (meat and bone meal, blood meal, feather meal, poultry by-product and FM) had no effect on milk yield, but did increase milk protein production by 8% in multiparous cows (Høngerholt and Muller 1998). However, in
situ measurements indicated that the RUP treatments only differed by 1.4% RUP, which may have been too close to elicit a milk yield response.

In high yielding, multiparous cows grazing mixed grass-legume pastures, blood meal increased milk yield by 17% and milk protein yield by 14% compared to cows supplemented with SBM (Schor and Gagliostro, 2001). Supplements were isonitrogenous, but CP degradability was 52% for blood meal and 92% for SBM. Blood meal increased RUP (% of CP) from 33.4 to 45.3 in these 16% CP diets and reduced rumen ammonia production by 16%. In another trial, early lactation dairy cattle grazing mixed-alfalfa based pastures, FM increased milk yield by 6% and milk protein yield by 11% compared to sunflower meal diets (Schroeder and Gagliostro, 2000).

Nitrogen Excretion

**Fecal Nitrogen.** Fecal N is comprised of MCP, undigested feed N, and endogenous N. These N forms vary in their utilization by plants in the soil. Organic forms of N, such as endogenous and MCP, readily contribute to crop N and may be available for plant uptake within the first year. However, undigested feed N mineralizes slowly in the soil, making it relatively unavailable in the short term (Powell et al., 1999).

**Urinary Nitrogen.** Ammonia not utilized for MCP is absorbed across the rumen wall or any other part of the gastrointestinal tract through passive diffusion. The liver removes this toxic ammonia from the blood and detoxifies it to urea, which is primarily excreted via kidneys in urine. However, depending on intake, diet composition and production requirements, 19 to 95% of the urea may be recycled to the gut via blood and 15 to 94% may be recycled to the rumen via saliva. Urea capture and recycling is an important feature of ruminant metabolism. When faced with low protein diets, sheep can utilize 85 to 90% of recycled urea-N for microbial growth in the rumen. However, when dietary CP increases (above 14%), less than 50% of recycled urea-N is utilized for microbial growth.

Urine is the primary excretion route for excess N. In 40 kg (88 lb.) wethers grazing grass pasture at maintenance levels, they consumed 14.5 kg of N intake, and 26% was excreted in feces, 70% was excreted in urine, and 3% was retained (Barrow and Lambourne, 1962). Sheep urine reportedly contains 0.08 to 2.44% N (Street et al., 1964) and is distributed in the form of urea, creatinine, purine derivatives, free amino acids and ammonia. Urea can represent up to 75% of this N pool. The urease enzyme produced by fecal and soil bacteria converts urea to ammonia, which may be lost to the environment through volatilization. A reduction in urinary N has the potential to minimize the environmental impact of livestock production.

The most effective way to decrease urinary N is to decrease protein intake. Increasing dietary CP consistently increases urea levels, as measured in blood, milk or urine. Sevi et al., (2006) reported that ewes consuming 16% CP diets excreted more feces, fecal N, total water, urinary N than ewes consuming 13% CP diets. In this indoor feeding trial, pens were cleaned in the same manner, but pens of ewes on high CP diets had higher somatic cell counts (SCC) and total coliform colony forming units. Thus, similar to dairy cattle, reducing urinary N excretion is a promising means of controlling and reducing N excretion (Tamminga, 1992).
**Milk Nitrogen.** Nitrogen in milk is distributed between true proteins (casein, whey) and non-protein N. The true protein content of milk is of particular importance to dairy sheep producers, as sheep milk is almost exclusively made into cheese. Milk protein contributes more to cheese yield than milk fat. However, modification of milk protein content of milk is difficult to achieve through nutritional manipulation (Pulina et al., 2006). Therefore, increasing N capture in milk protein may be dependent upon increasing milk production without affecting milk component concentrations.

Milk protein is derived from blood AA and synthesized in the secretory cells of the mammary gland. These AA are supplied by dietary RUP, post-ruminal degradation of MCP, transamination of AA in the liver, and mobilization of tissue protein. Post-ruminal MCP supply is influenced by energy supply to the rumen, supporting the positive relationship between milk protein and dietary energy in early lactation (Pulina et al., 2006).

**Milk Urea Nitrogen.** In addition to excretion via urine, blood urea may diffuse across cells in the mammary gland and equilibrate in milk (Baker at al., 1995; Jelinek et al., 1996). Milk urea N (MUN) does not contribute to the true protein fraction of milk, and its concentration serves as an indicator of N lost via urine (Kohn et al., 2005). Research indicates that MUN may also be used as an indicator of CP intake in dairy sheep (Cannas et al., 1998). Cannas (2002) recommend MUN levels for dairy ewes of 13 to 21 mg/dl. Low MUN can indicate insufficient dietary protein. High MUN levels indicate excess protein feeding and urea excretion.

**Nitrogen Efficiency**

With regard to milk N production, gross N efficiency may be calculated as:

\[
\text{N efficiency} = 100 \times \frac{\text{milk N}}{\text{feed N}}
\]

where: milk N = (g milk protein/day) / 6.38

feed N = (g feed crude protein/day) / 6.25

In dairy cattle, reported gross N efficiencies range from 26.2 to 33.8% (Wattiaux and Karg, 2004). However, N efficiency in dairy sheep ranged from 12 to 15% (Mikolayunas-Sandrock et al., 2009). One reason for lower N efficiency in sheep is that the efficiency of conversion of metabolizable protein to milk protein is lower in sheep than in dairy cattle, 0.58 vs. 0.67 (NRC, 2007). In addition, the intense genetic selection of dairy cattle for increased milk yield may have increased efficiency of N utilization of dairy cattle beyond the current genetic potential of dairy ewes. As an example, the energy requirement for lactation in dairy cattle may reach four times the energy requirement for maintenance while the energy requirement for lactation in dairy sheep is equal to the energy requirement for maintenance.

Strategies to improve N efficiency in lactating animals include improving milk yield (Mikolayunas-Sandrock et al., 2009; Jonker et al., 2002), feeding diets close to the animal’s nutritional requirements (Jonker et al, 2002), and altering dietary forage source (Dhiman and Satter, 1997; Wattiaux and Karg, 2004). Genetic improvement is one way to increase milk production. In the United States, dairy sheep production is based primarily on two breeds, the East Friesian and the Lacaune. Due to restrictions on importation from Canada and Europe, no new genetic lines have been imported into the United States since 2002. East Friesian genetics
in North America are comprised of approximately 14 genetic lines (Berger, 2009) and the Lacaune are limited to 6 lines in the United States. There also is no organized genetic improvement program for dairy sheep in North America so progress from selection is non-existent or very slow. Regarding forage source, replacing alfalfa silage with corn silage improved N efficiency in dairy cattle (Nagel and Broderick, 1992), due to the high levels of RDP in alfalfa silage compared to corn silage. However, due to concerns of listeriosis, corn silage is not generally fed to sheep. Another option to improve N efficiency is to feed ewes close to their nutritional requirements.

INDOOR TRIAL: DRIED FEEDS

Methods and Materials

**Ewes.** All of the reported trials were conducted at the Spooner Agricultural Research Station of the University of Wisconsin-Madison and all procedures were approved by the Animal Care and Use Committee of the College of Agricultural and Life Sciences. Eighteen third-lactation dairy ewes averaging 109 days in milk (DIM) (standard deviation = 6 days) were fed a mixture of the three experimental diets for 10 d before the start of the trial. At the evening milking of day 10 and the morning milking of day 11, individual ewe milk yield was recorded, and 24-hr milk yield was calculated. On the basis of this milk yield, ewes were divided into low and high milk yield blocks (LM: 1.58 ± 0.62 kg/day, n=9; HM: 2.49 ± 0.60 kg/day, n=9, respectively) and randomly assigned within block to pens of 3 ewes each. Within each block, pens were randomly assigned to one of three dietary treatments. Dietary treatment sequences were balanced for carryover and applied to pens for 14 days in two 3 x 3 Latin squares. Ewes were milked twice per day (0530 and 1700 h) and had access to water and a free-choice mineral-salt mixture. Ewes were weighed and body condition scored daily during the final 4 days of each treatment period (1 = very thin, 5 = very fat; Boundy, 1982).

Milk yield was measured during the final 4 milkings (2 days) of each treatment period using a graduated Waikato Goat Meter (Waikato Milking Systems NZ Ltd., Hamilton, NZ). Milk fat and protein percentage were determined on samples containing proportional amounts of morning and evening milk on the final 2 days of each period using a CombiFoss 5000 (Foss Electric, Hillerod, Denmark; AgSource Milk Labs, Menomonie, WI). Milk fat yield and protein yield were calculated for each ewe from daily milk yield and fat and protein percentages. A pen milk sample was compiled from proportional amounts of milk from each ewe and was analyzed for MUN using a Foss FT6000 (Foss Electric, Hillerod Denmark; AgSource Milk Labs, Menomonie, WI).

**Dietary Treatments.** Three dietary treatments were formulated to provide varying concentrations of rumen-degradable protein (RDP) and rumen-undegradable protein (RUP); 12% RDP and 6% RUP (12-6), 14% RDP and 4% RUP (14-4), 12% RDP and 4% RUP (12-4) (% of DM) and similar metabolizable energy (2.41, 2.45, and 2.39 Mcal/kg, respectively). Diets were initially formulated based on NRC (2007), and protein degradability was evaluated based on in situ degradation in a dairy cow. After the trial was conducted, N fractions in feeds and orts were analyzed for the Cornell N fractions.
Based on the Small Ruminant Nutrition System (SRNS, 2008) model, the estimated concentrations of RDP and RUP actually offered by the 12-6, 14-4 and 12-4 treatments were greater than the calculated diets (Table 2). If the SRNS (2008) model estimations are correct, the diets offered provided 1.4 to 1.7 percentage units less RDP (average of 1.5 percentage units lower), 2.6 to 3.7 percentage units more RUP (average of 3.3 percentage units greater) and approximately 2.3 percentage units more total protein than the diets were designed to provide. However, the differences in percentage RDP and RUP between the offered diets and the formulated diets were similar. The final composition of the diets is presented in Table 1.

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>12-6</th>
<th>14-4</th>
<th>12-4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfalfa-timothy hay, cubed</td>
<td>54.3</td>
<td>59.7</td>
<td>62.5</td>
</tr>
<tr>
<td>Corn, whole</td>
<td>5.7</td>
<td>-</td>
<td>3.1</td>
</tr>
<tr>
<td>Oats, whole</td>
<td>-</td>
<td>4.5</td>
<td>-</td>
</tr>
<tr>
<td>Soybean meal, expeller²</td>
<td>4.3</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Pellet</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beet pulp</td>
<td>5.7</td>
<td>-</td>
<td>7.8</td>
</tr>
<tr>
<td>Corn, ground</td>
<td>8.6</td>
<td>7.5</td>
<td>9.4</td>
</tr>
<tr>
<td>Soybean meal, dehulled</td>
<td>5.7</td>
<td>16.4</td>
<td>9.4</td>
</tr>
<tr>
<td>Soy hulls</td>
<td>5.7</td>
<td>11.9</td>
<td>7.8</td>
</tr>
<tr>
<td>Soybean meal, expeller²</td>
<td>10.0</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

**Table 1.** Composition of the diets (% of diet DM) fed to lactating ewes.

12-6 = 12% RDP and 6% RUP, 14-4 = 14% RDP and 4% RUP, and 12-4 = 12% RDP and 4% RUP.
SoyPLUS, West Central Soy, Ralston, IA.

Pens were fed *ad libitum* to allow 5% refusals. This low level of refusals was chosen because the physical form of the diets resulted in sorting among the pellet, grain, and cube components of the diets. The calculated percentage of RUP and RDP in the dietary treatments assumed consumption of the total diet, and with a low level of refusals, each pen was forced to consume as close to the total mixed diet as possible. Refusals were predominantly alfalfa-timothy cubes. During the final 4 days of each treatment period, orts were weighed and compiled by pen and used to calculate pen intake.

Individual feeds and orts were sampled from each period. All samples were stored at -20º C and ground to pass through a 1-mm screen in a Wiley mill before analysis. Dry matter was determined by drying samples overnight at 100º C in a forced-air oven. Neutral detergent fiber was determined using sodium sulfite and α-amylase (Sigma no. A3306, Sigma Chemical Co., St. Louis, MO) in the Ankom²⁰⁰ fiber analyzer (Ankom Technology, Macedon, NY) and was corrected for ash concentration according to Van Soest et al. (1991). Non-sequential acid detergent fiber was determined using the method of Goering and Van Soest (1970), adapted for
the Ankom\textsuperscript{200}. Total N and Cornell N fractions were analyzed according to Licitra et al. (1996). Cornell N fractions include non-protein N (A), true protein with decreasing solubility (B\textsubscript{1}, B\textsubscript{2}, B\textsubscript{3}) and N insoluble in acid detergent that is assumed to be indigestible (C). Ether extract was analyzed according to AOAC method 920.39 (AOAC, 1997; Dairyland Laboratories, Arcadia, WI). Non-fiber carbohydrates were calculated based on the equation \(\text{NFC} = 100 - \text{CP} - \text{aNDF} - \text{ash} - \text{ether extract} + \text{NDICP}\).

**Statistical Analyses.** Data were analyzed as two 3 x 3 Latin squares with pen as the experimental unit. Individual ewe measures of milk, fat, and protein yield, percentage fat and protein, MUN, BW change from the previous period, and BCS at the end of the period were averaged by pen prior to statistical analysis. Intake of diet DM and nutrient DM and nitrogen efficiency (milk protein N / protein N intake) were measured by pen. Pen means and pen measurements were analyzed using the MIXED procedure of SAS (Version 9.1, SAS Institute Inc, Cary, NC). The model included square (i.e. milk production level), treatment, period*square, treatment*square, and the random effect of pen within square. Least squares means and standard errors of the mean are reported for each trait. Significant differences between least squares means were declared at \(P < 0.05\) unless otherwise noted and tendencies were considered at \(0.05 < P < 0.10\). Differences between least squares means were calculated using a Tukey-Kramer adjustment for multiple comparisons of means.

**Results**

For all traits, there was no statistically significant interaction of square*dietary treatment, therefore only least squares means for the main effect of milk production level and dietary treatment are reported.

**Dry Matter and Nutrient Intake.** The dry matter intake (DMI) and calculated nutrient intakes are presented in Table 2. The higher milk producing ewes consumed more \((P < 0.05)\) DM and nutritional components than LM ewes, suggesting that intake was regulated by energetic demands for milk production. The ability of dairy ewes to adjust their DMI to meet their energetic needs also has been reported by Cannas et al. (1998); ewes on low NE\textsubscript{L} diets increased DMI to achieve the same intake of NE\textsubscript{L} as ewes on high NE\textsubscript{L} diets. There were no differences in DMI among protein degradability treatments.

Neutral detergent fiber intake in the 12-6, 14-4, and 12-4 treatments was 34, 37, and 37% of DMI, respectively, and within the range of 28 to 38% recommended by Cannas (2002). Non-fiber carbohydrate intake was lower \((P < 0.01)\) in 14-4 compared to the 12-6 and 12-4 treatments. However, the concentration of net energy of lactation (NE\textsubscript{L}) in the diet consumed, as calculated from the SRNS (2008), was similar across milk production levels and dietary treatments (Table 3). These NE\textsubscript{L} values were within the range fed by Cannas et al. (1998) in an evaluation of high and low energy diets for dairy ewes (1.55 vs. 1.65 Mcal/kg).

The CP concentrations of the consumed diets (20.6, 20.5 and 17.8% of DM) were greater than the formulated dietary CP levels (18, 18, and 16%, respectively), but the target difference in % CP was achieved. Analysis of the N fractions in feed consumed, measured by difference of N fractions in feed offered and orts (Licitra et al., 1996), indicate the relative degradability of the
intake protein (Table 2). The HM ewes consumed greater ($P < 0.05$) amounts of protein fractions $B_2$ and $B_3$ and tended to consume greater ($P = 0.0503$) amounts of fraction $A$ than LM ewes. Among dietary treatments, there were no significant differences in intake of the highly soluble protein fraction $A$. Ewes on the 14-4 treatment consumed more ($P < 0.01$) of the highly rumen-degradable protein fraction $B_1$ than did ewes on the other two treatments. Intake of protein fraction $B_2$ was lower ($P < 0.01$) in 12-4 compared to 12-6 and 14-4. Ewes fed treatment 12-6 consumed more ($P < 0.01$) of the $B_3$ protein fraction, which makes a greater contribution to RUP, than did ewes fed the other two treatments. There was no difference in the intake of protein fraction C. Based on these N analyses, the relative difference in protein degradability of the diets was achieved; 12-6 supplied more RUP than 14-4 and 12-4, and 14-4 supplied more RDP than 12-6 and 12-4.

### Table 2. Dry matter and nutrient intake of lactating dairy ewes.

<table>
<thead>
<tr>
<th>Intake, kg/pen/d</th>
<th>Milk production level</th>
<th>Dietary treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LM(^1)</td>
<td>HM(^2)</td>
</tr>
<tr>
<td>DMI</td>
<td>8.7(^d)</td>
<td>10.8(^c)</td>
</tr>
<tr>
<td>aNDF</td>
<td>3.07(^d)</td>
<td>3.87(^c)</td>
</tr>
<tr>
<td>NFC</td>
<td>3.24(^d)</td>
<td>4.02(^c)</td>
</tr>
<tr>
<td>CP</td>
<td>1.71(^d)</td>
<td>2.11(^c)</td>
</tr>
<tr>
<td>EE</td>
<td>0.18(^d)</td>
<td>0.23(^c)</td>
</tr>
<tr>
<td>NE(^6), Mcal/kg</td>
<td>1.60</td>
<td>1.59</td>
</tr>
</tbody>
</table>

Protein Fractions\(^7\)

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B(_1)</th>
<th>B(_2)</th>
<th>B(_3)</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.23</td>
<td>0.28</td>
<td>0.01</td>
<td>0.25</td>
<td>0.25</td>
</tr>
<tr>
<td></td>
<td>0.16</td>
<td>0.19</td>
<td>0.01</td>
<td>0.14(^b)</td>
<td>0.25(^a)</td>
</tr>
<tr>
<td></td>
<td>1.12(^d)</td>
<td>1.35(^c)</td>
<td>0.08</td>
<td>1.36(^c)</td>
<td>1.28(^cd)</td>
</tr>
<tr>
<td></td>
<td>0.15(^d)</td>
<td>0.20(^c)</td>
<td>0.01</td>
<td>0.22(^a)</td>
<td>0.14(^b)</td>
</tr>
<tr>
<td></td>
<td>0.07</td>
<td>0.11</td>
<td>0.03</td>
<td>0.07</td>
<td>0.07</td>
</tr>
</tbody>
</table>

\(^1\)Low milk yield (1.58 ± 0.62 kg/d at the start of the trial, n=9).
\(^2\)High milk yield (2.49 ± 0.60 kg/d at the start of the trial, n=9).
\(^3\)12% RDP, 6% RUP.
\(^4\)14% RDP, 4% RUP.
\(^5\)12% RDP, 4% RUP.
\(^6\)Based on diet evaluation by Small Ruminant Nutrition System (2008) model.
\(^7\)Protein fractions: A = non-protein N, B\(_1\) = buffer-soluble true protein, B\(_2\) = buffer-insoluble protein, B\(_3\) = neutral detergent insoluble protein – acid detergent insoluble protein, and C = acid detergent insoluble protein.
\(^a\)\(^b\)Means within milk production or dietary treatment with different superscripts differ at $P < 0.01$.
\(^c\)\(^d\)Means within milk production or dietary treatment with different superscripts differ at $P < 0.05$.

**Milk Production and Composition.** The effect of initial milk production level and dietary treatment on lactation traits and BW and BCS is presented in Table 3. The highest RUP diet (12-6) increased ($P < 0.01$) milk yield of 14% compared to the low RUP diets (14-4 and 12-4; 2.05
vs. 1.80 and 1.79 kg/day, respectively). The benefit of supplemental RUP in this trial is likely the increased flow of AA to the small intestine. In this trial, RUP from expeller soybean meal, a protein source high in Lys but low in Met, also increased milk yield.

There was no effect of additional RDP (14-4 vs. 12-4) on milk yield (Table 3). All diets contained RDP levels above the 8.6% degraded intake protein requirement indicated by NRC (2007), and NFC levels were greater than the minimum 28% recommended by Cannas (2002). Since microbial growth should not have been limited, additional RDP provided by the 14-4 diet was likely excreted in feces and urine, providing no additional AA to in the small intestine.

Table 3. Effect of initial milk production level and dietary treatment on production traits of dairy ewes.

<table>
<thead>
<tr>
<th>Milk production level</th>
<th>Dietary treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LM(^1)</td>
</tr>
<tr>
<td>Milk, kg/d</td>
<td>1.53(^b)</td>
</tr>
<tr>
<td>Fat, %</td>
<td>6.17</td>
</tr>
<tr>
<td>Fat, g/d</td>
<td>91.2(^b)</td>
</tr>
<tr>
<td>Protein, %</td>
<td>4.71</td>
</tr>
<tr>
<td>Protein, g/d</td>
<td>69.9(^b)</td>
</tr>
<tr>
<td>MUN, mg/dl</td>
<td>24.87</td>
</tr>
<tr>
<td>N efficiency, %(^6)</td>
<td>12.09(^d)</td>
</tr>
<tr>
<td>BW change, kg</td>
<td>-0.37</td>
</tr>
<tr>
<td>BCS</td>
<td>2.98</td>
</tr>
</tbody>
</table>

1 Low milk yield (1.58 ± 0.62 kg/d at the start of the trial, n=9).
2 High milk yield (2.49 ± 0.60 kg/d at the start of the trial, n=9).
3 12% RDP, 6% RUP.
4 14% RDP, 4% RUP.
5 12% RDP, 4% RUP.
6 Calculated as milk N / feed N, where milk N = (g milk protein/pen/d) / 6.38 and feed N = (g feed crude protein/pen/d) / 6.25 * 100.

\(^a\)\(^b\) Means within milk production or dietary treatment with different superscripts differ at \(P < 0.01\).

\(^c\)\(^d\) Means within milk production or dietary treatment with different superscripts differ at \(P < 0.05\).

There was no significant effect of milk production level or dietary treatment on milk fat percentage. High milk yielding ewes produced more \((P < 0.01)\) milk fat than LM ewes (Table 3). Compared to the 12-4 diet, supplemental RUP (12-6) increased \((P = 0.04)\) milk fat yield by 15%. However, in the dairy cattle trials reporting a milk yield response to RUP, there was no effect of RUP on milk fat concentration or milk fat yield (Cunningham et al., 1996; Broderick et al., 2002). Compared to 12-4, supplemental RDP (14-4) also tended to increase \((P = 0.08)\) milk fat yield.
There was no significant effect of milk production level or dietary treatment on milk protein percentage. The high milk yielding ewes produced more ($P < 0.01$) milk protein than LM ewes. Compared to the 12-4 and 14-4 treatments, ewes consuming the 12-6 diet produced 14 and 13% more ($P < 0.01$) milk protein, respectively. Previous authors have reported trends towards increased milk protein yield in response to RUP supplementation in sheep and cattle (Robinson et al., 1979; Broderick et al., 2002).

**Nitrogen Efficiency.** Gross N efficiency was calculated as $100 \times (\text{milk N} / \text{feed N})$, where milk N = (g milk protein/pen/d) / 6.38 and feed N = (g feed crude protein/pen/d) / 6.25. In this trial, N efficiency ranged from 12.09 to 15.08% (Table 3). High milk yielding ewes were 25% more ($P = 0.02$) efficient than LM at converting intake protein N to milk protein N. Ewes in LM and HM were similar BW and would have similar N maintenance requirements. Therefore, at similar levels of N intake HM had greater partial efficiency for milk production compared to LM ewes. Among dietary treatments, ewes consuming the 14-4 diet had 11 and 15% lower ($P < 0.05$) N efficiency than ewes consuming the 12-6 and 12-4 diets, respectively. The 12-6 and 12-4 diets resulted in a similar N efficiency, but the 12-6 diet produced more milk, milk fat, and milk protein compared to 12-4, supporting supplementation of RUP to increase milk yield per ewe.

**Milk Urea Nitrogen.** There was no difference between MUN levels of the high CP diets (12-6 and 14-4). However, the MUN of 12-4 was lower ($P < 0.05$) than 12-6 and tended ($P = 0.053$) to be lower than the 14-4 treatment. These results suggest that milk urea levels in this study were more related to CP intake than to the degradability of the protein. While the 12-6 diet resulted in the capture of more intake protein in milk protein compared to the 14-4 diet, the MUN data suggest that both of these treatments provided excess total dietary protein.

**FRESH FORAGE TRIALS: CUT AND CARRY AND GRAZING**

**Materials and Methods**

**Cut and Carry Trial.** In June 2008, sixteen third-lactation dairy ewes in mid-lactation (104 DIM; SD = 8) with similar milk production (2.37 kg/d; SD = 0.22) were randomly assigned to eight pens of two ewes each. Pens were randomly assigned to one of two supplementation treatments, receiving either 0 (NS) or 0.3 kg/day Soy Pass (Borregaard LignoTech, LignoTech USA Inc., Rothschild, WI; S), a chemically derived source of RUP. Within each supplementation treatment, pens were assigned to one of four forage treatments. Dietary forage treatments were balanced for carryover and applied to pens for 10-day periods in a $4 \times 4$ Latin Square. All ewes were milked twice per day (0530 and 1700 h) and had access to water and a free choice mineral-salt mixture. All ewes received 0.4 kg DM/day of an equal mixture of whole corn and soy hulls in the milking parlor at each milking.

Forage treatments were composed of the following proportions of dry matter from orchardgrass (*Dactylis glomerata* L.) and alfalfa (*Medicago sativa*): 25% orchardgrass and 75% alfalfa (25:75), 50% orchardgrass and 50% alfalfa (50:50), 75% orchardgrass and 25% alfalfa (75:25), and 100% orchardgrass (100:0). All pens were fed 50:50 for a 5 day adaptation period before the trial began. Forages were clipped daily at 0600 h at a height of 5 cm above the soil
surface using a walk behind, sickle bar mower (Jari Products Inc, Minneapolis, MN). Clipped forages were fed to ewes at 0800 and stored at 7 °C until feeding again at 1100 and 1800 h. Multiple feedings per day were designed to imitate the grazing behavior of ewes. Forage DM was determined on day 2 and 7 of each experimental period by drying forages in 37º C forced-air oven until they reached a constant weight. As-fed forage amounts were calculated based on these DM determinations. Pens were fed ad libitum to allow 5% refusals. Forages were clipped to maintain similar stages of development.

Grazing Trial. In July 2009, twelve third-lactation dairy ewes in mid-lactation (126 DIM; SD = 6) with similar milk production (2.32 kg/d; SD = 0.16) were randomly assigned to supplementation treatments, receiving either 0 (NS) or 0.3 kg/day of SoyPLUS (West Central Soy, Ralston, Iowa; S), a modified expeller source of RUP. Within each supplementation treatment, groups of 2 ewes each were assigned to one of three forage treatments. Dietary forage treatments were balanced for carryover effects and applied to ewes for 10-day periods in a 3 x 3 Latin Square. All ewes were milked twice per day (0700 and 1900 h) and had access to water and a free choice mineral-salt mixture. All ewes received 0.4 kg DM/day of an equal mixture of whole corn and soy hulls in the milking parlor at each milking.

Forage treatments were composed of paddocks containing the following proportions of orchardgrass (*Dactylis glomerata* L.) and alfalfa (*Medicago sativa*) surface area: 50% orchardgrass and 50% alfalfa (50:50), 75% orchardgrass and 25% alfalfa (75:25), and 100% orchardgrass (100:0). Forages were planted in monoculture strips and clipped to a height of 7.5 cm to allow 20 d of regrowth at the start of each period. No plot was grazed more than once and the maximum age of forage regrowth was 30 d. Paddocks were created using a combination of portable electric and wooden fencing. Ewes were given fresh forage daily and paddock size was based on the relative residual from the previous day.

Sample Collection, Analysis and Calculations. In both trials, individual ewe milk yield was measured during the final 4 milkings (2 days) of each treatment period using a graduated Waikato Goat Meter (Waikato Milking Systems NZ Ltd., Hamilton, NZ). Individual milk samples were analyzed for fat, protein and MUN. Milk fat and protein were measured using a CombiFoss 5000 (Foss Electric, Hillerod, Denmark; AgSource Milk Labs, Menomonie, WI) and MUN was analyzed using a Foss FT6000 (Foss Electric, Hillerod Denmark; AgSource Milk Labs, Menomonie, WI). Milk fat yield and protein yield were calculated for each ewe from daily milk yield and fat and protein percentages. In both trials, ewes were weighed during the final 2 days of each treatment period and BW change was calculated as initial BW minus final BW.

In both trials, all feeds were sampled and orts were sub-sampled on the final 2 days of each experimental period. All samples were analyzed according to methods mentioned in the previous trial.

Statistical Analyses. For the cut and carry trial, data was analyzed as two 4 x 4 Latin Squares with pen as the experimental unit, supplement as the square and forage composition as the treatment. Milk production, milk component yield, and nitrogen efficiency (milk N/ N intake) for each ewe was averaged across pen. Milk production and milk composition means, pen DMI, intake of feed components, and MUN were analyzed using the MIXED procedure of
For the grazing trial, data was analyzed as two 3 x 3 Latin Squares with each pair of ewes as the experimental unit, supplement as the square and forage composition as the treatment. Milk production, milk component yield, and MUN values were averaged across pairs of ewes. Means were analyzed using the MIXED procedure of SAS (Version 9.1, SAS Institute Inc, Cary, NC). For all measures, the model included square, treatment, square*treatment and the random effect of pair of ewes (square). For both trials, all values presented are least squares means and standard errors of the mean. Significant differences between least squares means were declared at \( P < 0.05 \) unless otherwise noted and tendencies were considered at \( 0.05 < P < 0.10 \). Differences between least squares means were calculated using a Tukey-Kramer adjustment for multiple comparisons of means.

Results

**Milk Production and Composition.** While milk production and composition was completed for both trials, analyses of feed are only complete for the cut-and-carry trial. The nutrient composition of feeds is presented in Table 4. The CP content varied throughout the trial, but was lower for orchardgrass (10.8 to 15.2% CP) compared to the alfalfa (18.7 to 20.0% CP). The NDF content of these forages was high in period 2, but lower for alfalfa compared to orchardgrass. Based on the nutrient composition and intake, the intake of DM, CP and NDF is presented in Table 5.

### Table 4. Nutrient composition of feedstuffs fed during cut-and-carry trial.

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Orchardgrass</th>
<th>Alfalfa</th>
<th>Corn and Expeller SBM (Soy Pass)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Period</td>
<td>Period</td>
<td>Soy hull</td>
</tr>
<tr>
<td>DM</td>
<td>27.5, 17.4, 25.1, 21.1</td>
<td>15.6, 15.3, 25.9, 25.6</td>
<td>89.0, 88.6</td>
</tr>
<tr>
<td>CP</td>
<td>10.8, 11.8, 9.0, 15.2</td>
<td>20.0, 19.7, 18.1, 18.7</td>
<td>9.8, 45.8</td>
</tr>
<tr>
<td>NDF</td>
<td>45.9, 54.3, 49.0, 49.8</td>
<td>29.0, 36.4, 32.0, 36.5</td>
<td>35.9, 31.2</td>
</tr>
</tbody>
</table>

While supplementation with 0.3 kg/day of Soy Pass had no effect on DMI, forage composition significantly affected DMI (Table 5). Ewes consuming 100% orchardgrass consumed less \( (P < 0.05) \) than ewes fed 25:75 or 50:50 diets. Consistent with dietary treatments, CP intake and CP intake as a % of DM were linearly related \( (P < 0.01) \) to orchardgrass content of the diet. Ewes consuming Soy Pass had greater \( (P < 0.01) \) CP intake than ewes not supplemented with Soy Pass. The NDF content of the diet consumed was also linearly related to forage content: ewes offered more of the higher NDF forage (orchardgrass) consumed greater \( (P < 0.01) \) NDF than ewes consuming 25% orchardgrass. The 50:50, 75:25 and 100:0 treatments consumed diets greater than 38% NDF, the level recommended by Cannas (2002).

Milk yield and milk composition results from both fresh forage trials (cut-and-carry and grazing) are presented in Table 6. For both trials, there was no interaction of RUP supplementation and forage composition. Supplementing ewes with RUP increased milk.
production by 9 to 10%, representing a numerical increase of 0.16 and 0.17 kg/day, but this increase was only significant in the cut-and-carry trial. The effect of RUP may not have been statistically detectable in the grazing trial due to the experimental design, which gave more power to detecting an effect of forage composition than RUP supplementation.

Table 5. Nutrient intake of dairy ewes in cut-and-carry trial.

<table>
<thead>
<tr>
<th>Soy Pass Supplement¹</th>
<th>Forage Composition²</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>NS</td>
<td>S</td>
<td>P&lt;</td>
</tr>
<tr>
<td>DMI, kg/pen/d</td>
<td>5.64</td>
<td>5.54</td>
</tr>
<tr>
<td>CP intake, g/pen/d</td>
<td>789.0</td>
<td>831.3</td>
</tr>
<tr>
<td>Intake (% of DM)</td>
<td>CP</td>
<td>13.97&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>NDF</td>
<td>42.06</td>
<td>40.04</td>
</tr>
</tbody>
</table>

¹Supplemented with 100 g/d SoyPass.
²Percentage of DM from Orchardgrass, remaining portion from Alfalfa.

Within a row and treatment, means with no superscript in common are different at \( P < 0.01 \).

Within a row and treatment, means with no superscript in common are different at \( P < 0.05 \).

In both trials, there was a tendency for forage composition to affect milk yield (\( P = 0.053 \) in cut-and-carry and \( P < 0.10 \) in grazing). Increasing dietary alfalfa from 100:0 to 50:50 increased milk production by 11 to 21%, representing a numerical increase of 0.2 to 0.32 kg/day. In cut-and-carry, there was no additional response in milk yield in 50:50 compared to 25:75. However, both trials demonstrated a significant linear effect of forage composition on milk yield, emphasizing the importance of pasture quality in dairy sheep production.

In comparing the two trials where ewes ate fresh forages, ewes in the cut-and-carry trial had greater MY which may be due to stage of lactation. In addition, these ewes did not have energetic costs for grazing and were not affected by adverse weather. In the grazing trial, ewes reduced grazing due to high temperatures and, during one sampling period, they were removed from pasture at 1200 h when temperatures reached above 90°F.

Milk fat yield was not affected by RUP or forage composition. The effect of RUP on milk protein yield was not significant in the cut-and-carry trial, but there was a trend towards increased milk protein yield with RUP supplementation in the grazing trial. In this trial, RUP increased milk protein yield by 11%, which closely reflects the 10% increase in milk yield. These data indicate that there was no effect of RUP supplementation on milk protein percentage. An increased proportion of orchardgrass decreased (\( P < 0.05 \)) milk protein yield in both trials. In the cut-and-carry trial, increasing alfalfa in the diet up to 75% increased milk protein yield by 15% or 12.8 g/d. In the grazing trial, increasing alfalfa to 50% increased milk protein yield by 25% or 19.7 g/d compared to the 100% orchardgrass diet.
Milk urea N was greater ($P < 0.05$) in ewes consuming RUP in the cut-and-carry trial. This reflects the difference in CP intake between these treatments, as seen in Table 6. There was no difference observed in the grazing trial, though the RUP treatment was numerically greater than the unsupplemented treatment. Similar to milk protein yield, MUN increased linearly ($P < 0.01$) in relation to alfalfa content of the diet in both trials. In the cut-and-carry trial, the MUN levels of 100:0 and 75:25 are lower than recommended by Cannas (2002) (14 to 21 mg/dl). This supports the use of MUN as an indicator of CP intake from fresh forage. In the grazing trial, MUN levels were higher than the cut-and-carry trial, which may be reflective of the CP content of forages actually selected and grazed by the ewes. This will be evaluated once forage samples from this trial are analyzed.

**Table 6. Effect of RUP and forage composition on milk and component yield in dairy ewes.**

<table>
<thead>
<tr>
<th>Cut and Carry (104 DIM)</th>
<th>RUP Supplement$^1$</th>
<th>Forage Composition$^2$</th>
<th>$P &lt;$ Forage -Linear</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NS</td>
<td>S</td>
<td>$P &lt;$</td>
</tr>
<tr>
<td>Milk, kg/d</td>
<td>1.79$^g$</td>
<td>1.95$^g$</td>
<td>0.10</td>
</tr>
<tr>
<td>Fat, g/d</td>
<td>121.6</td>
<td>123.1</td>
<td>n.s.</td>
</tr>
<tr>
<td>Protein, g/d</td>
<td>89.7</td>
<td>94.8</td>
<td>n.s.</td>
</tr>
<tr>
<td>MUN, mg/dl</td>
<td>12.3$^c$</td>
<td>15.1$^d$</td>
<td>0.05</td>
</tr>
<tr>
<td>N efficiency$^3$</td>
<td>23.9</td>
<td>23.8</td>
<td>n.s.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Grazing (126 DIM)</th>
<th>RUP Supplement$^1$</th>
<th>Forage Composition$^2$</th>
<th>$P &lt;$ Forage -Linear</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk, kg/d</td>
<td>1.65</td>
<td>1.82</td>
<td>n.s.</td>
</tr>
<tr>
<td>Fat, g/d</td>
<td>104.9</td>
<td>114.9</td>
<td>n.s.</td>
</tr>
<tr>
<td>Protein, g/d</td>
<td>84.4</td>
<td>94.0</td>
<td>0.10</td>
</tr>
<tr>
<td>MUN, mg/dl</td>
<td>18.1</td>
<td>19.8</td>
<td>n.s.</td>
</tr>
</tbody>
</table>

$^1$Supplemented with 300 g/d Soy Pass in cut and carry, supplemented with 300g/d SoyPLUS in grazing trial.

$^2$Percentage of DM from Orchardgrass, remaining portion from Alfalfa.

$^3$Milk N (milk protein/6.38) g/pen/d / Feed N (feed crude protein/6.25) g/pen/d * 100.

Within a row and treatment, means with no superscript in common are different at $P < 0.01$.

Within a row and treatment, means with no superscript in common are different at $P < 0.05$.

Within a row and treatment, means with no superscript in common are different at $P < 0.10$.

**Nitrogen Efficiency.** Gross N efficiency was calculated as 100*(milk N / feed N), where milk N = (g milk protein/pen/day) / 6.38 and feed N = (g feed crude protein/pen/day) / 6.25. In the cut-and-carry trial, N efficiency ranged from 20.1 to 30.4% (Table 7). While RUP did not affect N efficiency, there was a linear effect of forage composition. Ewes consuming 100:0 were more efficient ($P < 0.05$) at capturing feed N in milk N, compared to all treatments containing alfalfa. While 25:75 and 50:50 produced more milk, they also excreted more N in milk and urinary urea. Similar to the previous trial, MUN is more reflective of dietary CP% than protein degradability.
Conclusions

Across these three trials, supplementation of RUP increased milk and milk protein yield in low and high producing dairy ewes. This effect is likely due to increased supply of AA to the small intestine and the mammary gland, which supports both milk and milk protein production. This is particularly relevant to dairy sheep producers, since the majority of sheep milk is processed into cheese and protein and fat yield are important in determining cheese yield.

Forage composition, and resulting CP intake, also affected milk, milk protein yield, and N utilization. Milk production increased as the proportion of alfalfa in the pasture increased to 50%, but no benefit was observed above 50% of pasture composition.

The excretion of urea, as indicated by MUN, was higher for ewes on high CP diets compared to ewes on low CP diets. The MUN results indicate that MUN level closely reflects CP intake, regardless of protein degradability. Gross N efficiency, or the capture of intake protein in milk protein, was greater in low RDP diets, including the 100% orchardgrass diet.

Increased milk yield may be realized by supplementing RUP to grazing dairy ewes and maintaining mixed grass-legume pastures with at least 50% legume.

References


EFFECTS OF PREPUBERTAL GROWTH RATE OF EWE LAMBS ON THEIR SUBSEQUENT LAMB AND MILK PRODUCTION

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¹Department of Animal Sciences and ²Spooner Agricultural Research Station
University of Wisconsin-Madison
¹Madison and ²Spooner, Wisconsin, USA

Introduction

In many sheep production operations in the Midwestern and Eastern U.S., lambs are managed for maximum body weight gain and fed high-energy diets continuously from shortly after birth until they are marketed as slaughter lambs. Flock owners will replace 20 to 25% of the ewes in their flock each year with ewe lambs raised in their flock or purchased from other producers. Since all lambs in a flock generally are managed together, these replacement ewe lambs are often managed for maximum gains on high-energy diets along with the other lambs in the flock destined for slaughter. Management of all lambs as one group results in easier management and allows for more accurate selection of replacement ewe lambs for high average daily gain.

However, the practice of feeding replacement ewe lambs for maximum body weight gain may have detrimental effects on their milk production as ewes. While relatively little research has been conducted with sheep to address this issue, much has been conducted with cattle. The majority of well-designed studies have shown that high feeding levels for dairy heifers during the prepubertal period is detrimental to milk production as cows (reviews by Sejrsen and Purup, 1997 and Sejrsen et al., 2000 and the book by Akers, 2002). Increased feeding levels for beef heifers during their prepubertal period also has been shown to result in decreased milk production or decreased weaning weights of their calves (Holloway et al., 1973; Martin et al., 1981; Johnsson and Obst, 1984; Buskirk et al., 1996).

Studies evaluating the effects of prepubertal feeding level in ewe lambs on udder development, subsequent milk production, or lamb weaning weights are fewer in number and are less conclusive than the studies in cattle. Umberger et al. (1985), McCann et al. (1989), Johnsson and Hart (1985), and Johnsson et al. (1986) found slightly greater amounts of udder parenchyma (milk production tissue) in meat-type ewe lambs that had been fed at lower levels in the prepubertal period compared to ewe lambs that had been fed at higher levels, but the differences were not statistically significant. In contrast, McFadden et al. (1990) reported a non-significant increase in parenchymal udder tissue in full-fed compared to restricted-fed meat-type ewe lambs. In the studies of Umberger et al. (1985) and McCann et al. (1989), the ewe lambs fed at the lower levels had increased milk production in five out of six trials (differences were not always significant). Milk production in the latter two studies was estimated one or three times during the lactation period using the weigh-suckle-weigh technique (weighing lambs before and after suckling to estimate milk production) or by using an injection of the hormone oxytocin to remove milk. In a study with dairy sheep, milk production at first lactation was not different between levels of prepubertal feeding for Lacaune ewe lambs, but Manchega ewe lambs fed at the lower level produced 41% more ($P < 0.05$) milk than Manchega ewe lambs fed at the higher
level (Ayadi et al., 2002). Each of the above sheep studies was conducted with a relatively small number of animals, and only one study measured milk production over the entire lactation.

In their review of the cattle and sheep literature on the effects of prepubertal nutrition on milk production for application to the U.S. dairy sheep industry, Tolman and McKusick (2001) concluded that U.S. dairy ewe lambs should be restricted in energy intake to 65 to 75% of their ad libitum intake from 4 to 6 weeks of age through 20 weeks of age in order to increase the rate of mammary growth and to increase the total amount of epithelial tissue that will later develop into milk-secreting tissue.

The objective of this study was to estimate the effects of growth rate of dairy ewe lambs on their lamb and milk production as adult ewes. The study involves larger numbers of ewes than in previous sheep studies and measures milk production over the entire lactation in a commercial-like dairy sheep setting.

**Materials and Methods**

The study was conducted at the Spooner Agricultural Research Station of the University of Wisconsin-Madison. Two hundred fifty two ewe lambs born in the late winter and early spring of 2004 (n = 104), 2005 (n = 85), and 2006 (n = 62) were utilized in the study. The ewe lambs were of high percentage East Friesian (EF) or Lacaune (LA) breeding or various crosses of these two dairy breeds, with the exception of 18 ewe lambs born in 2004 that were sired by Dorset rams with less than ½ of their genetic composition from the EF and/or LA breeds.

Ewe lambs were removed from their dams at 1 to 2 days of age and raised on milk replacer and a high concentrate (22 % crude protein) ad libitum diet until approximately 30 days of age. They continued on the high concentrate ad libitum diet for an additional 2 to 3 weeks after weaning from the milk replacer and then were randomly assigned to one of two growth treatments – full feed (FULL) or restricted feed (REST). Both treatment groups were fed a 13 % crude protein grain mix of whole shelled corn and a high protein pellet in straw-bedded pens (2 pens of lambs on each treatment each year). A small amount of alfalfa hay was also provided – less than 0.50 lb. per head per day.

Ewe lambs in the FULL group received as much of the grain mix as they could consume, and average per head feed consumption was calculated daily. Each ewe lamb in the REST group received approximately 70 % of the average per head intake of the FULL group from the day before. The goal was to have REST lambs gain at 70 % the growth rate of FULL lambs. Lambs were weighted weekly. If the REST lambs were gaining markedly faster or slower than 70 % of the growth rate of FULL lambs, the proportion of the FULL intake that was fed to them was decreased or increased.

Ewe lambs remained on the nutrition treatments for approximately 100 days until they were approximately 5 months of age. After the end of the treatments, all ewes were managed together. They were fed alfalfa hay ad libitum and 2 lb. of corn/head/day. The corn was decreased to 1 lb./head/day about 2 weeks before the start of mating. Ewe lambs were first mated in October-November at slightly over 7 months of age and lambed in March and April. Yearling and older
ewes were bred approximately a month earlier to lamb in February and March. The vast majority of lambs were removed from these ewes at 1 to 2 days of age and raised on milk replacer, and the ewes were then placed on twice per day milking in the parlor. In 2005, 17 of the 2004-born ewes were allowed to raise their lambs for approximately 30 days before the lambs were weaned and the ewes placed in milking. Ewes were pastured on kura clover-orchard grass pastures during the grazing season, fed haylage at other times, and fed 2 lb. of concentrate per head per day in the milking parlor.

Results

Average per head feed consumption of the 12 pens of lambs over the years of 2004, 2005, and 2006 is presented in Table 1. As designed in the experiment, the REST group ate less \( P < 0.05 \) of the grain mix than the FULL group (1.94 vs. 2.67 lb./head/day). Grain mix and total feed consumption of the REST group was 73 and 75 %, respectively, the consumption of the FULL group.

Table 1. Feed consumption least squares means for full- or restricted-fed dairy ewe lambs.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>No. pens</th>
<th>Grain/hd/d, lb.</th>
<th>Hay/hd/d, lb.</th>
<th>Total feed/hd/d, lb.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full feed</td>
<td>6</td>
<td>2.67(^a)</td>
<td>.45</td>
<td>3.12(^a)</td>
</tr>
<tr>
<td>Restricted</td>
<td>6</td>
<td>1.94(^b)</td>
<td>.41</td>
<td>2.35(^b)</td>
</tr>
<tr>
<td>Restricted/Full</td>
<td></td>
<td>.73</td>
<td>.91</td>
<td>.75</td>
</tr>
</tbody>
</table>

\(^a,b\) Means within a column and within a treatment group with no superscripts in common are statistically different \( P < 0.05 \).

Figure 1 illustrates that the nutritional treatments were successful in creating weight differences between the FULL and REST ewe lambs with the REST lambs lighter than the FULL lambs at the end of the trial. By chance, the ewe lambs on the REST treatment were 1.8 lb. heavier \( P < 0.10 \) than the ewe lambs on the FULL treatment at the start of the trial (Table 2). However, by the end of the trial period, REST ewe lambs were 14.3 lb. lighter \( P < 0.05 \) than the FULL ewe lambs. The average daily gain of the REST ewe lambs was 75 % that of the FULL ewe lambs; somewhat greater than the 70 % sought in the study but still within the range recommended by Tolman and McKusick (2001).

Also presented in Table 2 are the effects of breed of ewe lamb. The ewe lambs were divided into two groups: a majority of East Friesian (EF) or Lacaune (LA) breeding. The 18 Dorset-sired ewe lambs in the study were from dairy cross ewes and were assigned to the dairy breed representing the greatest proportion of their genetic composition. Ewe lambs of a majority of EF breeding had greater \( P < 0.05 \) end weights and slightly greater \( P < 0.10 \) average daily gains than ewe lambs of a majority of LA breeding.
Figure 1. Body weights of ewe lambs during the treatment period.

Table 2. Age, weight, and average daily gain least squares means for East Friesian- or Lacaune-sired and full- or restricted-fed dairy ewe lambs.

<table>
<thead>
<tr>
<th>Breed:</th>
<th>Start</th>
<th>End</th>
<th>Average daily gain, lb.</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 50% EF</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. ewe lambs</td>
<td>Age, d</td>
<td>Weight, lb.</td>
<td>Age, d</td>
</tr>
<tr>
<td>126</td>
<td>49.9</td>
<td>38.9</td>
<td>147.4</td>
</tr>
<tr>
<td>&gt; 50% LA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>50.3</td>
<td>37.5</td>
<td>148.0</td>
</tr>
<tr>
<td>Nutrition:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Full feed</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. ewe lambs</td>
<td>Age, d</td>
<td>Weight, lb.</td>
<td>Average daily gain, lb.</td>
</tr>
<tr>
<td>129</td>
<td>50.8</td>
<td>37.3</td>
<td>147.6</td>
</tr>
<tr>
<td>Restricted</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. ewe lambs</td>
<td>Age, d</td>
<td>Weight, lb.</td>
<td>Average daily gain, lb.</td>
</tr>
<tr>
<td>123</td>
<td>49.4</td>
<td>39.1</td>
<td>147.8</td>
</tr>
<tr>
<td>Restricted/Full</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. ewe lambs</td>
<td>Average daily gain, lb.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Restricted/Full</td>
<td></td>
<td>.75</td>
<td></td>
</tr>
</tbody>
</table>

Superscripts: 

- Means within a column and within a treatment group with no superscripts in common are statistically different ($P < 0.10$).
- Means within a column and within a treatment group with no superscripts in common are statistically different ($P < 0.05$).

An important finding from this study was that the lower weights of the REST ewe lambs at the end of the trial period did not have a long-term effect on their body weights. The REST ewe lambs had greater ($P < 0.05$) average daily gains from the end of the trial to their first mating approximately 2 months later and from their first mating to their first lambing at slightly over 1 year of age (Table 3). While the FULL ewes were still heavier ($P < 0.05$) than the REST ewes at first mating, the REST ewes more than compensated in the following 5-plus months and were actually slightly heavier ($P < 0.10$) than FULL ewes at first lambing (Table 3). Therefore,
restricting feed intake to 75% of ad libitum intake in ewe lambs should not have any effect on adult ewe body weight.

By first lambing, the EF and LA ewes were of similar weights (Table 3).

Table 3. Least squares means for ewe lamb mating and lambing weights of ewes sired by East Friesian or Lacaune rams and full- or restricted-fed as ewe lambs.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>No. ewe lambs mated</th>
<th>Mating wt., lb.</th>
<th>ADG end of trial to first mating, lb.</th>
<th>Lambing wt., lb</th>
<th>ADG mating to first lambing, lb.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breed:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt; 50% EF</td>
<td>121</td>
<td>135.5&lt;sup&gt;a&lt;/sup&gt;</td>
<td>.43&lt;sup&gt;c&lt;/sup&gt;</td>
<td>163.6</td>
<td>.17</td>
</tr>
<tr>
<td>&gt; 50% LA</td>
<td>124</td>
<td>131.5&lt;sup&gt;b&lt;/sup&gt;</td>
<td>.41&lt;sup&gt;d&lt;/sup&gt;</td>
<td>163.1</td>
<td>.18</td>
</tr>
<tr>
<td>Nutrition:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Full feed</td>
<td>127</td>
<td>135.5&lt;sup&gt;a&lt;/sup&gt;</td>
<td>.35&lt;sup&gt;b&lt;/sup&gt;</td>
<td>161.0&lt;sup&gt;d&lt;/sup&gt;</td>
<td>.15&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Restricted</td>
<td>118</td>
<td>131.5&lt;sup&gt;b&lt;/sup&gt;</td>
<td>.48&lt;sup&gt;a&lt;/sup&gt;</td>
<td>165.7&lt;sup&gt;c&lt;/sup&gt;</td>
<td>.20&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>a,b</sup> Means within a column and within a treatment group with no superscripts in common are statistically different ($P < 0.05$).

<sup>c,d</sup> Means within a column and within a treatment group with no superscripts in common are statistically different ($P < 0.10$).

Reproductive and lactation performance was collected through the lactation in 2008. Therefore performance was available on the 2004-born ewes when lambing at 1, 2, 3, and 4 years of age, the 2005-born ewes when lambing at 1, 2, and 3 years of age, and the 2006-born ewes when lambing at 1 and 2 years of age.

As ewe lambs, there were no statistically significant differences in fertility (ewes lambing/ewes mated) or prolificacy (lambs born/ewes lambing) between FULL and REST ewe lambs (Table 4). EF-sired ewe lambs gave birth to approximately 14 more ($P < 0.10$) lambs per 100 ewes lambing than did LA-sired ewe lambs. We have shown an advantage of EF breeding over LA breeding for prolificacy in a previous study (Thomas et al. 2005).

Table 4. Least squares means for reproductive traits at approximately one year of age of ewes of a majority of East Friesian or Lacaune breeding and full- or restricted-fed as ewe lambs.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>No. ewes</th>
<th>Fertility, %</th>
<th>Prolificacy, no.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breed:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt; 50% EF</td>
<td>120</td>
<td>88.3</td>
<td>1.56&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>&gt; 50% LA</td>
<td>124</td>
<td>88.2</td>
<td>1.42&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Nutrition:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Full feed</td>
<td>126</td>
<td>85.7</td>
<td>1.48</td>
</tr>
<tr>
<td>Restricted</td>
<td>118</td>
<td>90.1</td>
<td>1.50</td>
</tr>
</tbody>
</table>

<sup>a,b</sup> Means within a column and within a treatment group with no superscripts in common are statistically different ($P < 0.10$).
Neither nutrition treatment nor breed had an effect on ewe fertility or prolificacy of older ewes (Table 5). Among ewes 2 years of age and older, at least 93% of them lambed, and they gave birth to over 2 lambs per ewe.

Table 5. Least squares means for reproductive traits at two years of age and greater of ewes of a majority of East Friesian or Lacaune breeding and full- or restricted-fed as ewe lambs.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>No. ewes</th>
<th>No. exposures</th>
<th>Fertility, %</th>
<th>Prolificacy, no.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breed:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt; 50% EF</td>
<td>99</td>
<td>184</td>
<td>93.7</td>
<td>2.07</td>
</tr>
<tr>
<td>&gt; 50% LA</td>
<td>104</td>
<td>170</td>
<td>94.6</td>
<td>2.03</td>
</tr>
<tr>
<td>Nutrition:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Full feed</td>
<td>102</td>
<td>176</td>
<td>95.5</td>
<td>2.03</td>
</tr>
<tr>
<td>Restricted</td>
<td>101</td>
<td>178</td>
<td>92.8</td>
<td>2.06</td>
</tr>
</tbody>
</table>

None of the differences between nutrition treatments for lactation traits were statistically significant, but mean values were actually slightly higher for FULL ewes compared to REST ewes (Table 6). The results of this study contradict the majority of the cattle data and the limited amount of sheep data that show increased milk production resulting from slower compared to higher prepubertal growth rates.

EF ewes had 57.9 lb. greater ($P < 0.01$) milk yield than LA ewes, but Lacaune ewes had greater ($P < 0.01$) percentages of milk fat and milk protein than EF ewes resulting in similar amounts of fat and protein yield for the two breeds (Table 6).

Table 6. Least squares means for lactation traits of ewes of a majority of East Friesian or Lacaune breeding and full- or restricted-fed as ewe lambs.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>No. ewes</th>
<th>No. lactations</th>
<th>Lactation length, d</th>
<th>Milk yield, lb.</th>
<th>Fat, %</th>
<th>Fat yield, lb.</th>
<th>Protein, %</th>
<th>Protein yield, lb.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breed:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt; 50% EF</td>
<td>99</td>
<td>242</td>
<td>186.2</td>
<td>639.1&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.52&lt;sup&gt;b&lt;/sup&gt;</td>
<td>35.8</td>
<td>4.72&lt;sup&gt;b&lt;/sup&gt;</td>
<td>30.7</td>
</tr>
<tr>
<td>&gt; 50% LA</td>
<td>106</td>
<td>234</td>
<td>183.0</td>
<td>581.2&lt;sup&gt;b&lt;/sup&gt;</td>
<td>6.06&lt;sup&gt;a&lt;/sup&gt;</td>
<td>36.0</td>
<td>5.01&lt;sup&gt;a&lt;/sup&gt;</td>
<td>29.9</td>
</tr>
<tr>
<td>Nutrition:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Full feed</td>
<td>102</td>
<td>236</td>
<td>185.9</td>
<td>620.2</td>
<td>5.84</td>
<td>36.7</td>
<td>4.88</td>
<td>30.8</td>
</tr>
<tr>
<td>Restricted</td>
<td>103</td>
<td>240</td>
<td>183.4</td>
<td>600.2</td>
<td>5.74</td>
<td>35.2</td>
<td>4.85</td>
<td>29.8</td>
</tr>
</tbody>
</table>

<sup>a,b</sup>Means within a column and within a treatment group with no superscripts in common are statistically different ($P < 0.01$).

This study indicates that prepubertal ewe lambs that are fed for maximum body weight gains are at no disadvantage relative to ewe lambs fed for slower body weight gains (75% of maximum gains) for lactation traits.
Two hundred forty five of the ewe lambs in the feeding trial were mated at seven months of age. Ewes left the flock through death or were culled for extremely unthrifty condition and severe mastitis, and in some cases, for failure to lamb or very high somatic cell counts. There was little or no culling on milk yield. Table 7 presents the proportion of ewes still in the flock on June 30, 2009 and the average age at which ewes left the flock.

There were no significant effects of breed or ewe lamb nutrition on survival of ewes in the flock (Table 7), although there was a tendency for LA-sired ewes to be leaving the flock at a faster rate than EF-sired ewes.

Table 7. Least squares means for measures of survival of ewes of East Friesian or Lacaune breeding and full- or restricted-fed as ewe lambs.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>No. ewe lambs mated</th>
<th>% remaining, 6/30/09</th>
<th>Average age when leaving the flock, months&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breed:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt; 50% EF</td>
<td>121</td>
<td>48.1</td>
<td>39.6</td>
</tr>
<tr>
<td>&gt; 50% LA</td>
<td>124</td>
<td>40.0</td>
<td>37.2</td>
</tr>
<tr>
<td>Nutrition:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Full feed</td>
<td>127</td>
<td>45.9</td>
<td>37.5</td>
</tr>
<tr>
<td>Restricted</td>
<td>118</td>
<td>42.3</td>
<td>39.3</td>
</tr>
</tbody>
</table>

<sup>a</sup> Ewes still present on 6/30/09 were assigned their age on 6/30/09. If all ewes were still present on 6/30/09, these means would be approximately 53 months.

Conclusions

The two nutrition treatments in this study for prepubertal dairy ewe lambs (ad libitum intake of concentrate and 73% of ad libitum intake of concentrate) resulted in no differences in reproduction, lactation performance, or survival of ewes through four years of age. Producers could save on feed costs on replacement ewe lambs by feeding them less feed separately from the full-fed market lambs or they could leave the ewe lamb replacements with the full-fed market lambs for convenience of management – whichever system they prefer.

Literature Cited

GENETIC MARKERS FOR MILK PRODUCTION

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\textsuperscript{1}Oklahoma State University, Stillwater, Oklahoma, USA
\textsuperscript{2}Cornell University, Ithaca, New York, USA

Background

Sheep milk production is becoming an economically important trait due to an increased interest of U.S. consumers in sheep milk cheeses. This interest is currently supported by importing sheep milk cheeses, imports that have increased from 14.5 million kg in 1986 to 33.1 million kg in 2006 (FAO, 2006).

In contrast with many European and Mediterranean countries which have a long standing tradition in dairy sheep production and where the implementation of selection programs have resulted in highly specialized dairy breeds with high genetic potential for milk yields, most of the sheep breeds available to the U.S. producers have been selected intensively for meat and wool. Improvement of milk production through selection can be expected to be successful given the moderate to high heritability reported for this trait, however, phenotypic selection is more difficult for milk yield than other traits because of the repetitive nature of the phenotype (milk production over 200 to 250-day lactation) which requires multiple measurements for an accurate description and also because the expression is limited to only females. Therefore, knowledge of the genes controlling this trait, or markers linked to these genes to be used in marker-assisted selection should provide the tools needed to implement effective (more accurate and faster) genetic improvement programs for increased milk production in sheep.

Several genes have been investigated in dairy cattle for their relationship with milk yield (for a review see Ogorevc et al., 2009). If their association with milk yield could be proven in dairy sheep, they could provide tools needed for more efficient breeding programs by providing more information to estimate breeding values. In addition, genetically superior individuals could be identified early in life, leading to shorter generation intervals and increased rates of genetic progress.

The breeding value of an animal is defined as the sum of the independent (additive) effects of all that animal’s genes controlling a trait. The true breeding value of an animal is fixed at conception and does not change during the life of an animal. In other words, each animal has an inherent genetic ability to perform. The breeding value of an animal cannot be measured, but it can be estimated from its performance records as well as records of its relatives. The estimated breeding value (EBV) is the best estimate of the real breeding value made from all available information. As the information gets better (more plentiful), so does the estimate. The accuracy associated with an EBV gives an indication of its reliability and is based upon the amount of performance information available at the time of analysis. The present study investigated the association between prolactin (PRL), beta-lactoglobulin (\textit{\beta}-LG) and kappa-casein (CSN3) gene polymorphisms and estimated breeding value (EBV) for milk production weighted by its accuracy in a population of East Friesian dairy sheep.
Materials and Methods

**Milking records and estimated breeding values**

A total of 685 East Friesian sheep from the Old Chatham Sheepherding Company (OCSC), NY were used in this study. The OCSC began in 1994 and it is today one of the largest dairy sheep farms in the Unites States with more than 800 purebred East Friesian and crossbred Lacaune ewes.

Ewes were milked twice daily and individual milk yields were recorded once monthly in the OCSC database for the entire lactation period. Milking records and pedigree information available through the end of July 2007 were used to perform a genetic evaluation and estimate breeding values for all animals.

**Genotyping**

Blood (10 mL) was collected into a heparinized tube from the jugular vein of each sheep. Genomic DNA was extracted from whole blood, using a commercial kit (Qiagen, Valencia, CA). A 2.5 kbp fragment spanning intron 2 of the ovine PRL gene was amplified, as described by Vincent and Rothschild et al. (1997), and subsequently digested with HaeIII restriction enzyme. Allele A contained three restriction sites for HaeIII and resulted in four fragments of 1,400, 530, 360, and 150 bp, while the presence of an additional restriction site in the B allele resulted in four fragments of 1,400, 530, 360, 150, and 20 bp. For the β-LG gene, a 120 bp fragment including parts of intron 1 and exon 2 was amplified, as described by Feligini et al. (1998), and subsequently digested with Rsal restriction enzyme. Allele A contained two restriction sites for Rsal and resulted in three fragments of 66, 37, and 17 bp, while the absence of one restriction site in the B allele resulted in only two fragments of 103 and 17 bp. Genotyping of the SNP described by Feligini et al. (2005) in the sheep CSN3 was performed with a common forward primer and two reverse primers (SNP-C and SNP-T) that differed in the 3’ end base and the presence of a 12 bp poly-G tail in SNP-C. The presence of the poly-G tail allowed the discrimination of the two alleles, allele T being 85 bp long while allele C was 97 bp long.

**Statistical Analysis**

Estimation of breeding values for all animals from OCSC was performed using a test-day animal model (Carvalheira et al., 1998; Stanton et al., 1992) and included monthly test day production collected from the ewes in the flock from January 1st, 1997 to July 31st, 2007.

Gene and genotypic frequencies were calculated using the ALLELE procedure of SAS (SAS Inst., Inc. Cary, NC) and their accordance with Hardy-Weinberg equilibrium was tested by a chi-square test in the same procedure. The effect of each polymorphism on the estimated breeding value weighted by its accuracy was evaluated using the GLM procedure of SAS. The statistical model used in the analysis for each polymorphic site within each of the three genes included the overall mean and PRL HaeIII (AA, AB or BB), β-LG Rsal (AA, AB or BB), or SCN3 Rsal genotype (TT, TC or CC). Orthogonal contrasts were constructed to compare the PRL genotypes (AA & AB vs. BB and AA vs. AB), β-LG genotypes (AA & AB vs. BB and AA vs. AB) and SCN3 genotypes (CC & CT vs. TT and CC vs. CT).
Results and Discussion

Estimated Breeding Values

The pedigree file consisted of 365 rams and 3219 ewes, for a total of 3584 animals. The ratio of genetic variance relative to phenotypic variance provided estimates of heritability for each lactation, ranging from 0.32 to 0.39. These estimates are higher than those reported for other dairy sheep (El-Saied et al., 2005; Othmane et al., 2002; Ugarte et al., 1996), probably due to the use of a test-day animal model and because data were from a single flock with a smaller environmental variance due to more uniform management.

The genetic merit was estimated relative to the average production in the entire population, which was 1,171 g of milk per day. The EBVs for the 696 individuals genotyped for the three genes varied from -483.77 to +835.7 with a mean of +108.9 g of milk per day relative to the average production in the population. The distribution of EBVs is shown in Figure 1. The accuracy of the EBVs varied from 0.22 to 0.95 with a mean of 0.78.

Figure 1. Distribution of estimated breeding values (EBVs) for milk yield for 696 individuals genotyped for all three genes.

Gene and Genotypic Frequencies

Gene frequencies were 0.13 and 0.87 for the PRL HaeIII polymorphism (alleles A and B, respectively), 0.69 and 0.31 for the β-LG RsaI polymorphism (alleles A and B, respectively), and 0.51 and 0.49 for the SCN3 RsaI polymorphism (alleles C and T, respectively). Genotypic frequencies for all three genes are presented in Table 1.
Table 1. Genotypic frequencies for PRL HaeIII, β-LG RsaI and SCN3 RsaI polymorphisms\textsuperscript{a} and Least Square Means for the estimated breeding values (EBV) for milk production

<table>
<thead>
<tr>
<th>Gene</th>
<th>Genotype</th>
<th>Frequency</th>
<th>Milk EBV, g/d</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRL</td>
<td>AA</td>
<td>0.01</td>
<td>153.21\textsuperscript{b,c}</td>
</tr>
<tr>
<td></td>
<td>AB</td>
<td>0.23</td>
<td>167.44\textsuperscript{b}</td>
</tr>
<tr>
<td></td>
<td>BB</td>
<td>0.76</td>
<td>91.17\textsuperscript{c}</td>
</tr>
<tr>
<td>β-LG</td>
<td>AA</td>
<td>0.43</td>
<td>112.83\textsuperscript{b}</td>
</tr>
<tr>
<td></td>
<td>AB</td>
<td>0.52</td>
<td>115.77\textsuperscript{b}</td>
</tr>
<tr>
<td></td>
<td>BB</td>
<td>0.05</td>
<td>79.06\textsuperscript{b}</td>
</tr>
<tr>
<td>CSN3</td>
<td>CC</td>
<td>0.12</td>
<td>105.39\textsuperscript{b}</td>
</tr>
<tr>
<td></td>
<td>TC</td>
<td>0.77</td>
<td>120.03\textsuperscript{b}</td>
</tr>
<tr>
<td></td>
<td>TT</td>
<td>0.10</td>
<td>88.34\textsuperscript{b}</td>
</tr>
</tbody>
</table>

\textsuperscript{a}Total number of animals with genotypes were 629, 551 and 678 for PRL, β-LG and CSN3, respectively.

\textsuperscript{b,c}LSM estimates without a common superscript within a column (within gene), differ (P < 0.05).

The gene frequency reported in this study in the East Friesian breed is in contrast with the frequency reported by Ramos et al (2009) in the Serra da Estrela and Merino breeds, where the A allele at the PRL HaeIII locus occurred more frequently than the B allele. While breed differences could explain these discrepancies, another possible explanation is the presence of a founder effect in the respective populations. The gene and genotypic frequencies at the β-LG RsaI locus are similar to the frequencies reported in Pag and Valle de Belice sheep (Cubic-Curik et al., 2002) and in East Friesian sheep from Saxony, Germany (Wessels et al., 2004), where the B allele was found to be predominant. The gene and genotypic frequencies at the SCN3 RsaI locus are similar to the frequencies reported in Prameka (Serbia) and Sarda breeds (Feligini et al., 2005).

Genotypic Effects on Estimated Breeding Value for Milk Production

Prolactin. The least squares means for the EBV for milk production grouped according to PRL HaeIII genotype are presented in Table 1. There was a significant effect of the PRL HaeIII polymorphism on EBV for milk production (P < 0.05). The orthogonal contrasts (Table 2) indicated that ewes carrying at least one A allele have the genetic ability to produce 138.3 g more milk per day than ewes with no A alleles (P = 0.09). There was no statistical difference between ewes with only one A allele and ewes with two A alleles. While both β-LG and CSN3 gene have been intensely investigated for a potential association with milk production traits, we are aware of only one other study investigating the PRL effect on milk yield in dairy sheep. Ramos et al. (2009) found a significant effect of PRL genotype on milk yield, fat and protein content in the Serra da Estrela breed but no effect was found in the Merino breed. In both breeds, the A allele occurred more frequently than the B allele and Serra da Estrela ewes carrying the AA genotype had lower milk yields when compared to ewes with AB and BB genotypes, which is the opposite of the results presented in this study for East Friesian ewes.
Table 2. Effect estimates, SE and probability >| t| for orthogonal contrasts evaluating the effect of PRL HaeIII, β-LG Rsal and SCN3 Rsal genotypes on the estimated breeding value (EBV) for milk production (g of milk/day)

<table>
<thead>
<tr>
<th>Contrast</th>
<th>Milk Production EBV</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Constant</td>
</tr>
<tr>
<td>Effect of PRL HaeIII genotype</td>
<td></td>
</tr>
<tr>
<td>AA and AB vs BB</td>
<td>138.33</td>
</tr>
<tr>
<td>AA vs AB</td>
<td>-14.23</td>
</tr>
<tr>
<td>Effect of β-LG Rsal genotype</td>
<td></td>
</tr>
<tr>
<td>AA and AB vs BB</td>
<td>70.49</td>
</tr>
<tr>
<td>AA vs AB</td>
<td>-2.94</td>
</tr>
<tr>
<td>Effect of SCN3 Rsal genotype</td>
<td></td>
</tr>
<tr>
<td>CC and CT vs TT</td>
<td>-2.42</td>
</tr>
<tr>
<td>CC vs CT</td>
<td>-31.69</td>
</tr>
</tbody>
</table>

The HaeIII polymorphism does not result in a change in amino acid substitution in the PRL polypeptide and, therefore, it is considered a “silent” mutation. The classical view is that silent mutations do not alter the composition or function of the protein produced by a gene. Recently, it has been shown that silent mutations interfere with several stages of the protein-making process, from DNA transcription to the translation of mRNA into proteins (Chamary et al., 2006). Although the possibility of a direct effect of the polymorphism needs to be explored, the association with milk production is more likely due to linkage with a functional mutation. Different alleles being associated with high milk production in different breeds could therefore be the result of different linkage phases between the HaeIII polymorphism and the functional mutation. In both populations studied, the beneficial allele is present in a low frequency. The East Friesian population in the present study was started in 1993 with a few East Friesian rams with limited availability of additional East Friesian genetics. Thus, the very low frequency of the beneficial allele could be due to a founder effect.

Beta-lactoglobulin. There was no significant effect of the β-LG Rsal polymorphism on EBV for milk production in the present population. Beta-lactoglobulin is one of the major whey proteins found in milk and a considerable number of studies investigated a possible association between the genetic variants of β-LG gene and milk related traits (Cubic-Curik et al., 2002; Dario et al., 2008; Feligini et al., 1998; Nassiry et al., 2007). The polymorphism investigated in the present study is the most studied polymorphism, a T → C nucleotide transversion in exon 2 of the β-LG gene produces the Rsal RFLP (Feligini et al., 1998) and results in the substitution of the Tyr20 with His in the β-LG polypeptide (Kolde and Braunitzer, 1983).

The results from different studies are conflicting, indicating superiority of either the A or B allele or no relationship with milk yield. In Valle del Belice ewes, the AA genotype was associated with higher milk yield (Giaccone et al., 2000). Another study that utilized East Friesian ewes showed that ewes with the AA genotype had the highest milk yield in the first lactation, while BB genotype ewes had the highest milk yield in the following lactations (Schmoll et al., 1999). Other studies point toward superiority of the B allele. Rampilli et al.
(1997) presented a trend for the BB genotype in Massese ewes to have higher milk production and similarly, in Sardinian ewes, the BB genotype was identified to have higher milk yields when compared to AB and AA genotypes (Bolla et al., 1989). In addition, in Serra da Estrela ewes, the AA genotype had the lowest milk yields, with no significant difference in milk yields between AB and BB genotypes (Ramos et al., 2009). The findings with Serra da Estrela ewes was also similar to findings in Merino ewes where again the AB and BB genotypes produced higher milk yields (Ramos et al., 2009).

Our results are similar to those of Pietrolla et al. (2000) in Sarda ewes, where no significant differences could be detected among genotypes; however, the authors reported a trend for the AA genotype to show the highest values for milk yield and the AB genotype to be always the intermediate between the AA and BB genotypes. Similarly, in our study there is a trend for ewes carrying at least one A allele to be genetically superior for milk production, but this difference did not reach statistical significance, probably because of small number of BB genotypes in the population caused a large SE associated with the difference.

Kappa-Casein. The present study did not find a significant effect of the SCN3 RsaI polymorphism on EBV for milk production. Among the four caseins (αs1-, αs2-, β-, and κ-casein) κ-casein is the least studied with respect to its effect on milk yield and composition. A positive association between genetic variants of CSN3 and milk traits has been reported in cattle (Ng-Kwai-Hang et al., 1984), while Caravaca et al. (2009) reported an association with total casein and protein content in goats, but no association between CSN3 and milk yield have been reported.

Conclusions

The dairy sheep industry is a new but growing industry in North America. Given the high demand for sheep milk cheeses currently satisfied by importing sheep cheese, there is an enormous opportunity for growth. For this opportunity to be realized, selection programs that target increased milk production are needed. Marker assisted selection could play an important role in this development, especially considering two characteristics of dairy sheep compared to dairy cattle: infrequent use of artificial insemination and limited production records, as implementing a production recording system is more costly relative to dairy cattle due to lower income per ewe. Among the three genes studied, only PRL showed a strong association with milk production, indicating that the PRL HaeIII could potentially be used as a DNA marker for milk yield in this East Friesian population. However, given the inconsistencies regarding the effect of this polymorphism on milk yield in dairy sheep, its association with milk production requires further validation in other populations before it is used in marker assisted selection.

Acknowledgments

This project was supported by National Research Initiative Grant no. 2005-35205-17680 from the USDA Cooperative State Research, Education, and Extension Service; by Oklahoma Agricultural Experiment Station; and by New York Agricultural Experiment Station Hatch Project 470. We appreciated the help of Old Chatham Shepperding Company in collecting blood samples and providing milking records.
References


INDUCTION OF ESTRUS AS A REPRODUCTIVE MANAGEMENT TOOL IN ANESTROUS EWES

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Background

Bright spots in the sheep industry in the US have been relatively few in recent years, but the increasing demand for meat and the increase in milking sheep to make cheeses have been two of those that are significant. Here in the Northeast an influx of ethnic groups who eat lamb has been an important contributor to the greater demand. Prices for lamb products have risen along with demand, but because of seasonal production, there has been an associated increase in the importation of lamb and lamb products. I expect that is true also for sheep’s milk cheeses, as I see many of them of foreign origin on my supermarket shelves. The survival and re-growth of the sheep industry require that producers increase efficiency of operation with the use of improved technologies so that they are better poised to take advantage of the improved consumer demand. Many of these technologies are used routinely by producers outside the US. However, limited usage of previously approved reproductive management products by US producers, coupled with a long-term decline in sheep numbers in the US, have made pharmaceutical companies reluctant to seek approval for commercial use of new products in this country.

Lamb production is a seasonal enterprise for most producers. Typically, ewes are bred in the fall (when reproductive activity and ovulation rate are greatest) and lamb in the spring. As a result, there are wide monthly fluctuations in both the numbers of lambs available and in the prices received by producers. Seasonal lambing patterns affect prices, as many producers are marketing lambs during the same time period. Further, the inconsistent supply reduces the efficiency of lamb processors and results in periods of low availability to the consumer. Likewise seasonal production of milk can affect functionality and profitability of a sheep cheese enterprise.

Induction of estrus in ewes during the non-breeding season (spring/summer) to achieve lambing in the fall has been attempted with limited success. Some programs have been aimed at increasing the number of lambings per year (3 every 2 years), taking advantage of seasonally high prices, and (or) making more efficient use of labor and other resources. Others have divided the flock to provide lambing in different seasons. Here in New York, the so-called Star System, developed at Cornell University, provides lambs born at five times in a two-year period. As we shall see, methods have been improved by some modifications, and relatively simple approaches can be effective if managed carefully.

Reproductive Pattern of the Ewe

Sheep are seasonally polyestrous animals, meaning that the ewe displays estrus (“heat”) every 16 to 18 days during a limited breeding season. The onset of the breeding season at this latitude is associated with decreasing day length (after summer solstice) and temperature. The
peak of the breeding season, as represented by the greatest proportion of the flock showing cyclic estrous activity or by the greatest ovulation rate (and thus the greatest expected pregnancy rates and litter sizes) is in October and November.

Breed, age, and nutritional status affect the exact time of onset and duration of the breeding season. Among breeds, the Southdown and Cheviot exhibit a relatively short breeding season, while the Dorset, Rambouillet, Merino and Finn-sheep exhibit extended breeding seasons. The black-faced breeds typically found in much of the Eastern US, Hampshire and Suffolk, have breeding seasons intermediate in length. Many of the hair sheep breed types, such as the Katahdin, Barbados Blackbelly, Virgin Island White and West African Hair Sheep are considered year-round breeders.

According to Dr. Antonio Lopez Sebastian (personal communication), the most seasonal dairy breed in Europe is the Friesian (anestrus from February to October), Lacaune and Assaf are anestrus from February to September and the other Mediterranean breeds from February to June-July. He stated that the most important difference between meat and dairy sheep in terms of interval from lambing to next pregnancy, is that length of this interval is influenced not only by anestrus, but also by the production system, in that some dairy breeds are managed in an intensive milking system (high producers with high lactation duration) with one lambing per year, as is the case for the Assaf breed in Spain.

The breeding seasons of ewe lambs start later and conclude earlier compared to adult ewes. Therefore, the first breeding season of the ewe lamb is shorter and it is much more difficult to breed ewe lambs out of season. In general, ewes or ewe lambs that are not receiving an adequate plane of nutrition will initiate their breeding season later in the fall. Ewe lambs that have not achieved an appropriate weight or age will not be bred during their first year of life. A minimum age of 7 months and a minimum weight of 100 pounds are reasonable recommendations for most of the common breeds and crosses.

**Hormonal Regulation of the Estrous Cycle**

Just before the onset of estrus, the pituitary gland, under the control of the hypothalamus in the brain, releases increasing amounts of luteinizing hormone (LH, Figure 1). Luteinizing hormone stimulates the final maturation of the ovarian follicle(s) containing the egg(s) and stimulates the follicle to produce more of the hormone estrogen that brings the ewe into estrus. The rising concentration of estrogen (Figure 1) stimulates a surge in LH that causes ovulation (release of the egg) and stops further secretion of estrogen by the follicle.

Once an egg has been released, LH transforms the follicle into a corpus luteum (CL), which produces progesterone (Figure 1). Progesterone secretion limits the tonic secretion of LH, thus limiting estrogen secretion by the growing follicles and preventing another estrus, LH surge and ovulation. If the ewe is not pregnant, prostaglandin F2α (PGF2α) secreted by the uterus, causes the CL to regress, and with the decrease in progesterone, a rise in estrogen, estrous behavior, an LH surge and ovulation can occur again.
Figure 1. Patterns of concentrations of follicle stimulating hormone (FSH), luteinizing hormone (LH), estradiol-17\(^\beta\) (E\(_2\)), progesterone (P\(_4\)), and prostaglandin F\(_2\alpha\) in peripheral blood of the ewe during the estrous cycle.

If the ewe becomes pregnant, the CL is required for maintenance of pregnancy. Secretion of interferon tau by the embryonic membranes causes the uterus to secrete prostaglandin E\(_2\) and these two hormones cause the CL to become resistant to PGF\(_2\alpha\) and to be maintained and continue to produce progesterone. Thus the pregnancy can be maintained, because progesterone prevents uterine contractions as well as preventing another estrus and ovulation. An understanding of these events in the cycle has helped us to develop tools for inducing or synchronizing estrus.
The Anestrous Period

As day length increases in late winter or early spring, the non-pregnant ewe ovulates the last egg(s) of the season. Upon regression of the CL and decline in progesterone, LH secretion fails to increase and estrus and ovulation do not occur, because melatonin secretion by the pineal gland is low, pulses of gonadotropin releasing hormone secretion from the hypothalamus are infrequent and pulses of LH are infrequent. This failure to ovulate represents the entrance into the non-breeding season (known as anestrus). That period, which lasts until mid-summer, is associated with decreased secretion of LH, and an absence of estrus and ovulation (and as a result the absence of a CL and extremely low concentrations of progesterone). When day length begins to decrease again in summer, melatonin secretion by the pineal gland increases, pulses of gonadotropin releasing hormone and LH become more frequent and as follicles grow and secrete more estrogen, an LH surge is triggered again and the ewe ovulates (first ovulation is without estrus). These changes are presented in the diagram in Figure 2.

Figure 2, Diagram of the regulation of seasonal breeding in the ewe by photoperiodic cues translated by the pineal gland, hypothalamus, anterior pituitary and ovary.

As first noted in 1946 by Underwood in Western Australia and confirmed in 1954 by another Australian scientist (P.G. Schinckel), the sudden introduction of rams to a group of ewes that have been isolated from rams can interrupt the anestrous period and result in fertile matings. This phenomenon is known as the “ram effect”. In response to introduction of rams, the anestrous ewe secretes increasing amounts of LH and estrogen. As estrogen increases, it triggers a surge of LH
from the anterior pituitary gland of the ewe. The LH surge causes ovulation within 1 to 3 days (in some ewes, response may be slower, 4 to 7 days), but this ovulation occurs without the expression of estrus. The absence of estrus at this time, even in the face of rising estrogen, is thought to be due to the absence of progesterone during anestrus. Progesterone priming and withdrawal are needed to increase the sensitivity of the behavioral centers of the brain to estrogen.

As illustrated in Figure 3 (panels 1 and 2), the CL that results from the first ram-induced ovulation has two possible fates that determine the actual day after the rams are first introduced that estrus occurs. If the CL has a normal life span (12 to 14 days) then upon its regression, estrus and ovulation occur around 16 to 17 days after introduction of rams, so fertile matings are possible at that time. However, the CL regresses early in about 50% of ewes, or more in some breeds and if further from the breeding season, and another ovulation without estrus occurs around 7 to 9 days after ram introduction. In this case, the first fertile mating can occur some 22 to 23 days following ram introduction. If the ewe is pretreated with progestogen or progesterone for 5 days or more, then the first ovulation after ram introduction is accompanied by estrus and the first cycle is usually normal in length (as shown in panel 3 in Figure 3). In that case, if the ewe is mated, there is time for maternal recognition of pregnancy (secretion of interferon tau by the embryo and PGE_2 by the uterus to maintain the function of the CL).

Several factors contribute to considerable variation in the percentage of ewes that are successfully bred out-of-season in response to ram introduction. Location is important; some breeds that were developed in tropical areas show little or no seasonality when raised in those areas. For example, Assaf dairy ewes (developed from a cross of East Friesian and Awassi) on 5 farms in Israel had lambing intervals of 272 days. In contrast, pure Awassi ewes had 330 days between lambings.

The breed of ram as well as ewe affects the response; in general, ewes and rams that have longer breeding seasons tend to breed more readily out-of-season in temperate areas. Further, among breeds, rams with greater sexual activity (such as Finnish Landrace and Dorset) induce more ewes to respond than do breeds with shorter seasons (such as Hampshire). Ewes that have been separated from the rams, and from their lambs for at least a month also respond better, because ewes lose their ability to respond to rams or ram lambs with which they have been joined continuously. However, introduction of novel rams can reinitiate cyclic activity. The postpartum interval and the nutritional and lactational status of the ewe also affect the response. More ewes ovulate in response to ram introduction as the days from lambing increase, likewise the longer that lambs have been weaned from the ewes, the better the response of the ewes. Ewes that are on a high plane of nutrition respond better than ewes that are nutritionally stressed. Both postpartum interval and lactation affect nutritional status. As the postpartum and post-weaning intervals increase, nutritional status should improve and so too, should the percentage of ewes that ovulate in response to ram introduction.

Ewes that lamb during the breeding season from out-of-season breeding are relatively easy to rebreed, even while lactating. They will often begin to cycle by 35 to 40 days postpartum, with good fertility at that time.
Figure 3. Types of ovulatory and estrous cycles of ewes vary in response to ram introduction. Male symbol and arrow represent the time of ram introduction. Dashed line represents concentrations of progesterone indicating function of the corpus luteum after ovulation induced by the ram introduction or subsequent ovulation. Solid bars denote estrus and solid lines indicate surges of luteinizing hormone (LH).

The ratio of ewes to rams is critical to the ram effect. As the number of ewes each ram must stimulate and service increases, the response decreases. In general, a ewe to ram ratio of no more than 15 to 1 is best. Success did not differ with 6, 9, or 12 ewes per ram, but ram lambs were less able to service 18 ewes than yearling rams, and in single ram lots, even yearlings had less success with 18 than with 12 ewes. Increasing the opportunity for contact among rams and ewes by keeping the animals in limited areas for the first day or two can potentially increase the response. The introduction of the ram is a powerful tool in overcoming anestrus and knowledge of the mechanisms underlying the ram effect has been used to develop systems for breeding ewes out-of-season.

Approaches to Breeding Ewes Out-Of-Season

In addition to the use of the ram effect, several techniques have been used to breed ewes out-of-season. In studies conducted during July through early September, just prior to the breeding season, the effectiveness of a 12-day treatment with the progestogen flurogestone acetate prior to ram introduction was evaluated. Pre-treatment with progestogen stimulated occurrence of estrus in association with the first ram-induced ovulation. Thus ewes had the opportunity for a fertile mating during the first 3 days that rams were present. Treatment with progestogen prevented the
occurrence of CL with reduced life span (short cycles) and therefore synchronized the second
service period 16 to 17 days later (Figure 3, third panel). Another treatment consisted of PGF$_2$\(\alpha\)
(5 mg, 2 X, 3 hours apart) given 12 days after introduction of rams. Each of these treatments led
to about 50\% of the ewes lambing to two service periods.

In a series of experiments carried out in Spain and West Virginia, the timing of injection of
PGF$_2$\(\alpha\) after introduction of rams was examined in ewes that received or did not receive a single
injection of progesterone at the time of ram introduction. A single injection of progesterone,
although insufficient to facilitate estrous behavior, prevented the occurrence of CL with a
reduced life span. When this treatment was combined with an injection of PGF$_2$\(\alpha\) 12 to 16 days
after ram introduction, a synchronized estrus occurred. In one study, PGF$_2$\(\alpha\) was given to the
ewes on either day 12, 14 or 16 after introduction of rams. In another study, a single injection of
progesterone (25 mg) was given at introduction of rams and PGF$_2$\(\alpha\) was given on day 14 or 16
after ram introduction. Injection of prostaglandin 12 to 16 days after ram introduction increased
the pregnancy rates to the first service (by 5 to 36 percentage points) and after two service
periods (by 13 to 30 percentage points) compared to ram introduction alone (Table 1). The
highest pregnancy rates were obtained when progesterone was injected at ram introduction and
PGF$_2$\(\alpha\) was given 16 days after ram introduction.

Table 1. Pregnancy rates of ewes exposed to rams (R), exposed to rams and injected with
PGF$_2$\(\alpha\) 12, 14 or 16 days later (RPG), or injected with progesterone (25 mg) at ram introduction
and injected with PGF$_2$\(\alpha\) 14 or 16 days later (PRPG) during the non-breeding season.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>No. ewes</th>
<th>First service</th>
<th>After two services</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td>60</td>
<td>35</td>
<td>45</td>
</tr>
<tr>
<td>RPG</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Day 12</td>
<td>220</td>
<td>40</td>
<td>67</td>
</tr>
<tr>
<td>Day 14</td>
<td>546</td>
<td>51</td>
<td>66</td>
</tr>
<tr>
<td>Day 16</td>
<td>481</td>
<td>51</td>
<td>62</td>
</tr>
<tr>
<td>PRPG</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Day 14</td>
<td>157</td>
<td>49</td>
<td>58</td>
</tr>
<tr>
<td>Day 16</td>
<td>219</td>
<td>71</td>
<td>75</td>
</tr>
</tbody>
</table>

Other approaches that have been used include treatment with melatonin, “the hormone of
darkness”. Melatonin is secreted by the pineal gland during the night. Treatment with melatonin
therefore mimics the short days of fall and ram introduction usually induces estrous behavior in a greater proportion of ewes after a minimum of approximately 35 days of treatment. Melatonin has been used in studies with dairy ewes. In Chura ewes in Spain, treated in March to May, melatonin implants did not change the interval from ram introduction to lambing, but increased litter size by 0.24 and 0.13 on two farms. In four Greek dairy breeds, treatment with melatonin advanced first estrus, increased ovulation rate in three of the four breeds, and increased conception rate. Similarly, conception date was advanced by two weeks and litter size was increased by 0.38 in Friesian ewes in Italy. In very recent work by the group in Zaragosa, Spain, undernutrition was detrimental to embryo viability in melatonin-treated ewes during the breeding season, but melatonin appeared to improve embryo quality during anestrus.

The percentage of ewes bred out-of-season can be increased by selection of ewes with naturally long breeding seasons such as Dorsets, Finn and hair sheep breeds or by selection within breeds or crosses. For example, D. R. Notter at Virginia Tech was able to increase the percentage of ewes lambing in a flock of crossbred ewes (50% Dorset, 25% Rambouillet, 25% Finnsheep) from 33 to 76% over a five-year period. These latter approaches (melatonin treatment and selection) do not synchronize estrus and must be combined with other treatments if a synchronized lambing to out-of-season breeding is desired.

Studies of the Efficacy of Intravaginal Devices for Out-of-Season Breeding

Intravaginal delivery devices for progestogens are easiest to use and have generated the most interest in recent years. The low amounts of progestogen incorporated into the original Synchro-Mate sponges marketed in the US in the 1970’s (20 mg FGA) and in the CIDR-G (300 mg progesterone) appeared to have resulted in lower fertility at the synchronized estrus in some cases during the breeding season in larger American ewes. Dosage of progesterone might be especially important in dairy ewes that are lactating, because significant amounts of progesterone are transferred into the milk (concentrations are greater in milk than in blood in the cow). Release of progesterone from the intravaginal devices declines with time, so short-term treatments might be beneficial.

When ewes are induced to ovulate and show estrus during the non-breeding season, ovulation rates and litter sizes (prolificacy) are lower than those observed during the breeding season. The hormone equine chorionic gonadotropin (eCG or PMSG), which has follicle stimulating hormone (FSH) activity in ruminants is widely used in other countries. In a study in Chile, intensively managed mature Laxta dairy ewes were treated with progestogen, gonadotropin and ram introduction at an average of 66 days in lactation. Seventy eight percent showed estrus, 70% of those conceived and 52% lambed in a 7-day period.

No gonadotropin preparation is currently approved for use in sheep in the US. The natural hormone FSH is conditionally approved for use in super-ovulation protocols in cattle. Thus it became of interest to evaluate the use of FSH in combination with progesterone pre-treatment and ram introduction for possible future use to increase litter size in ewes mated during the non-breeding season.
Experiment 1. Tests of new intravaginal devices with and without FSH. This study was conducted with 382 ewes on six farms during the anestrous period (May to July). Eighty-four of these ewes were determined to have high progesterone in blood (thus these ewes had been undergoing estrous cycles) and were removed from the study. The remaining ewes were assigned to one of four groups. One group received progesterone from a new intravaginal hormone releasing device (which contained 800 mg. progesterone) for 12 days (P12) alone or with a single injection of FSH (55 mg) on day 11 (P12F). Another group of ewes was assigned to receive the device for 5 days with FSH on day 4 (P5F), while the fourth group was exposed to rams only (C). Fertile rams with painted briskets were introduced to ewes at the time of insert removal at a ewe to ram ratio of 15:1. Blood samples were collected throughout the treatment period, ewes were observed for estrus, and pregnancy rates and litter sizes were recorded.

The new device did not increase concentrations of progesterone in the blood of the ewe as high as concentrations seen during the luteal phase of the estrous cycle or those reported previously for the original CIDR-G. In ewes treated for 12 days, the concentration of progesterone declined rapidly after the first 4 days, and was not different from that of untreated ewes by day 12.

Despite the low progesterone in the blood, 74% of the progesterone-treated ewes showed estrus during the first 5 days after ram introduction compared to 12% in ewes introduced to rams only (Table 2). The mean time from introduction of rams to estrus was 42 hours and did not differ with duration of treatment with progesterone (5 or 12 days).

The percentages of ewes lambing to the first (42%) and to both first and second service periods (64%) in progesterone-treated ewes were not affected by duration of progesterone treatment. In ewes introduced to rams only, the values were 0 and 41%, respectively (Table 2). Therefore, treatment with progesterone increased the overall proportion of ewes lambing by 23 percentage points.

Ewes lambing to the first service period that were treated with progesterone and given an injection of FSH had a larger litter size (0.2 to 0.3 more lambs born per ewe lambing) than ewes exposed to rams only (Table 2). Ewes treated with progesterone lambed earlier and in a more synchronized pattern (Figure 4). The majority (60 to 70%) of progesterone- treated ewes that lambed did so during the first 8 days of the lambing period. No ewes lambed between days 9 and 15, but another period of lambing occurred between days 16 to 25. Ewes introduced to rams lambed continuously between days 14 and 29 of the lambing period.
Table 2. Reproductive performance of anestrous ewes in 1998 (Experiment 1) in response to ram introduction (C), or ram introduction + 12-d PCL treatment (P12), 12-d PCL treatment + FSH (P12F) or 5-d PCL treatment + FSH (P5F) and in 1999 (Experiment 2) in response to ram introduction (C), or ram introduction + 5-d CIDR pre-treatment without (P5) or with FSH (P5F).

<table>
<thead>
<tr>
<th></th>
<th>Experiment 1, 1998</th>
<th>Experiment 2, 1999</th>
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<tbody>
<tr>
<td><strong>Variables</strong></td>
<td><strong>Treatment</strong></td>
<td><strong>Treatment</strong></td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>P12</td>
</tr>
<tr>
<td>Total Ewes</td>
<td>73</td>
<td>73</td>
</tr>
<tr>
<td>Ewes in Heat (%)</td>
<td>12</td>
<td>77</td>
</tr>
<tr>
<td>Conception Rate (%)</td>
<td>10</td>
<td>63</td>
</tr>
<tr>
<td>Ewes Lambing (%)</td>
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<td></td>
</tr>
<tr>
<td>A) First Service</td>
<td>0</td>
<td>45</td>
</tr>
<tr>
<td>B) Overall</td>
<td>41</td>
<td>66</td>
</tr>
<tr>
<td>Litter size:</td>
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<td></td>
</tr>
<tr>
<td>A) First Service</td>
<td>-</td>
<td>1.6</td>
</tr>
<tr>
<td>B) Second Service</td>
<td>1.5</td>
<td>1.4</td>
</tr>
<tr>
<td>C) Overall</td>
<td>1.5</td>
<td>1.5</td>
</tr>
</tbody>
</table>
Experiment 2. Examination of short-term treatment with the CIDR-G. In experiment 1, the new device did not deliver more progesterone than the original controlled internal drug releasing devices (CIDR-G; containing only 300 mg. progesterone). Treatment for 5 or 12 days seemed to be equally effective. Experiment 2 was aimed at testing the efficacy of a 5-day treatment with the original CIDR-G device with or without FSH given one day before removal of inserts compared to introduction of rams only. In this study, a total of 653 ewes on 7 farms were assigned to be controls (C; introduced to rams only), or to receive the CIDR-G device for 5 days, alone (P5) or in combination with an injection of FSH 1 day before insert removal (P5F).

The results were similar to those obtained in experiment 1 (Table 3). More ewes treated with progesterone (P5 and P5F) than controls were marked by rams during the first 3 days after ram introduction (77 vs 20%), and lambed to the first (46 vs 0%) or both services (63 to 67 vs 45%). Thus an additional 18 to 22 of every 100 treated ewes lambed due to progesterone pre-treatment. Ewes that were treated with FSH and lambed to the first service tended to have a larger litter size (by 0.2 to 0.3 lambs) than ewes not treated with FSH and control ewes.

In both studies, the response varied among farms and to a limited extent with the face color of the ewe (Table 4). The greatest responses in terms of overall ewes lambing were observed in
white-faced ewes (69%) other than North Country Cheviots. Although only a few North Country Cheviot ewes were studied, none of these ewes lambed in response to treatment.

Experiment 3. Effects of dosage, vehicle, and injection time on the response to FSH. In a third experiment, different dosages of FSH, vehicles for the FSH and times that FSH was injected relative to removal of the intravaginal insert were examined. Although dosages of FSH of 42 or 68 mg increased ovulation rate slightly when given 12 hours before insert removal, numbers of lambs born were not increased in most flocks. Vehicle in which the FSH was diluted did not affect the response, but injection of FSH 36 hours before insert removal was ineffective.

From these three experiments, it was concluded that progesterone treatment before ram introduction can be used to induce a synchronized fall lambing in the majority of ewes, which can allow producers to take advantage of seasonally higher lamb prices. Increases in litter size were not sufficient to justify the addition of FSH to the treatment regimen of progesterone and ram introduction. Canadian work by Pawel Bartlewski and coworkers led us to consider that one reason for the lack of effect of FSH may have been the relatively low concentrations of progesterone in ewes treated with the intravaginal devices. They saw that ovulation rate in two breed types of ewes was greater in the breed with lower concentrations of progesterone in their blood. Thus ovulation rates may have been greater because of the lower progesterone.

Experiment 4. Effects of concentrations of progesterone on ovulation rate and litter size. Based on our own and the Canadian findings, Ezra Devonish and Marlon Knights did an experiment in Barbados Blackbelly ewes in Barbados. These ewes naturally have a fairly high ovulation rate and litter size. Mature ewes were assigned to groups treated so that they would be expected to have low, medium or high progesterone (n = 23 or 33 per group in two seasons). Each ewe on low and high progesterone received a progesterone-containing intravaginal device from d 4 through d 14 after estrus. Ewes in the low group were given PGF\(_2\alpha\) on d 6 to regress corpora lutea (CL), so they received progesterone from only the device. Ewes with medium progesterone were untreated. Those on high progesterone had the devices as an extra source of progesterone in addition to the CL.

Ovaries in all ewes were observed by transrectal ultrasonography on d 7 after breeding. Numbers of CL formed (ovulation rate) increased linearly with decreasing progesterone. Conception rates did not differ with concentration of progesterone. Lambs born per CL on the ovaries decreased linearly with decreasing concentrations of progesterone. Thus the net effect was that litter size born did not differ among ewes treated to have low, medium or high concentrations of progesterone (2.0, 1.9, and 1.9 ± 0.1 lambs, respectively), despite greater ovulation rates in the ewes on lower progesterone. On a practical basis, altering progesterone before breeding did not change productivity of the ewe in terms of number of lambs born.
Table 4. Distribution and some reproductive characteristics of ewes by farm and face color.

<table>
<thead>
<tr>
<th>Variable</th>
<th>No. of Ewes Per Face Color/Breed Type</th>
<th>PR 1st service (%)</th>
<th>Ewes Lambing (%)</th>
<th>Prolificacy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tot B M W Ch</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Farm:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>52 9 15 28 0</td>
<td>40</td>
<td>52</td>
<td>1.7</td>
</tr>
<tr>
<td>2</td>
<td>47 33 8 6 0</td>
<td>40</td>
<td>87</td>
<td>1.8</td>
</tr>
<tr>
<td>3</td>
<td>75 60 14 1 0</td>
<td>44</td>
<td>72</td>
<td>1.7</td>
</tr>
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<td>4</td>
<td>34 13 8 3 10</td>
<td>21</td>
<td>24</td>
<td>1.4</td>
</tr>
<tr>
<td>5</td>
<td>15 15 0 0 0</td>
<td>60</td>
<td>47</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>67 51 11 4 1</td>
<td>16</td>
<td>43</td>
<td>1.5</td>
</tr>
<tr>
<td>Face Color:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Black (B)</td>
<td>181</td>
<td>43</td>
<td>59</td>
<td>1.6</td>
</tr>
<tr>
<td>Mottled (M)</td>
<td>56</td>
<td>49</td>
<td>61</td>
<td>1.8</td>
</tr>
<tr>
<td>White (W)</td>
<td>42</td>
<td>60</td>
<td>69</td>
<td>1.6</td>
</tr>
<tr>
<td>Cheviot (Ch)</td>
<td>11</td>
<td>0</td>
<td>0</td>
<td>-</td>
</tr>
</tbody>
</table>

The only breed identified specifically was North Country Cheviot (Ch). Black-faced ewes (B) on farm 5 were 100% Suffolk, but other black-faced ewes were grade and included Hampshire and Suffolk breeding. White-faced ewes (W) included Dorset and other breeding. Mottled-faced ewes (M) were crosses of black- and white-faced ewes.

PR = pregnancy rate, number of ewes pregnant on d 26 to 31 as a percentage of all ewes in groups treated with progesterone.

Ewes lambing to first or second service period of all ewes exposed and alive at lambing, including both progesterone treated and control ewes.

Lambs born per ewe lambing.

**Lactating Ewes: A Limiting Factor During Anestrus**

Lactation has little or no inhibitory effect on the ability of ewes to exhibit reproductive cycles during the breeding season. Estrus accompanied by ovulation occurs about 35 days after parturition in fall-lambing ewes, regardless of whether they are suckling lambs or non-lactating. However during anestrus, lactating ewes usually respond poorly to attempts to induce breeding.
activity by ram introduction or treatment with progestogens. In recent studies, effects of lactation on response to treatment with progesterone were examined in ewes that were treated in early July. The lambs had been weaned from ewes in one group and ewes in the other group were in the second and third month of lactation. All ewes received CIDR devices (that had been used previously for 5 days) for 5 days before introduction of rams.

In experiment 1, 105 weaned ewes and 53 lactating ewes were studied. Half of each group received an additional treatment of 30 micrograms of estradiol benzoate in 1 mL corn oil 24 hours after insert removal and ram introduction. The other half received just corn oil. Weaned ewes had higher pregnancy rates by ultrasonography at 26 to 30 days after first (59%) or second service (74%) periods than the lactating ewes (38 and 44%, respectively). Thus 81% of the weaned ewes, but only 44% of the lactating ewes lambed. Lambs born per ewe exposed (lambing rate) averaged 1.26 for weaned ewes and only 0.61 for lactating ewes. Lambing rate was greater in ewes that were treated with estrogen, (1.1) than in ewes receiving corn oil (0.8).

In experiment 2, 106 weaned ewes and 44 lactating ewes received either 0, 15 or 30 micrograms of estradiol benzoate 24 hours after insert removal and ram introduction. Again, more weaned (76%) than lactating (27%) ewes were pregnant to first service. More weaned (82%) than lactating (27%) ewes lambed, and lambs born per ewe exposed averaged 1.25 and 0.31, respectively. Treatment with estrogen increased pregnancy rate to first service and ewes lambing in weaned, but not in lactating ewes.

In summary, currently available methods are not suitable for induction of breeding out-of-season in lactating ewes that are suckling lambs. During March or April through July, it is recommended that lambs be weaned for at least 10 days before initiation of treatments to induce a fertile estrus. More studies are needed in milked ewes.

The Value of Synchronized Estrus

An added advantage of most systems to induce out-of-season breeding is that estrus is synchronized in a group of animals. Synchronization of estrus is extremely valuable either in- or out-of-season for producers using artificial insemination, because of the reduction of labor for breeding. In addition, synchronized breeding leads to synchronized lambing, thus concentrating and reducing labor requirements during lambing, and a more uniform lamb crop, which facilitates both management and marketing of the lambs. Ewes of the same breed-type that were bred in a single day usually lamb in a 7-day period and those bred over a 3-day period lamb during a period of 10 days or less. Therefore, knowing the average gestation length (145 to 150 days in most breeds and crosses), the producer using synchronized estrus can predict the days when most lambs will be born and can schedule lambing to occur when it fits to target specific markets for milk, cheese or meat. Lower lamb mortality can be achieved due to greater observation during the first three days of life when the danger of mortality is highest. Marketing costs are reduced as a result of having fewer weight/age groups to market.

Typically, farmers may expose their ewes to rams during the fall breeding season for the equivalent of two (35 days) or three estrous cycles (52 days). When exposed to rams for the equivalent of three estrous cycles, 90 to 95 percent of ewes lamb within a 60-day period.
Synchronization of estrus results in a similar percentage of ewes that conceive and lamb as with random mating. However, lambing occurs in three shorter and more concentrated lambing periods of 7, 10 and 10 days, with approximately 10-day intervals between these periods. This is because ewes are bred initially in a short period of two or three days, and those that do not conceive to first service remain synchronized and return to estrus within another short interval of about 5 days, an average of 16 to 17 days after the first breeding. The breeding period can be shortened to about 37 days, because the first service opportunity for all ewes occurs within the first three days.

**Unexpected Findings: Late Embryonic and Fetal Mortality**

During the recent studies in out-of-season breeding, pregnancy was diagnosed by ultrasonography of the reproductive tract of the ewes at 26 to 30 days after first and second service periods. In combination with the data for lambing, the data for pregnancy status at 26 to 30 days allowed us to estimate pregnancy retention. In out-of-season experiment 1, 91% of pregnancies to first service were retained to lambing and 73% of pregnancies resulting from the second service period were retained. Similarly, in out-of-season experiment 2, pregnancy retention rates were 88 and 80%, for first and second service periods, respectively.

These findings stimulated further studies of the numbers of embryos or fetuses present at 25, 45, 65 and 85 days after breeding and numbers of lambs born in both the breeding and non-breeding seasons. In 2000 and 2001, a total of 957 pregnant, non-lactating ewes of mixed breeding on 9 cooperating farms, bred either in early May and June (anestrus, season 1) or in late July, August or September (transition, season 2), were examined by ultrasonography. Late embryonic and fetal mortality was determined from these counts and numbers of lambs born. Breeding season and service period did not affect losses at any stage of pregnancy.

Individual embryos or fetuses were lost from multiple pregnancies, as well as complete losses of either single or multiple pregnancies. In fact, more ewes lost one or more, but not all, embryos/fetuses from day 25 to term than experienced complete loss of a pregnancy (Figure 5). Losses of potential offspring were continuous throughout gestation, with 4.3% of ewes experiencing loss of one or more embryos from day 25 to 45, 5.1% losing one or more fetuses from day 45 to 65, and 10.2% from day 65 to term. Mean losses of embryos or fetuses averaged 3.3% from day 25 to 45, 2.7% from day 45 to 65, 2.3% from day 65 to 85, and 8.5% from day 85 to term.

Treatment with FSH increased losses, measured as the proportion of potential offspring (number of corpora lutea) not represented by lambs born (0.25, 0.55 and 0.71 for 0, 42 and 62 mg of FSH, respectively). Late embryonic or fetal mortality totaled 18.5% from day 25 to term in the current study. Estimated total loss of potential offspring from determination of ovulation rate to lambing was 22.4%. By difference, only approximately 4% of potential offspring were lost from ovulation to day 25 of gestation in those ewes (72%) that were pregnant at day 25. Thus fertilization failure and/or early embryonic death were more important in total failures of pregnancy (28%) that occurred before day 25 than in the partial losses. Overall, it is important to realize that ovulation rate is not the only factor limiting litter size in sheep.
One of the findings in the studies of pregnancy loss was that losses were greater in ewes that had lower concentrations of progesterone on day 25, which was similar to findings in dairy cows. That observation was not surprising, because progesterone is required for maintenance of pregnancy in all mammals. Another finding was that black-faced ewes lost more embryos or fetuses than white-faced or mottled-faced ewes, even though the black-faced ewes had lower ovulation rates. These genetic differences in the ewes led us to examine effects of the sire of the embryo on embryonic and fetal losses. Tammy Holler and Dr. Robert Dailey are now analyzing data collected from 978 ewes on 9 farms in 5 states, including dairy sires at Spooner, Wisconsin. Preliminary analyses indicate that breed of ram is not very important, but rams within breeds vary greatly in losses of their potential offspring. Ewe breed and ewe age are very important. The East Friesian and Lacaune ewes at Spooner had fewer losses (about 15%) than meat type ewes in the study (for example, about 19% in the ewes at Arlington) but they were examined, on the average 14 days later in gestation (day 53) and had fewer fetuses at that time (1.69 vs 1.96) and produced fewer lambs (1.56 vs 1.83). Thus the fewer losses fit with a lower ovulation rate as seen in earlier studies.

**Conclusions**

Treatment of ewes during the anestrous period with progesterone for as little as 5 days before ram introduction can result in synchronized fall lambing in greater than 65% of ewes treated, an improvement of 20 percentage points over ram introduction alone. Treatment with FSH one (1) day before progesterone withdrawal will sometimes yield a small increase in litter size in ewes bred out-of-season, but only in flocks with naturally low ovulation rates, and FSH increased embryonic and fetal mortality. Therefore, general use of FSH cannot be recommended.
Once CIDR-G devices are approved for use in the US sheep industry and marketed in this country, treatment with a CIDR device for 5 days before ram introduction can be used to induce out-of-season breeding. This regimen can allow producers to target lamb markets when prices are highest. Its utilization in the industry could help to ensure a consistent supply of lamb or of milk.

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FERMENTABLE FIBER FOR FEEDING DAIRY SHEEP

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Introduction

Feed formulation is the art of combining ingredients to meet nutritional requirements of animals. Sheep are ruminants with a 4-compartment stomach made up of the rumen, reticulum, omasum, and abomasum or true stomach. The largest compartment is the rumino-reticulum, which contains bacteria and protozoa and functions as a fermentation vat in which fiber is digested. Thus, appropriate feed components are needed for normal ruminal bacteria and protozoa to flourish in order to develop (Warner et al., 1956) and maintain proper rumen function.

Diet for sheep should, therefore, be formulated to provide: 1) nutrients for fermentation by and multiplication of ruminal microbes; and 2) nutrients that are directly digested in the true stomach and intestines. The major end product categories of fermentation by ruminal microbes are 1) volatile fatty acids (VFA: acetate, propionate, butyrate), which are absorbed through papillae of the rumen wall; and 2) more bacteria and protozoa. The VFA are metabolized by dairy sheep into glucose and other carbohydrates or used directly as fuel and to synthesize tissues and milk. Some of the bacteria and protozoa are passed to the abomasum and small intestine where they are digested to provide high quality protein and other nutrients. Thus ruminal bacteria and protozoa can turn feed ingredients that simple-stomached animals; like humans, pigs and chickens; cannot digest into nutrients like carbohydrates, protein, and B-vitamins that are digestible in the lower gut.

This document will not discuss all aspects of dairy sheep nutrition. An excellent resource is the book edited by Giuseppe Pulina (Pulina, 2002) and particularly the chapter on feeding lactating ewes (Cannas, 2002).

Traditional Diet Formulation

In the past, ruminant diets have been balanced for energy, protein, vitamins, and minerals. In some systems, protein is balanced for 1) that degraded by ruminal bacteria and protozoa; 2) feed protein that escapes rumen fermentation so that it is digested in the lower gut; and 3) microbial protein digested in the lower gut. Energy values of feed ingredients and energy requirements of animals were used to determine the amount of feed necessary for maintenance, growth, wool growth, pregnancy, and lactation. Traditional diet formulation begins by estimating dry matter intake. Ingredients to meet nutrient requirements are then chosen to fit into the estimated dry matter intake.

Dietary energy comes mostly from carbohydrates with some contribution from protein, and lipids. Many energy systems have been developed and they all ignore the fact that the composition of the carbohydrate fractions (fiber, starch, pectins) can have a dramatic influence.
upon feed intake, rumen function and the nutrients that are available to the animal. Thus, as discussed below, any formulation system that estimates dry matter intake prior to diet formulation probably will result in formulation errors.

**Effect of Carbohydrate Fractions on Feed Intake**

Dietary carbohydrates are categorized as nonstructural (mainly starch and sugars) and structural. Structural carbohydrates are those that shape plants and their products and they are usually referred to as fiber. Until the 1960's, fiber was not measured in any chemically-defined way. Then, Peter Van Soest, working at the USDA lab in Beltsville, MD and later at Cornell University, developed the detergent system (Van Soest, 1964; Van Soest, 1967), which quantified total fiber – or cell walls – of feed ingredients using neutral detergent. Neutral detergent fiber (NDF) is a measure of plant cell walls and includes cellulose and hemicelluloses, which both can be fermented by rumen microorganisms, unless the fiber also contains too much indigestible lignin.

An analysis of experiments to define the minimum NDF requirements of growing lambs (Hogue, 1993; Hogue, 1994; Hogue and Jabbar, 1991; Thonney and Hogue, 2007) showed that the source of NDF had a major effect upon feed intake. When included at large dietary concentrations, NDF from low digestibility oat hulls reduced intake while NDF from highly digestible soy hulls increased intake. The effect on intake of other high-fiber ingredients; such as beet pulp, alfalfa meal, corn gluten feed, and wheat middlings; varied with their digestibilities. This led to the conclusion that high concentrations of indigestible NDF (INDF) reduce intake while high concentrations of fermentable NDF (FNDF) increase intake (Figure 1). Other experiments with lactating ewes nursing twin or triplet lambs (Hogue, 1994; Schotthofer et al., 2007), lactating dairy cows, and feedlot cattle (Baker et al., 2009) have shown that minimum levels of FNDF enhance intake and prevent rumen metabolic disturbances.

These results do not fit models that have used NDF (Mertens, 1987) and digestible dry matter (DDM) or functions of DDM such as net energy for maintenance (NE\textsubscript{m}) (Fox et al., 1992) to predict feed intake. The dry matter intakes of diets high in FNDF in our experiments and in commercial applications have been much higher than traditional models of feed intake would have predicted. In fact, traditional models of feed intake would have predicted lower – not higher – feed intake at the high NDF levels we have fed. In contrast and in support of the necessity to balance for FNDF, increased NDF fermentability resulted in higher feed intakes in dairy cows consuming diets with the same level of NDF (Oba and Allen, 1999). The dramatic intake-
enhancing effect of diets high in FNDF also indicates that ruminant diets cannot be balanced properly by assuming a given intake level independent of the feed ingredients included in the diet.

**A New(?) Concept for Diet formulation for Ruminants**

From the previous discussion, although ruminants can ferment nonstructural carbohydrates (NSCHO), it is obvious that sheep or any ruminant needs fermentable fiber. This should not be surprising to any ruminant nutritionist. Given the evolutionary development of ruminant animals, how else would the ruminal microbial population be able to function effectively? Somehow the evolution of ruminant nutrition has not included this simple concept.

The concentration of FNDF, INDF and nonstructural carbohydrates varies widely among feed ingredients. Because the dietary concentration of FNDF is so important to maintain rumen function and improve intake, ruminant diets should be balanced for minimum levels of FNDF. This has led to a revised approach to feed formulation.

**FNDF Values for Feed Ingredients**

Most feed ingredient tables do not contain values for FNDF, where FNDF is defined as the proportion of the ingredient dry matter (DM) that is fermentable NDF. The main reason for this is that traditional methods of balancing diets do not consider the separate carbohydrate fractions; instead, they lump them together into feed energy values. Most tables do, however, report some measure of digestibility, like total digestible nutrients (TDN) or digestible dry matter (DDM) which can be used in a simple calculation to compute FNDF.

The calculation is based on the assumption that feces are composed primarily of NDF and endogenous losses. Endogenous fecal losses range from 10% of the DM for concentrates to 15% of the DM for low quality forages (Van Soest, 1994). Thus, for each feed ingredient, an appropriate endogenous fecal loss is subtracted from indigestibility of DM to give indigestible NDF (INDF). Then, indigestible NDF is subtracted from NDF to give FNDF as a proportion of the ingredient dry matter. For example, if the DDM of alfalfa hay is 60%, then it is 40% indigestible. Subtracting 15% (endogenous loss) from 40% gives a value of 25%.

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**A note on terminology:**

We equate NDF fermentability with NDF digestibility. The reason for this is that NDF that disappears from the digestive tract must be fermented by microorganisms or end up in feces.

**Quantitative terms for NDF:**

**INDF (indigestible NDF):** Proportion of a feed ingredient or diet that is indigestible NDF when intake is 1X maintenance.

**dNDF (digestible NDF):** Proportion of NDF that is digested.

**pfNDF (potentially-fermentable NDF):** Proportion of a feed ingredient or diet that is fermentable NDF when intake is 1X maintenance. This is the same as assuming that all the NDF that can be digested will be digested and is calculated by subtracting INDF from NDF.

**FNDF (fermentable NDF):** Proportion of feed ingredient or diet NDF that is actually fermented.
for INDF. Assuming an NDF value of 46% for the alfalfa hay gives a value of 21% for FNDF.

"Energy" terms:

These 3 terms are approximately equal when expressed as percentages of the total:
TDN: total digestible nutrients
DDM: digestible dry matter
DE: digestible energy

Usually calculated from DE:
ME: metabolizable energy

NE terms are usually calculated from ME:
NE: net energy
NEₘ: net energy for maintenance
NEₙ: net energy for gain
NEₗ: net energy for lactation
NEL: net energy for lactation and maintenance at 3X maintenance intake

Note that there are significant errors associated with multiple equations that predict one value from another. From the point of view of practical feed formulation, it may be more appropriate to use known

Tabular values for DDM were originally determined at maintenance levels of intake, but there is a major effect of level of intake on digestibility (Tyrrell and Moe, 1975; Wagner and Loosli, 1967). This has been documented recently for DM and NDF by Hein et al. (2009) in weanling lambs and mature dry ewes and by Schotthofer et al. (2007) in lactating ewes. Because highly productive animals, like lactating ewes, consume feed at several times maintenance levels, feed passes through the digestive tract more quickly with less time for digestion.

FNDF values can be estimated by using the discount factors of Van Soest (1992), but the discount factors are affected by the animal species and particular batch of feed ingredient. In our feed formulation system, therefore, we assign potentially-fermentable NDF (pfNDF) values to ingredients by subtracting INDF from NDF.

Formulating Feeds with Fermentable Fiber

A new feed formulation approach (the "Dugway Nutritional Plan") was developed to provide an effective method of feeding ruminants and to overcome some limitations of traditional systems. Specifically, the new approach recognizes that diet formulation can have a significant effect on feed intake and also that the proper balance of dietary components can effectively prevent most metabolic disturbances such as acidosis and animals going off-feed.

Pooled energy values such as TDN, DE, ME, NE, NEₘ, NEₙ, NEₗ, and NEL are ignored in the new approach. Instead, diets are balanced on the carbohydrate components that generally make up those pooled values. The other dietary components are Ash, Ether Extract (EE) and Protein fractions (that is, crude protein or soluble, degradable, escape, and indigestible protein), which are comparable to generally accepted systems. Because both EE and ash in ruminant diets are generally about 5%, both are suggested to be included at about this level and not discussed further. For simplicity, the protein fraction(s) are only considered as the total or crude protein. The carbohydrates are divided

Feed components in the "Dugway" approach:

Carbohydrates
NDF (neutral detergent fiber)
pfNDF
INDF
NSCHO (Nonstructural carbohydrates)
Sugars
Starches
CP (crude protein)
Ash (minerals)
EE (ether extract = fat)

These components sum to 100% of the feed ingredient or diet.
into INDF, pfNDF, and NSCHO and are the variable fractions that receive the most emphasis in the new approach. Decreasing the INDF in the diet and/or increasing the feed intake are the most effective ways of increasing the supply of nutrients available for animal production. However, at high feed intakes, the proper balance between pfNDF and NSCHO becomes important, especially for preventing metabolic disturbances.

The Ash, EE, Protein fractions, INDF, pfNDF and NSCHO components can be summed together or properly pooled and adjusted to estimate a pooled energy value such as TDN or DE or ME or NE, but that pooling is unnecessary and redundant. Furthermore, the effects of the individual components are lost when pooled.

Minimum levels of pfNDF and maximum NSCHO are suggested. Animals fed diets high in good quality forage such as the beef cow herd and sheep either at maintenance or pregnant or suckling a single lamb usually will be fed diets that exceed the minimum pfNDF in the diet and not approach the maximum suggested level of NSCHO. Higher producing lactating dairy cows, ewes suckling 2, 3, or 4 lambs, milking ewes, feedlot lambs, and feedlot cattle fed high grain diets often will not meet the suggested minimum pfNDF and maximum NSCHO levels unless the diets are balanced carefully.

An example for lactating cows is demonstrated in Figure 1. This includes the proportions of each suggested component for cows producing from 0 to 120 lb of milk per day. Estimated components for high-producing milking ewes would be about the same except that maximum relative production for milking ewes would be in the 60- to 90-pounds of daily milk for cows.

Pectin like substances (PLS) are included in the pfNDF even though by analysis they will be included in the Neutral Detergent Soluble (NDS) fraction of the feed. The suggested level of both ash and EE (5%) is the same from maintenance (zero milk) to 120 lb of milk. The protein fractions are increased from 10 to 16%. Only the total of the protein fractions (CP) is indicated in this figure. The INDF is reduced linearly from 30 to 10%.

![DUGWAY NUTRITIONAL PLAN Feed Components](image)

Figure 1. The Dugway Nutritional Plan feed components and suggested dietary levels for lactating dairy cattle.
of the diet to account for comparable increases in DDM.

The remaining 2 components (pfNDF and NSCHO) are suggested at levels that should enhance feed intake and prevent metabolic disturbances, especially at the higher levels of milk production. The pfNDF is expressed as a suggested minimum and NSCHO as a suggested maximum. At lower levels of production, suggested levels of minimum pfNDF and maximum NSCHO are usually not approached as these animals are usually fed high forage diets that contain higher levels of pfNDF and lower levels of NSCHO than are suggested. At the highest level of production indicated on the figure (120 lb of milk), the minimum percentage of pfNDF is increased and the maximum percentage of NSCHO is decreased to take into account the possibly that the cow will have difficulty processing very high amounts of NSCHO at the high feed intake needed to produce 120 lb of milk.

Note that “feed components” rather than “nutrients” are used. The only “nutrient” that is intentionally avoided is a pooled energy value, such as NE (see box about energy terms above). Approximate “suggested dietary levels” are used instead of “requirements.”

Feed Component Values

Some approximate feed component values are given in Table 1. Included are several forages at different maturity levels, the major grains and a variety of by-products that now are widely available for feeding. Values are listed for NSCHO (sugars and starches), neutral detergent fiber (NDF) divided into potentially-fermentable (pfNDF) and indigestible (INDF), crude protein (CP), ether extract (EE), and ash. These components sum to 100% of the dry matter.

The DDM, CP, EE and Ash values were taken from existing tables, primarily those of Van Soest (1992). Digestible dry matter generally was considered to be equivalent to TDN except for feeds rich in EE or Ash. Furthermore, INDF is highly negatively correlated with DDM so that one or the other could be omitted. However, digestible dry matter at 1X maintenance was included so that INDF could be calculated as the difference between indigestibility and endogenous fecal losses. Intake levels higher than maintenance result in a depression in digestibility (Tyrrell and Moe, 1975; Van Soest and Fox, 1992; Wagner and Loosli, 1967). Because it is primarily fiber digestibility that is depressed as intake increases, FNDF levels of ingredients would be lower for producing animals with consumptions above maintenance. To compensate for this digestibility depression, correspondingly higher pfNDF levels were suggested in Figure 1 and in the FeedForm diet formulation package discussed below. Most feed components will have considerable variation and therefore the numbers in Table 1 and in the FeedForm package should be considered as being approximate.

FeedForm Diet Formulation Package

A simple Microsoft Access-based program, FeedForm was developed to balance diets based upon the approach discussed above. Included are modifiable tables of feed components and suggested levels of components for sheep and cattle. Formulation is based upon the substitution method. Premixes can be formulated and added directly to the table of feed components. After balancing a complete diet, the ingredients that are not the substitution
ingredient can be specified as a supplement. Details are available at [http://www.sheep.cornell.edu/sheep/management/economics/cspsoftware/feedform/], from where the Access file can be downloaded.

Table 1. Some approximate feed component values for intake at maintenance.

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>NSCHO</th>
<th>pfNDF</th>
<th>INDF</th>
<th>CP</th>
<th>EE</th>
<th>Ash</th>
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<tbody>
<tr>
<td><strong>Forages</strong></td>
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<td></td>
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<td>27</td>
<td>19</td>
<td>23</td>
<td>19</td>
<td>3</td>
<td>9</td>
<td>62</td>
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<tr>
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<td>25</td>
<td>21</td>
<td>25</td>
<td>17</td>
<td>3</td>
<td>9</td>
<td>60</td>
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<td>23</td>
<td>32</td>
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<td>37</td>
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<td>70</td>
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<td>40</td>
<td>21</td>
<td>11</td>
<td>3</td>
<td>7</td>
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<td>34</td>
<td>38</td>
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<td>13</td>
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<td>5</td>
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<td>15</td>
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<td>8</td>
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<td>Citrus pulp (15 pls$^a$ in pfNDF)</td>
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<td>32</td>
<td>6</td>
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<td>Corn germ meal$^b$</td>
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<td>29</td>
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<td>Dried brewers grains</td>
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<td>28</td>
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<td>Dried distillers grains</td>
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<td>12</td>
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<td>50</td>
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<td>2</td>
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<td>35</td>
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<tr>
<td>Soy hulls</td>
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<td>12</td>
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<td>Soybean meal, 44% CP</td>
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<td>5</td>
<td>49</td>
<td>2</td>
<td>7</td>
<td>80</td>
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</tbody>
</table>

$^a$Pectin-like-substances.

$^b$Error in CNC published values; altered on 10 December 2007.
Literature Cited


ECONOMICS OF DAIRY SHEEP OPERATIONS

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University of Wisconsin-Madison
Spooner, Wisconsin, USA

Introduction

As in any enterprise, milking sheep and selling the milk (or processed products) is all about making a profit. Of course, the financial return will be variable according to the producer’s reasons for starting a dairy sheep business (practical and/or philosophical); reasons which will influence the type of operation. Nevertheless, no matter the type of operation, it has to be a profitable one while respecting the agro-ecosystem principles of sustainability. There are practically as many types of operations as there are producers, but in North America most sheep dairy enterprises are small-scale family businesses (50 to 150 ewes) either looking for a supplemental income or trying to provide a full time occupation to at least one member of the household. These types of operations are generally oriented toward low labor and low financial inputs, lambing late in the spring to reduce the need of buildings and to take advantage of the growth of grass to cover the high nutritional demands of lactating ewes in full production. With this system, milk is generally produced at a lower cost but the lactation length is shorter because of the declining length of days and because of the high summer temperatures. In larger operations (more than 200 ewes), the initial investment for sheep dairying can be substantial because of the need for better milking equipment, larger freezer, etc. Such operations could look at the feasibility of milking all year around by dividing the flock for spring, autumn and winter lambing. However, the system described in this article has older ewes lamb in early winter and young ewes one or two months later. Although demanding more labor and feed inputs, winter lambing and milking offers many advantages.

In order to have a good economic idea of various systems, we developed a spreadsheet in which a producer can enter his/her own numbers. We think that after more than 15 years of sheep milking experience, we now have a better understanding of what it takes to produce milk at various levels.

This spreadsheet is available on the internet for everyone to use at http://www.ansci.wisc.edu/Extension-New%20copy/sheep/index.html All numbers highlighted in yellow (shaded if printed in grayscale) can be changed to reflect your particular situation and costs.

The following budget analysis example is for a winter lambing operation with 300 ewes (250 mature ewes and 50 young ewes). The example does not include any incentives provided by the government (e.g. wool LDP payments). Starting in 2008, the milk sold through the WI Sheep Dairy Co-op was paid for on components using a cheese yield formula with an incentive for low somatic cell count. Fixed expenses would be very different depending on amount of debt so an example is given for both a high and a low debt service.
Milk production. The total amount of milk produced per ewe is the most important factor for the success of the enterprise, therefore it should be maximized. Some natural factors such as cold temperatures optimize feed intake, which favors higher milk production. The lengthening of daylight also favors milk production by sustaining lactation for a longer period. Higher milk production can be achieved by removing lambs from their dams soon after birth, raising all lambs on milk replacer and milking the ewes twice per day from 3 to 4 days post parturition. About 30% of the total milk yield is produced during the first month of lactation. This system is routinely used at the Spooner Research Station. The average milk production of all ewes during the 2008 season at the Spooner Research Station was 789 pounds for mature ewes and 530 pounds for young ewes in 1st lactation. This production is for high-percentage dairy ewes of East Friesian and Lacaune breeding.

The complete milking (twice a day – lambs raised on milk replacer) or partial milking (once a day - ewes are raising their lambs) during the first month of lactation has to be seriously considered when working with high producing ewes. The amount of milk produced by those ewes during the first 30 days is generally well above the needs of 2 or even 3 lambs. The surplus milk should be collected to avoid a high rate of mastitis.

Labor. There is no doubt that winter lambing requires more labor because, with the climate such as in Wisconsin, lambing occurs in a barn. Ewes and newborn lambs are generally isolated in lambing jugs, stored feed has to be distributed, pens have to be cleaned, etc. Moreover, the rearing of lambs on milk replacer will add an extra burden unless the producer is well set up for this endeavor. We consider that 1 3/4 people, beside occasional family help, are needed for the care, lambing, and milking of 300 ewes.

Labor is well utilized at a period when outside work is near impossible. The peak of lactation for most ewes (therefore longer milking time) occurs before field work begins. In spring when outside work becomes possible and necessary, milking is already a routine phase. When summer comes, milking can be phased down to once a day or, better yet, to 3 milkings in 48 hours (milking time could be 6 am, 10 pm, 2 pm etc...) leaving more time for family summer activities.

Feed. The highest nutritional needs (end of gestation and early lactation) are met with expensive stored feed. The needs are generally covered with high quality hay and corn. Dairy quality hay can cost as high as $200 a ton (2009 price). During the months of November, December and January in late pregnancy, ewes are given roughly 4 pounds of average quality hay, and this is increased to 6 pounds of high quality hay during the first 3 months of lactation. Whole corn is provided at a rate of 2 pounds/head/day during the first 3 months of lactation and at a rate of 1 pound/head/day for the next 3 months. As soon as the growing season allows, all ewes are grazed on 35 acres of Kura clover-orchard grass pastures in a rotational grazing system. All lambs and replacement ewe lambs are raised in complete confinement.

Lambs consume 103 pounds of a 21% CP creep/grower feed between birth and sale at a live weight of 80 pounds.
Lambs raised on milk replacer consume an average of 18 pounds of milk powder between birth and weaning at 28 days of age. High quality lamb milk replacer can be purchased for $1.05/lb. in 2009 when ordered in a large quantity.

**Equipment and Buildings.** The equipment requirement for the milking of 300 ewes is independent of the type of management and season of milking. The system has to be efficient for rapid milking twice a day, and the freezing capacity (if milk is sold frozen) should be sufficient for the rapid freezing and storage of 800 to 1200 pounds of milk daily during the peak of lactation. An additional advantage of winter or early spring milking is that the freezer does not work quite as hard as in June, July or August. In 2008, freezers in most farms were less and less used because of the ability of the Wisconsin Sheep Dairy Co-op to market fluid milk.

Buildings are necessary for successful winter lambing, especially in cold areas. Their role is to provide protection against the natural elements but do not need to be very sophisticated. They should consist of a main barn where lambing occurs and where ewes spend a minimum amount of time (a few days) and several three-sided shelters with loafing areas where recently freshened ewes and young lambs are transferred shortly after lambing. “Hoop” or “Green house“-type barns with natural ventilation are good investment for the rearing of lambs on milk replacer. They are quickly set up for a fraction of the cost of a more permanent building. New or extensively remodeled buildings will significantly increase the fixed cost of the operation. However, on well established farms, buildings are generally present and can be used for sheep with relatively little investment.

The concentration of sheep in a barn has always been perceived as a leading cause of pneumonia. Therefore, barns should be well ventilated. East Friesian lambs or high percentage East Friesian crossbred lambs are very susceptible to pneumonia, so rearing them in barns should be of some concern. However, in our experience, pneumonia in lambs is much more prevalent in spring lambing when there is a wide variation of temperature between days and nights.

**Bedding.** Winter lambing and the use of buildings lead to a high consumption of bedding, especially in a dairy sheep operation. Conventional straw bedding is becoming very expensive. In order to keep the 300 ewes of the operation (and their lambs) as clean as possible for milking, a total of 35 tons of straw might be necessary. Good quality straw is difficult to find in the Midwest for less than $100/ton. Alternatives such as slotted floors could be a solution to reduce the cost of bedding.

**Budget Analysis**

The Return to Labor and Management (the take home pay of the producer) using the high milk production obtained at the Spooner Research Station is as low as $48,000 with a high debt service and as high as $66,000 if the farm has a low debt service. High fixed expenses appear to be the leading cause of the high cost of production. Variable expenses can be lowered only as long as it does not affect the well being of the animals or the operator or does not result in a large decrease in milk production. In our example, the ewe feed cost represents 35% of the variable expenses and it is certainly possible to reduce this amount without affecting the total milk production. Research has shown that high producing ewes have a better feed efficiency than
lower producing ewes. Therefore, with higher producing ewes, the (ewe feed cost/receipt from milk) ratio would be greatly improved. Also, less expensive feedstuffs such as haylage should be envisaged.

Total gross income, also, has a large influence on the Return to Labor and Management, and in the case of a dairy operation, the sale of milk can represent 70% of the total income. A flock milk yield of at least 450 pounds (low debt) and 550 pounds (high debt) was needed in 2008 to reach the breakeven point. Five hundred fifty pounds per ewe is a respectable average flock yield, which cannot be obtained with poor quality feedstuffs and poor management. Moreover, with a lower yield it would become difficult to sell high price breeding stock. In a winter lambing operation, cost of production can be reduced only by so much before dramatically reducing the total income and thus the Return to Labor and Management. Spring lambing systems, on the other hand, offer more possibilities for the reduction of cost of production and have been shown to allow for a slightly better Return to Labor and Management, at least in a lamb/wool only operation. The total receipt from milk would be lower due to lower overall milk production.

The adoption of a lambing system, however, is more often dictated by the conditions, the resources, and the availability of goods in or around the farm rather than by real choice. It will be up to the ingenuity, the knowledge, and the skills of the producer to make it work.

| CALCULATION OF RETURN TO LABOR & MANAGEMENT |
| FOR A DAIRY SHEEP OPERATION |

| Information About Your Flock |
| Are you or will you be a member of WSDC (yes=1, no=0) | 1 |
| Number of ewes in the flock | 300 |
| Number of ewes desired for the following year | 300 |
| Percentage of ewes lambing | 94% |
| Average number of lambs born per ewe | 2 |
| Percentage of dead lambs | 15% |
| Percentage of ewe loss | 5% |
| Percentage replacement | 25% |
| Number of rams | 7 |
| Number of ewe lambs sold for breeding | 40 |
| Number of ram lambs sold for breeding | 4 |
| Average weight of lambs at sale | 80 |
| Average weight of ewes | 170 |
| Average milk production per ewe (pounds) | 750 |
| Average # of ewes milked per hour | 140 |
| Average set up and cleaning time before and after each milking | 0.5 |
| Average # of days each ewe is milked | 210 |
| Percentage of milk sold frozen | 0% |
### Flock Results

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<thead>
<tr>
<th>Description</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of lambs born</td>
<td>564</td>
</tr>
<tr>
<td>Number of lambs raised</td>
<td>479</td>
</tr>
<tr>
<td>Number of replacement ewe lambs to keep</td>
<td>90</td>
</tr>
<tr>
<td>Number of lambs for sale</td>
<td>389</td>
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<tr>
<td>Number of lamb sold for meat</td>
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<tr>
<td>Number of cull ewes</td>
<td>75</td>
</tr>
<tr>
<td>Number of ewes milked (90% of total ewes)</td>
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</tr>
<tr>
<td>Minimum number of acres of <strong>improved pastures</strong> (8 ewes/acre)</td>
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### Price of Products for Sale

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<tr>
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<td>Price of breeding ewe lambs</td>
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<td>Price of breeding ram lambs</td>
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<td>Price of cull ewes per pound</td>
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<td>Price of wool including LDP</td>
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<td>Average price of fresh milk per pound</td>
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### RECEIPTS

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<td>Ewe Lambs sold for breeding</td>
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<td>Ram lambs sold for breeding</td>
<td>$2,400</td>
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<td>Fresh milk</td>
<td>$151,875</td>
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<td>Frozen milk</td>
<td>$-</td>
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<td>Packaging of pallets of frozen milk (WSDC members only)</td>
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<td>Culled ewes</td>
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<td>Wool</td>
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<td>Other income</td>
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### VARIABLE EXPENSES

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<tr>
<td># months on pasture</td>
<td>6</td>
<td>$3.00</td>
<td>month/ewe</td>
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<td># months average quality hay (3% DM intake)</td>
<td>1.5</td>
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<td>Tons of average quality hay needed and price</td>
<td>38</td>
<td>$120.00</td>
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<td># months average hay for rams (5lb/day/ram)</td>
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<td>4</td>
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<td># months corn for rams (2lb/day/ram)</td>
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<td># months corn at 1 lb/day/ewe</td>
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</tr>
<tr>
<td>Mineral 20 lbs/ewe/year</td>
<td></td>
<td>$0.40</td>
<td>lb</td>
<td>$2,456</td>
</tr>
<tr>
<td><strong>Total Ewe Feed</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>$54,051</strong></td>
</tr>
</tbody>
</table>
### VARIABLE EXPENSES (continued)

<table>
<thead>
<tr>
<th><strong>Lamb Feed</strong></th>
<th><strong>Quantity</strong></th>
<th><strong>$</strong></th>
<th><strong>Unit</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Creep feed 21% CP</td>
<td>80</td>
<td>$ 0.16</td>
<td>lb</td>
</tr>
<tr>
<td>Finish ration 13% CP</td>
<td>0</td>
<td>$ 0.12</td>
<td>lb</td>
</tr>
<tr>
<td># days on pasture</td>
<td>0</td>
<td>$ 0.03</td>
<td>day/lamb</td>
</tr>
<tr>
<td>High quality hay for replacement ewes</td>
<td>15</td>
<td>$200.00</td>
<td>ton</td>
</tr>
<tr>
<td>(2.5 lb for 120 days)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corn replacement ewes (1 lb for 120 days)</td>
<td>10800</td>
<td>$ 0.08</td>
<td>lb</td>
</tr>
<tr>
<td>Milk replacer</td>
<td>18</td>
<td>$ 1.05</td>
<td>lb</td>
</tr>
<tr>
<td><strong>Total Lamb Feed</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Other Expenses</strong></th>
<th><strong>Quantity</strong></th>
<th><strong>$</strong></th>
<th><strong>Unit</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Shearing</td>
<td>2</td>
<td>$ 2.50</td>
<td>/ewe</td>
</tr>
<tr>
<td>Marketing-trucking</td>
<td></td>
<td>$ 7.00</td>
<td>/ewe or lamb</td>
</tr>
<tr>
<td>Milk production testing (# of times tested)</td>
<td>7</td>
<td>$ 1.00</td>
<td>/ewe/time</td>
</tr>
<tr>
<td>Vet-Med</td>
<td></td>
<td>$ 5.00</td>
<td>/ewe</td>
</tr>
<tr>
<td>Supplies sheep</td>
<td></td>
<td>$ 5.00</td>
<td>/ewe</td>
</tr>
<tr>
<td>Supplies milking</td>
<td></td>
<td>$ 5.00</td>
<td>/ewe</td>
</tr>
<tr>
<td>Bedding straw (lb/ewe)</td>
<td>250</td>
<td>$ 0.05</td>
<td>/lb</td>
</tr>
<tr>
<td>Electricity freezer (very variable)</td>
<td></td>
<td>$ 0.05</td>
<td>/lb of milk</td>
</tr>
<tr>
<td>Electricity other</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Machine operation cost</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ram cost (1/3 of rams changed every year)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maintenance and repair</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vehicle expenses</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hired labor for milking (hours)</td>
<td>1020</td>
<td>$ 10.00</td>
<td>/hour</td>
</tr>
<tr>
<td>Hired labor for other (hours)</td>
<td>800</td>
<td>$ 10.00</td>
<td>/hour</td>
</tr>
<tr>
<td>Unplanned and unforeseen expenses</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other Equipment rental</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Other</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interest on operating loan</td>
<td>8%</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total Variable Expenses</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## FIXED EXPENSES

<table>
<thead>
<tr>
<th></th>
<th>Investment</th>
<th>Terms</th>
<th>Interest %</th>
<th>High Debt</th>
<th>Low Debt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farm payment</td>
<td>$ 200,000</td>
<td>30</td>
<td>6</td>
<td>$ 14,530</td>
<td></td>
</tr>
<tr>
<td>Livestock</td>
<td>$ 50,000</td>
<td>15</td>
<td>6</td>
<td>$ 5,148</td>
<td></td>
</tr>
<tr>
<td>Sheep Equipment</td>
<td>$ 10,000</td>
<td>20</td>
<td>6</td>
<td>$ 872</td>
<td></td>
</tr>
<tr>
<td>Buildings</td>
<td>$ 30,000</td>
<td>30</td>
<td>6</td>
<td>$ 2,179</td>
<td></td>
</tr>
<tr>
<td>Milking equipment</td>
<td>$ 80,000</td>
<td>15</td>
<td>6</td>
<td>$ 8,237</td>
<td>$ 8,237</td>
</tr>
<tr>
<td>Freezer</td>
<td>$ 12,000</td>
<td>15</td>
<td>6</td>
<td>$ 1,236</td>
<td>$ 1,236</td>
</tr>
<tr>
<td>Pick up truck (used)</td>
<td>$ 5,000</td>
<td>5</td>
<td>6</td>
<td>$ 1,187</td>
<td>$ 1,187</td>
</tr>
<tr>
<td>Machinery</td>
<td>$ 10,000</td>
<td>5</td>
<td>6</td>
<td>$ 2,374</td>
<td>$ 2,374</td>
</tr>
<tr>
<td>Feed storage</td>
<td>$ 5,000</td>
<td>10</td>
<td>6</td>
<td>$ 679</td>
<td>$ 679</td>
</tr>
<tr>
<td>Property Taxes</td>
<td>$ 2,000</td>
<td></td>
<td></td>
<td>$ 2,000</td>
<td>$ 2,000</td>
</tr>
<tr>
<td>Insurance</td>
<td>$ 1,000</td>
<td></td>
<td></td>
<td>$ 1,000</td>
<td>$ 1,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$ 39,442</strong></td>
<td></td>
<td></td>
<td><strong>$ 16,713</strong></td>
<td></td>
</tr>
</tbody>
</table>

## RETURNS

<table>
<thead>
<tr>
<th></th>
<th>High debt</th>
<th>Low debt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Income</td>
<td>$ 198,889</td>
<td>$ 198,889</td>
</tr>
<tr>
<td>Less Variable Expenses</td>
<td>$ 125,247</td>
<td>$ 125,247</td>
</tr>
<tr>
<td><strong>Return to Labor and Capital</strong></td>
<td><strong>$ 73,642</strong></td>
<td><strong>$ 73,642</strong></td>
</tr>
<tr>
<td>Less Fixed Expenses</td>
<td>$ 39,442</td>
<td>$ 16,713</td>
</tr>
<tr>
<td><strong>Return to Labor and Management</strong></td>
<td><strong>$ 34,200</strong></td>
<td><strong>$ 56,929</strong></td>
</tr>
<tr>
<td>Per Ewe</td>
<td>$ 114</td>
<td>$ 190</td>
</tr>
</tbody>
</table>
The NCIMS is an organization that functions to allow changes to regulations governing the interstate shipment of milk or Grade A milk products as written in the Grade A PMO.

I was asked to become a member of the Other Species Milk Committee in 2007 to assist in an Antibiotic Residue Validation Study for Sheep Milk. I attended the thirty second annual conference in Orlando, Florida in April 2009. The following topics relative to DSANA interest were presented:

1. Request for approval of Antibiotic Residue Validation Study for Sheep Milk. In 2007, the FDA advised that an approved protocol for the detection of beta lactam drug residues be completed by the end of 2009 or Grade A sheep milk products would not be allowed to cross state lines. I was asked to assist with the study because we ship grade A sheep milk products throughout the country. I was then asked to join the NCIMS Other Species Milk Committee.

With great help from Chris Hylkema of NYS Ag & Markets, a study protocol was developed and executed in early 2009 using milk and animals from Old Chatham Sheepherding Company. The results of the study have been accepted and approved and the Charm SL test is now required for testing for antibiotics in sheep milk.

2. To provide for consistency in testing for somatic cell count the Pyronine Y-Methyl Green Stain or New York modification shall be used. This testing method direction will help laboratories test for SCC in a consistent manner.

3. Approval was given to raise the cell count limit in goat milk from 1,000,000/mL to 1,500,000 based on various studies. Studies have been conducted on sheep milk and there is no data that justifies raising the limit above 750,000/mL.

4. A section was presented on clarification of TB and Brucellosis testing.

The USDA has informed FDA that cattle and other hooved mammals (goats, sheep, water buffalo, etc.) are covered under the Federal USDA Tuberculosis Eradication Program. Therefore, if a State is classified as Modified Accredited Advance Tuberculosis status or higher within the Federal USDA TB Eradication Program they are considered to be in compliance with Section 8 of the PMO for cattle and other hooved mammals (goats, sheep, water buffalo, etc.)

As far as Brucellosis is concerned sheep are not covered by the Federal USDA Brucellosis Eradication Program and it is up to State Veterinarians to assess and document that Grade
“A” non-cattle dairy herds and/or flocks within their jurisdiction are under a documented State surveillance program and are determined to be free of brucellosis.

As the dairy sheep industry’s representative on the NCIMS OTHER SPECIES MILK COMMITTEE, I will be happy to assist in gathering information and/or answering questions for Grade A milk and milk product producers (tomclark@blacksheepcheese.com)
OVINSHIRE FARM – A WORK IN PROGRESS

Scott Burrington and Terri MacKenzie
Ovinshire Farm
Fort Plain, New York, USA

Originally, Scott and his dad, Donald, were going to milk cows. They searched from Maine to Kentucky for just the right farm. Then one day back in 1988, Don read an interesting article about the milking potential of sheep “Why don’t you milk sheep?” he asked. They had always had a small flock of mixed meat sheep on their 75-acre New Hampshire holding, to keep the freezer full and the fields mowed. Why not? Everything seemed to fall into place, and in the spring of 1989, Scott milked 47 Polypay, Finn, Dorset, commercial ewes and a token Tunis for 90 days. He sold his milk to a yoghurt maker. In July that year he attended the North American Dairy Sheep Symposium hosted by the University of Minnesota’s William Boylan, which cemented his decision to milk sheep.

Sadly, his market disappeared that fall but he never gave up the dream. Scott spent the next 11 years looking for land with more than the three inches of topsoil the place in New Hampshire had and for an environment that supported agriculture.

In February 2002, he found 143 acres in upstate New York and on July 4th he arrived with 22 purebred East Friesian ewes and 4 rams. He lived in a tent for three months before moving into the comfort of the basement of what is now our house. Gracious neighbors fed both Scott and the ewes for the first couple of years, curious that someone would actually be thinking about milking sheep. They all thought he was a little bit crazy.

A bit of background on the flock…the 10 foundation ewes and one ram were purchased as lambs in 2000 from Axel Meister, Wooldrift Farm, Markham, Ontario and Peter Welkerling of Saskatchewan respectively. Add three lambing seasons, A Lacaune ram from Spooner in 2006, 170 ewes from Wisconsin in 2007 and over 200 ewes from Old Chatham in 2009, Ovinshire Farm now has about 700 sheep on staff. We milk them and sell fresh milk to Old Chatham Sheepherding Company. We make no sheep milk products at Ovinshire other than for personal consumption. As Scott says, “our strength is at extracting milk from the sheep…” so this is what we focus on. We practice intensive rotational grazing in the summer and feed baylage, haylage and dry hay in winter. We feed a 16% custom high energy pelleted mix to all but the early dry groups on a year-round basis.

Terri arrived on the scene in 2004, assisting with that year’s lambing while Scott did his seasonal tax job from January to mid-April. That was the last year we lambed before May for a while. Actually it couldn’t have been that bad; we were engaged by September. In 2005, Scott set up his parlor with the 6-unit cascading locking head gate he used back in 1989 in the neighbor’s dairy barn he had been wintering in since moving to NY. He milked 42 ewes for 100 days…and then the Amish came.

We had hoped to stay another year while we decided what, where and how to build on our own property and got used to being a married couple. But we needed to be out of the neighbor’s
barn and we panicked momentarily. Thankfully, the previous summer, Scott had salvaged a 30’ x 96’ greenhouse for $250 that we had planned on using as our first barn. It was erected before the first snowfall (just) and we are using it to this day. The only problem was, it was not large enough to accommodate any replacement ewe lambs the next year. Enter an acquaintance’s Dorper ram. The next spring, after tax season and between lambings, Scott built our milkhouse and erected a 24’x26’ coverall we purchased on sale for $1900 from Farmtek the previous fall to house our parlor. We got that idea from the GLDSS farm tour to Neil Urie’s place in VT that fall. We started a bit late with stale ewes, but managed to milk 67 the summer of 2006 for about 70 or 80 days. In addition, we had these fabulous Dorper cross lamb sales to help with the bottom line.

So now we had a milkhouse and a parlor. No holding area, no attached barn. That came later. Over the winter of 2006-07 a local welder (Rod’s Welding, Cherry Valley, New York) assisted Scott to design and then build our double-12, rapid exit parlor. In 2007, we were ready! We finally milked for a whole season (June – October)! In October that year, we took the plunge and built our 156’x60’ pole barn. Scott looked at the wide-open space and the mortgage and purchased 170 ewes from Wisconsin to help fill the barn and pay the bills the following spring. In 2008 we peaked at 157 ewes in the parlor, milking from March through October and this year we peaked at over 300 through the parlor in June and July. Scott is also going to be milking year-round this year for the first time.

We cannot do all of this alone. In January 2008, we took on our first employee, that summer our second. We peaked this year with 6 part-timers and now have three. Good agricultural employees are hard to find, harder to keep, no matter where you live. We encourage ours to participate, to learn and to ask questions. They contribute ideas that make our lives easier. We try to show our appreciation with periodic dinner meetings and impromptu pizza lunches.

As one can see, Ovinshire Farm is a work in progress. It had conservative beginnings and has flourished. (Scott will tell you he is not finished yet). We want to encourage by example that anyone with the desire to enter the dairy industry can do so, with careful planning. There is no set way to tackle it. You get there eventually as Scott dreamt he would. We couldn’t have done it without a lot of support and encouragement from friends in the community, our families and our employees. Comments are no longer “You want to milk what?” but are “Oh, you are the guy who milks sheep”. It’s satisfying to be adding to the agricultural landscape, to add job opportunities to the community, to provide the odd educational moment, and to be succeeding in the dairy sheep industry. We thank you for your interest and hope you enjoy your visit to Ovinshire Farm.
The Old Chatham Sheepherding Company was founded in 1993 on open land. We actually received the 115 Dorset sheep from Cornell University before we had the barn built and had to house elsewhere until the facility was completed.

- Wrong kind of sheep - needed East Friesian

Plan for the ultimate number of animals you will have.
- Make everything bigger than you expect.

We designed the first three buildings - the sheep barn, the hay barn and the shop as we were only going to milk the sheep and send the milk to a nearby cheese maker. We designed the sheep barn with a center aisle and a very good amount of windows and doors for ventilation.
- Wrong- needed more ventilation.
We designed the barn with a large door at each end and many garage doors at the side.

- Wrong - needed three doors at each end of the barn as we have two sheep pens with a center feeding aisle. We also should not have had the center parlor bulge in the middle of the barn on one side keeping you from driving the cleaning skid steer from one door to the other door at the opposite end of the barn.
- The side doors are good for ventilation and also allow the animals to go outside but you find they only want to eat and lie down, forget going outside.

We designed the barn with a dirt floor and a 12 foot center aisle

- Wrong - dirt does not work for a feeding aisle and is difficult to clean. We later put macadam down the center aisle which works very well.
• The dirt pens for the animals worked well for a while but then we wanted cleaner pens and added blacktop to the pen base which works much better allowing the manure pack to build up 3-4 inches and allows for easier cleaning of the pens completely every 5-6 weeks, breaking the cycle of parasites. This we learned the hard way.
• Wrong-The center aisle should have been 16 feet wide to accommodate the many differing pieces of equipment which need to be driven down the aisle.
• Feeding aisle should allow 6 ½ inches for head room in the head bar and 1 foot per sheep for feeding. i.e. if you have 200 sheep -your feeding pens should be 200 feet combined length. Feed should be right in front of the sheep – most efficient.
• We designed each animal pen with its own waterers.
• Maintain CONSISTANT feeding program so each animal gets the same nutrients.

We failed to realize the fact that the ewes are always having babies.
• We needed to have a separate barn for the pregnant ewes as they need to come inside from the fields, where they are for the first 4 months of gestation. The moms need to be fed a vitamin and mineral rich diet, not just field hay, getting them ready for birthing. So we changed the hay barn into the lambing barn.

Now where do you put the hay?
• Build a hay barn with storage for feed, square and round bales and bedding.
Where do you put the lambs after they are weaned from their mothers as you need the mom’s milk? You need to put them in the parlor. You can supplement the lambs with milk replacer.

- Build a greenhouse for the lambs. This works very well as there is plenty of sunlight with kills the bacteria in the pens.

![Image of greenhouse]

The sides of the greenhouse go up for ventilation and they go up at the level you need for the correct ventilation for the babies.

- The entire greenhouse is blacktopped which makes it much easier to keep it clean for the babies.
  - Blacktop floor if retrofitting – we did it later
  - Cement floor if building from scratch

It is important to disinfect the floors for the lambs so blacktop or a cement floor is desirable. There are other schemes for the layout of the barn.

- The key is to have the animals come to the parlor easily. You must have holding pen areas. This can often be done with changing gate latching systems in the aisle just outside the parlor.
• We also found that you needed a pit for the milking operation. Luckily we had designed this from the beginning. The girls come into the parlor on the same level as the barn.
• The milkers go down into the pit allowing for a low line DeLaval milking system.
• We have a DeLaval automatic take off system which we find really helps with the health of the moms and efficiency of your staff.

• For washing, everything needs to be slanted toward the drain.
• We also planned a basement under the parlor for equipment.
• You also need a place for sick lambs. We designed a vet room to keep supplies and a sick bay area just off the main barn.
No matter what kind of farm buildings, rodent control is always a necessity for rats, mice, squirrels, woodchucks, coyote, mountain lions, black bear and any other predators particular to your region.

- Companies have protocols rotating different poisons
- From Gemblar’s catalog we use 6 months HAWK, 3 months JAGUAR, and 3 months Rampage.

The sheep barn, lambing barn and the lamb greenhouse worked fine to only milk the animals but we fast found that we would be doing the cheese making also.

The creamery is now in the old mechanic shop.

- Retrofit the mechanic shop for the creamery
- Build a new mechanic shop

This center section is the original Mechanic shop. The rest has been added in 3 phases. We have a 6 foot basement under the main new section which has allowed for the mechanical systems.

- Wrong- 6 feet of head room is not 6 foot of head room.
  - The pipes and other mechanical equipment hang below and there is only bent over body room, which is VERY ANNOYING AND AWFUL!!!!!!

ALWAYS BUILD A FULL, AT LEAST 8 FOOT, BASEMENT IF NOT HIGHER.

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