Evaluating Alfalfa Stands in the Spring - When and How Should You Evaluate an Alfalfa Stand?

Below are descriptions of two methods that can be used to determine the viability of an alfalfa stand. An alfalfa producer should use not only one of these methods but their feel for the vigor of the particular stand they wish to evaluate as well as the production history of that field.

The first method consists of counting the number of plants per square foot. Current research information suggests that when stand counts fall below 3 to 5 plants per square foot, it’s time to either rotate out of pure alfalfa or interseed a grass crop such as festulolium, tetraploid ryegrass, or annual ryegrass or interseed another legume not hurt by the autotoxicity seen in year old or older alfalfa stands. Red clover is the legume of choice and should be planted at 6 to 8 lbs pure live seed per acre either by broadcasting it on in very early spring or seeding it with a no-till drill (plant either in very early spring or in early to mid-Sept after the last harvest of the season).

The second evaluation method derives from research out of Wisconsin by Dr. Dennis Cosgrove that indicates that stem number rather than plant number is a more accurate determination of when to plow down or interseed an alfalfa stand. Cosgrove suggests using a value of 55 or more stems per square foot to indicate that the stand will produce maximum yield. A reduction in stem number per square foot to 40 stems or less will result in a 25 percent yield reduction. At this critical level, alfalfa fields begin to lose profitability and should be rotated to another crop for one or two years.

Although you can get some idea on the potential of your alfalfa stand by counting either the number of plants or the number of tillers per square foot, you will need also to consider checking on the health of those plants to have an accurate basis for a decision on keeping or destroying an alfalfa stand. To do this in the spring when new growth is about 4 to 6 inches tall, check a random one square foot site for each 5 to 10 acres of alfalfa or at least 4 to 5 sites on small fields. Dig up several plants at each site and slice open the crown and root (longitudinally) with a sharp knife to determine the health of the crown and tap root. Healthy roots and crowns will be firm and white to slightly yellow in color. Diseased roots will have dark brown areas extending down the center, especially if crown rot is a problem. Reduce your counts of plants per square foot or tillers per square foot so only the healthy plants present are counted. Plants with roots that are mushy or soft are likely to die; and although those with a few brown spots may survive, the overall vigor of the stand will be compromised by the presence of disease.
If you must decide on whether to reseed before growth begins in the spring (and you do not plan to take a first harvest of alfalfa before planting another crop) or after a very hard winter with significant heaving or winter injury, base your decision to reseed on the number of plants per square foot (Table 1). If a decision to reseed can be made during the growing season or after about 4 to 6 inches of growth has occurred in the spring, either evaluation method can be used (Table 1). In Table 1 below, I’ve modified various estimates for good, marginal, and poor stands to give the grower possible guidelines to consider in making a decision on keeping the stand or interseeding a grass or other legume.

Table 1. Suggested plants per square foot or tillers per square foot () criteria for evaluating alfalfa stands on Delmarva.

<table>
<thead>
<tr>
<th>Age of stand</th>
<th>Good stand</th>
<th>Marginal stand</th>
<th>Consider replacement* or renovation ** with interseeded grass or red clover</th>
</tr>
</thead>
<tbody>
<tr>
<td>New</td>
<td>25-40 plts (&gt; 75)</td>
<td>15-25 plts (&lt; 55)</td>
<td>&lt; 15 plts (&lt; 50)</td>
</tr>
<tr>
<td>1 year old</td>
<td>&gt; 12 plts (&gt; 60)</td>
<td>8-12 plts (&lt; 55)</td>
<td>&lt; 8 plts (&lt; 45)</td>
</tr>
<tr>
<td>2 years old</td>
<td>&gt; 8 plts (&gt; 55)</td>
<td>5-7 plts (&lt; 50)</td>
<td>&lt; 5 plts (&lt; 40)</td>
</tr>
<tr>
<td>3 years old</td>
<td>&gt; 6 plts (&gt; 50)</td>
<td>4-6 plts (&lt; 45)</td>
<td>&lt; 4 plts (&lt; 40)</td>
</tr>
<tr>
<td>4 years old or older</td>
<td>&gt; 4 plts (&gt; 50)</td>
<td>3-4 plts (&lt; 40)</td>
<td>&lt; 3 plts (&lt; 40)</td>
</tr>
</tbody>
</table>

* If the stand is to be plowed for replacement, growers often find it economically favorable to take a first cutting and then plow and plant a rotational crop that can use the nitrogen mineralized from the decomposing alfalfa plants. Rotate out of alfalfa at least until the next fall (14 to 18 months) but preferably for 2 to 4 years. This will allow time for a reduction in the potential for alfalfa diseases and provide the grower the opportunity to correct soil nutrient and pH (acidity) problems as well as make use of the residual N mineralization potential that exists in a field following an alfalfa crop. 

**, If you consider renovation or extending the stand life, try no-tilling a grass crop such as orchardgrass, tetraploid annual or perennial ryegrass, or one of the new varieties of festulolium (a cross between meadow fescue and one of the ryegrasses). The grass will increase your tonnage especially if you fertilize for the grass with nitrogen fertilizer. This also has the effect of driving out alfalfa at the same time as production levels are maintained for an additional year or two. Another option for extending an alfalfa stand’s life for 1 to 2 years is to seed in 6 to 8 lbs of red clover per acre. This option will maintain the higher protein production from the field.

Richard W. Taylor, Extension Agronomist, University of Delaware, rtaylor@udel.edu

**Alfalfa Fertilization Practices for Maximum Economic Yield**

Whether grown for quality hay or as a component in either pure or mixed legume-grass stands for use in a grazing-based system, alfalfa is often an essential part of dairy production. The dairy producer’s goal is to grow and harvest the most protein and digestible dry matter at the least cost.

Alfalfa removes considerable quantities of K2O (about 50 lbs per ton) and can produce economic
yield increases up to 500 to 750 lbs K\(_2\)O/ac, depending on price structure. The current P:K (phosphorus to potassium or potash) ratio of 1:4 is not adequate to maintain more than surface (0 to 6 inch) soil test P concentrations. To maintain minimal soil test P concentrations at depths greater than 6 inches, a higher ratio of 1:3 (P:K) may be necessary. Alfalfa needs not only adequate quantities of P and K but also sulfur (S), boron (B), and lime [calcium (Ca) and magnesium (Mg)].

Research conducted by Dr. Ed Jones, Harris Swain, and Sandra Jacobsen at Delaware State University was released as Bulletin No. A-112. The research was conducted from 1990 through 1998 and examined sustainable fertilization of alfalfa in Delaware.

The research indicated that K fertilization was essential for maximum economic yield in long-term alfalfa production fields. By the third production year, yield was significantly impacted by the rate of K fertilizer applied. Averaged over the seven year study after significant differences among treatments occurred, a rate of 500 lbs K\(_2\)O/ac/year yielded 1.1 tons DM/ac more than a rate of 250 lbs K\(_2\)O/ac/year and both far out yielded (6 and 4.9 tons DM/ac, respectively) the zero potash treatment. The lowest application rate (250 lbs K\(_2\)O/ac/year) yielded 1 T/A more than the control the first production year, 1.5 T/A more in the second year, and 2 T/A more by the third year when significant differences occurred among the application rates. By the seventh production year (the alfalfa stand was killed and reseeded after six years), even a rate of 500 lbs K\(_2\)O/ac/year was not enough to sustain either yield production levels or soil test values. The next highest rate (750 lbs K\(_2\)O/ac/year) did maintain production and produced about 1 T/A more than a rate of 500 lbs K\(_2\)O/ac/year.

Dr. Jones’ team did evaluate the effect of residual K fertilization rates and after ten years of experience concluded that production can be maintained for only two to three years without fertilizer additions regardless of the initial rates. They found that increasing K fertilization rates did not meaningfully extend this grace period without having an adverse effect on yield.

The team also evaluated protein production as affected by fertilization practices. In about a quarter of the harvests, there was a significantly reduced protein yield at any level of K fertilization. This likely was due to a dilution effect of increased yield levels that reduced the crude protein concentration in the alfalfa hay. When evaluating residual K fertilization effects, their results indicated that you could go one additional year (three to four rather than two to three) without fertilizer additions before total protein yield began to decline.

Another interesting finding of the group was related to the effect fertilization had on soil nutrient levels. Soil was tested in six-inch increments down to 2 ½ feet. Even though the field was limed with 2 ton/A every four years, reduced soil Ca concentrations were found at a depth of 1-foot while soil Mg concentration was higher at depths of 1 to 2 ½ feet. Although both Ca and Mg concentrations remained adequate for alfalfa growth, the depletion of soil calcium at deeper depths may indicate a need for more frequent lime applications even though the total amount applied need not be changed.

A P:K ratio of 1:4 was used during the study but soil test results indicated that soil P concentrations declined at four of the five depth intervals tested at K fertilization rates of 250 to 500 lbs. K\(_2\)O/A/year. Only the surface six-inch increment remained unchanged at these rates. At the highest K fertilization rates, only the surface six-inch depth increased in soil test P level while the deeper depths again declined to very low levels.

For soil K concentrations, rates of 250 and 500 lbs. K\(_2\)O/A/year still allowed reductions in K concentration at depths greater than 6 inches. The rate of 750 lbs. K\(_2\)O/A/year increased soil K concentration at the 0 to 6 inch and 6 to 12 inch depths and only just maintained the original K concentration at greater depths.
In summary, fertilization of well-managed high yielding alfalfa fields at a rate between 500 and 750 lbs. K₂O/A/year can produce economic yield increases, depending on the price structure of the hay, P, and K. Annual fertilization with B at a rate of 2 to 4 lbs./A is also important. The current recommended ratio of 1:4 P:K appeared to be inadequate to maximize yield or maintain soil fertility levels. Depending on the cost of fertilizer a ratio closer to 1:3 is more appropriate for high production alfalfa fields. Finally, more frequent lime application without changing the quantity applied per year may maintain soil test Ca concentrations.

Richard W. Taylor, Extension Agronomist, University of Delaware, rtaylor@udel.edu

Help in Choosing an Effective Silage Inoculant

Microbial inoculants can make silage fermentation more efficient thereby preserving more nutrients and dry matter and some times improve animal performance. Some inoculants have also been designed to specifically improve aerobic stability. This is important because a large portion of DM lost in a silo is actually due to aerobic spoilage. There are so many silage inoculants and claims that it is no wonder that producers are often confused as to which inoculant to use. Here are a few tips that might help you make a more informed choice.

An effective silage inoculant will have independent, statistically analyzed, and published data supporting its use. Of course, the more of this, the more credibility a product has. I will take an educated guess and say that no more than 10 to 15% of the silage inoculants in the marketplace have more than 5 publications showing that they work. Be cautious as I have seen brochures from companies showing “research data” from many University studies that have not been published. I personally put much more weight on research that was independently published, was statistically analyzed and is in a citable form that can be found in an indexed search of the literature (this would include articles published as journal articles and abstracts [e.g. Journal of Dairy Science, Journal of Animal Science, Animal Feed Science and Technology, etc.]) When reviewing the published literature on a product I also check to see if there are some studies where the product did not work. No product works all the time, but the better products work a high proportion of the time. Companies with high integrity will share both the positive and negative results with you.

You may hear the argument that because a company sells an inoculant that has bacteria with the “same name” used in other studies, that those studies support its use. Many bugs have the same name, but not necessarily the same activity or properties. Thus, this is not a valid argument.

The most common types of bugs that are in our silage inoculants include homolactic acid bacteria, heterolactic bacteria, and sometimes, Propionibacteria. Homolactic acid bacteria (e.g. Lactobacillus plantarum, Enterococcus faecium, and several species of Pediococci) improve the initial fermentation process by speeding up the production of lactic acid. A quick drop in pH can reduce protein degradation and prevent the growth of several undesirable microbes in silage (e.g. Enterobacteria and Clostridia). This can lead to improvements in the recovery of dry matter and sometimes improvements
in animal production because of more efficient fermentations. However, homolactic acid bacteria are not very effective in improving the aerobic stability or shelf life of silage. On a dairy farm, a large portion of dry matter loss in a silo is actually due to poor shelf life (not just fermentation losses). Of the heterolactic acid bacteria, only \textit{Lactobacillus buchneri} is acceptable as a silage inoculant. \textit{Lactobacillus buchneri} by itself has minimal effects on the initial fermentation process but during storage it converts moderate amounts of lactic acid to moderate amounts of acetic acid which is a potent inhibitor of yeasts and molds. As an added benefit, sometimes there is production of propionic acid, another good inhibitor of yeasts and molds, in silages treated with \textit{L. buchneri} (but this is not a direct end product from \textit{L. buchneri}). Theoretically, Propionibacteria convert moderate levels of lactic acid to acetic and propionic acid. However, there is not enough compelling research to support the fact that this consistently happens in silage. Thus, the effect of these bacteria in silage is questionable.

Many silage inoculants contain multiple types of bacteria. In some studies, combinations of organisms have led to improved efficacy but all combination products are not necessarily better than an inoculant with only one organism. Recently homolactic acid bacteria have been combined with the heterolactic organism, \textit{L. buchneri}, to provide stimulation of early fermentation and prolonged shelf life during storage and feed out.

In order for silage inoculants to be effective they must be added at a high enough rate to compete against detrimental organisms and dominate the ensiling process. For homolactic acid bacteria, the industry standard is a final application rate of 100,000 colony forming units (cfu)/gram of fresh forage. The probability of a silage inoculant being effective is markedly reduced if it supplies less than this number of homolactic acid bacteria. In some formulations containing \textit{L. buchneri}, the final application rates are several fold higher (400,000 cfu/g for silages and 600,000 cfu/g for high moisture corn) which further increases its probability of success in the field. Accurate calibration of equipment and distribution of the inoculant onto the silage are also essential to using a silage inoculant. Never add half the recommended rate to save a few cents. By doing this, you have decreased the probability of the product working. Likewise I am skeptical of companies that tell you to add 2 to 4 times more than recommended because this now makes the product much less cost effective. (If you already paid $1/treated ton for the inoculant can you really afford to put 4 times the level and drive the cost to $4/ton?).

Although technical service is not directly related to the effectiveness of a silage inoculant, this should be factored into your decision making process. Certainly, companies that are willing to assist you in times of need should be highly considered.

A low or premium price alone should not be the driving factor for choosing an inoculant (remember: research, research, research!) In general, homolactic acid inoculants are less expensive than those containing \textit{L. buchneri} because this organism is more difficult to produce and because in some formulations, the final application rate is very high. Additionally, one should not make a comparison between a homolactic acid-based inoculant and one that contains \textit{L. buchneri} on cost alone because the two products were designed for different goals. In the end, most silage inoculant will only cost several cents per cow per day but yet yield some good insurance.

Here are a few examples of how to choose the best type of inoculant based on some specific situations:

**Situation 1:** Any silo type that has no shelf life or summer heating TMR issues but could benefit from a more efficient fermentation.

Type of silage inoculant to consider: homolactic acid based inoculant

**Situation 2:** Large bunker or pile silo with a face that may be too wide and thus prone to
spoilage because of a slow rate of feed out.

Type of silage inoculant to consider: inoculant with *L. buchneri* (with homolactic acid bacteria as an option)

**Situation 3:** Silage sold and left on intermediate feeding piles for several days or silage that will be moved from one silo to another is prone to spoilage because of the exposure to air.

Type of silage inoculant to consider: inoculant with *L. buchneri* (with homolactic acid bacteria as an option)

**Situation 4:** Several bag silos, three will be fed out during cold winter months but two will be fed out in the hot summer and there are issues with heating in summer silage.

Type of silage inoculant to consider: Winter bags should be treated with a homolactic acid inoculant. Summer bags can be treated with an inoculant with *L. buchneri* (with homolactic acid bacteria as an option)

**Situation 5:** One large upright silo, top portion is fed out in the winter, the bottom is fed out during the summer with issues of heating in summer silage.

Type of silage inoculant to consider: Treat the top with a good homolactic acid bacteria based inoculant, treat the bottom with *L. buchneri* (with homolactic acid bacteria as an option), as an option treat the whole silo with a *L. buchneri* + homolactic acid bacterial inoculant.

**Situation 6:** Very wet forages have problems of not getting the pH low enough in grass and alfalfa silages to prevent clostridial fermentations that produce butyric acid and may excessively degrade proteins.

Type of inoculant to consider: homolactic acid based inoculant.

**Situation 7:** High DM corn or alfalfa silage often have problems of excessive heating and spoilage.

Type of silage inoculant to consider: an inoculant with *L. buchneri* (with homolactic acid bacteria as an option)

**Situation 8:** Sealed storage structure, oxygen limiting, no shelf life issues but still want to optimize fermentation.

Type of silage inoculant to consider: homolactic acid based inoculant.

Silage inoculants should not be used in place of good management. However, there are a variety of silage inoculants that are extremely helpful in improving the fermentation and shelf life of silages. Determine your need based on the crop, silo, or challenges and then pick a research proven inoculant to help.

Limin Kung, Jr., Dairy Nutritionist, University of Delaware

LKSILAGE@UDEL.EDU
Making Baleage: Quick Tips

1) Start with high quality forage as mature forage has hard stems that can make holes plastic.

2) Wilt as fast as possible and bale between 50 and 60% moisture. Prolonged wilts lead to low sugar content and poor ensiling.

2) Orient stems with direction of baler to minimize holes in plastic. Slow baler down with wetter forage

3) Bale tightly at 10-12 lb of DM per cubic ft. Tight baling minimizes exposure to air to maintain forage quality.

4) Wrap bales as soon as possible (within 2 hr in warm weather; within 12-24 h in cool weather). Delays in wrapping will lead to poor ensiling and forage quality. The total plastic thickness (optimum is 6-8 mil) is more important than number of wraps – e.g. wrapping 4-5 layers of 1.5 mil plastic rather than wrapping 6 layers of 1 mil plastic. Overlap plastic by at least 50%. Use plastic with UV protection and don’t wrap when raining. Avoid string with oil as this may break down UV protection in the plastic.

5) Store bales in clean/safe area that is well drained, well mowed and clear of rocks, etc. Stack bales on sides, not on ends, align rows in North-South direction to avoid exposure to afternoon sun, store in shady area if possible. Check regularly for holes and patch as needed.

6) Feed baleage as quickly as possible as prolonged storage increases the chances for damage to plastic and poor fermentations because of moisture migration.

The majority of information on this fact sheet was summarized from an article by Vough et al., 2006 published in NRAES – 181.
Limin Kung, Jr., Dairy Nutritionist, University of Delaware
LKSILAGE@UDEL.EDU

Harvesting Alfalfa for Haylage: Quick Tips

1) Start with high quality forage - if you start with full bloom alfalfa, you start with poor quality forage!

2) Methods for determining time of harvest for 1st cutting:
   a) Visual: for dairy lactating cows, harvest at bud stage for high quality (between 38 and 40% NDF); this is about 150-160 RFV.
   b) Use the PEAQ stick method; measuring plant height and maturity; See more info at: http://forages.coafes.umn.edu/Estimating_Alfalfa_RFV_in_the_Field_Using_PEAQ_and_Scissors_Cut.html
   b) Scissors cut method: obtain cuttings and send to lab for analysis. Depending on acreage, harvest equipment and weather: start at 35% NDF and complete no later than 40% NDF. Begin harvest slightly earlier because of field/harvest losses. More information may be found at: http://www1.umn.edu/mfgc/scissors.htm

3) Cutting for subsequent cuttings: harvest at 28 to 32 d intervals depending on growing season; use longer intervals if stand persistence is the primary goal

4) Harvesting goal: minimize time crop is in the field drying; prolonged drying time in the field increases DM losses. Mow after the dew is gone.
5) Consider wide swathing to increase drying rate. When wide swathing, mow only what can be harvested in a day.

7) Chop at optimum moisture of between 55 and 60% (range may vary depending on storage structure); avoid chopping when moisture is more than 65% as this may lead to clostridial fermentations

8) Use a proven microbial inoculant with homolactic acid bacteria (the final application rate must be a minimum of 100,000 colony forming units per gram of wet forage). Calibrate and check application frequently; use a liquid applied inoculant if possible.

9) Keep knives sharp and chop at 3/8 to 1/2 inch theoretical (depending on moisture and other forages fed) length for good effective fiber

A great reference for alfalfa may be found at: http://www.asa-cssa-ssa.org/publications/pdf/alfalfa_guide_harvest.pdf

Limin Kung, Jr., Dairy Nutritionist, University of Delaware
LKSILAGE@UDEL.EDU

---

Silage Storage and Feeding: Quick Tips

1) Filling silos
- goal: make the system anaerobic as fast as possible and keep it that way
- the faster a silo is filled and quicker it is sealed the higher the nutrient recovery will be
- never leave chopped forage in a wagon or pile overnight; if you chop it you must pack it immediately
- clean out wagons (bird droppings, moldy forage, etc.) and silos

2) Bunks and piles:
- shape drive over piles with narrow feeding face and longer length (no ovals or circle shapes)
- pack in 6 in. layers
- target 14 to 16 lb of DM/cubic ft.
- use heavy tractors
- extra packing for more than an hour or so at the end is not beneficial
- cover with plastic and tires immediately after filling; delayed sealing leads to nutrient losses
- consider plastic on the side walls in bunks to minimize water damage
- overlap plastic at any seam by at least 8 ft
- maximize weight on plastic to keep air from penetrating into the silage mass- patch holes, etc.; tires and plastic are not any good if they are not managed properly
- white plastic with UV protection is better than black because it reflects heat
- thicker plastic is better: 8 mil is better than 6 mil, 6 mil is better than 4 mil
- new gravel bags for holding plastic down are a good alternative to tires
3) Bagging silage
- use tunnel extension on older baggers for tighter packing
- use stretch marks on bags to determine pack
- the top of the bag should be flush w/the tunnel
- over packing destroys the integrity of the plastic and allows for more bleeding of air through the plastic
- be sure teeth on bagger are sharp; this will improve packing
- adjust brake tension based on moisture
- use tractor with adequate HP; > 80-90 HP
- feed forage evenly into bagger to avoid clumping
- pack tightly (12 lb of DM per cubic ft)
- if you start a bag, finish it, do not leave to the next day
- seal end immediately
- use a vent cap to vent silo gasses for 2-3 days
- check and patch holes on a regular basis; clean area with alcohol on bags when patching (they have beeswax on them to help them slide)
- keep brush and grass down by bags

4) Upright silos
- fix doors, cracks, etc.
- after filling, even out forage on top and put on silo cap immediately (if not feeding out right away)
- watch moisture levels: too wet leads to seepage and clostridial fermentations; too dry leads to poor packing and heat damaged forage

5) Feed out management
- remove sufficient silage in hot weather to keep ahead of spoiling; there is no magic number for this; remove more if silage is dry, chopped too long, or packed poorly; less may be removed in cold weather
- keep tires on plastic to minimize air infiltrating between the plastic and silage; remove only enough plastic to expose enough silage for a day’s feeding
- manage silage faces to minimize infiltration of air; knock down only enough silage for the immediate feeding
- separate spoiled silage and discard

Limin Kung, Jr., Dairy Nutritionist, University of Delaware
LKSILAGE@UDEL.EDU

Determining DM or Moisture With a Microwave Oven

The determination of DM or moisture of forages and silages can be done with the use of a microwave oven. The items you’ll need include:
1) a microwave (preferably equipped with a rotating plate)
2) sample containers (e.g. a paper plate)
3) a digital gram scale
4) a small cup for water

Start with a representative sample!
Mix the chopped forage well. “Tare” or “zero” your scale with your empty sample container so that the scale reads “00.00” with your empty pan on it.
Place and spread out 50 g of sample into the pan. After removing your sample it is important that you do not rezero the scale until your next sample.
If your scale automatically shuts off, then you must obtain the pan weight as well.

Place about 1/4 cup of water into the back of the microwave. This will help to keep your sample from burning.

Next, place your sample into the microwave and put on a high setting for 3 min.

Remove your sample and return to the scale…record the new weight. Mix the sample well.

Repeat this process as needed until the weight of your sample does not change more than a few tenths of a gram.

You will also have to use your nose, to make sure that you have not burnt your sample.

To calculate the DM or moisture of your sample, Subtract the final wt of your sample from the original 50 g rams then, multiply that number by 2….this is you DM%. Moisture is the 100 minus the DM%.

Example:
Initial wt. of forage was 50.0 g.
After 3 minutes the reading is 41.2 g.
After another 2 minutes the reading is 30.0 g.
After 2 minutes the reading is 21.5 g.
After 1 minute the reading is 20.5 g.
After 1 minute the reading is 19.8 g.
After 1 minute the reading is 19.7 g.
After 1 minute the reading is 19.7 g.

The DM % is 19.7 × 2 = 39.4%
The moisture% is 100 – 39.4 = 60.6%

Limin Kung, Jr., Dairy Nutritionist, University of Delaware
LKSILAGE@UDEL.EDU

The Delaware Dairy Report

Dr. Limin Kung
Ruminant Nutrition and Microbiology
Research and Extension
Department of Animal & Food Science
(302) 831-2522 Email lksilage@udel.edu

Editor

University of Delaware
Department of Animal & Food Sciences
531 South College Ave.
Newark, DE 19716-2150