NUTRITIONAL QUALITY OF LARGE ROUND BALE SILAGE AS AFFECTED BY COMPACTION, COLOR OF WRAP, OR PRESERVATIVE IN SOUTHCENTRAL ALASKA

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A

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Abstract

Large round bale silage (LRBS), fermented hay, baled at 45-65% moisture content might be a better product than air-dried hay for farmers and ranchers in Southcentral Alaska. Variable weather and sometimes unfavorable conditions for drying hay to the required 18% moisture content makes high quality hay production unpredictable. Our study was designed to determine what practices might produce the highest nutritional quality LRBS. Treatments included using black and white plastic bale wrap, two different baler compaction levels, and application of a buffered propionic acid preservative. The study used four different forage fields over a two year period. Three fields were harvested on each cutting date. We measured dry matter (DM), neutral detergent fiber, acid detergent fiber, lignin, acid detergent insoluble nitrogen, crude protein, and digestible energy. Fermentation analysis measured levels of lactic, acetic, propionic and butyric acids, ammonia and pH on LRBS. The denser bales, bales wrapped in black plastic, and those treated with preservative produced highest quality forage. Dense bales had lower DM, lower pH, and also had the highest lactic acid. Ammonia levels declined when moisture content decreased.

Table of Contents

List of Figures

Page

List of Tables

Page

List of Appendices

Page

List of Other Materials

Page

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Disclaimer

To simplify terminology, we may use product or equipment trade names. We are not endorsing products or firms mentioned.

Chapter 1 Literature Review on Nutritional Quality of Large Round Bale Silage (LRBS) from Compaction, Color of Wrap, and Additives

INTRODUCTION

In Southcentral Alaska, the cool temperatures and usually abundant precipitation during summer promote active growth of forage grasses during the entire growing season (Klebesadel, 1994). The farmers can usually get at least one good hay cutting during late June/early July. However, subsequent harvests are difficult to obtain due to frequent rainfall. Matanuska-Susitna Valley farmers normally struggle in late August/early September to cut and cure grass to 18-20 percent moisture content required for hay baling, which makes large round bale silage (LRBS) a reasonable alternative (J. Ericksen, personal communication, 18 May 2004). Large round bale silage, often called balage, is the product of cutting forage crops with conventional hay harvest equipment (Mayer, 1999; Henning et al., 2001), allowing the forage to wilt (dry) to 35 – 60 percent dry matter (DM), baling the forage into tight bales, and quickly wrapping the bales in plastic so that the oxygen is excluded. The forage in the bale then goes through the ensiling process (Walton, 1983; Clarke, 2001; Henning et al., 2001).

Large round bale silage originated in northern Europe, where drying conditions are not conducive to the production of high-quality hay (Coblentz, 2005). Ensiling of green forage is a traditional way to conserve animal feed. Large round bale silage is gaining importance and is replacing hay production and direct feeding of green forage. The technology is simple and includes compression of the forage, followed by airtight sealing (Danner et al., 2003). There is an increased interest in LRBS techniques because they

offer the potential for storing high-quality forages without prolonged periods of field-drying, which can result in loss of quality if drying conditions are not ideal. This approach may also allow a regular second harvest of cool-season grass crops before the summer dormancy period begins (Coblentz, 2005).

Some advantages of feeding LRBS instead of hay to Alaskan livestock are higher quality feed (high energy and protein), excellent palatability, highly digestible, and it is dust free (reducing chances of Chronic Obstructive Pulmonary Disease) (Noeller and Thomas, 1985; Morse and Sedivec, 1990; Wright, 1999; Stocks, 2003). The big bale provides a convenient method of feeding in situations of grass shortage and/or poor unpredictable weather (Larsen and Rider, 1985; Morse and Sedivec, 1990; Undersander et al., 2003), as in Southcentral Alaska. Large round bale silage requires less wilting time, and is therefore less prone to spoilage or loss of nutrients than hay, especially in highly variable climates such as Southcentral Alaska. Reduced handling and a shortened drying time can greatly reduce mechanical shattering and rain damage. Forage containing more than 40 percent moisture resists mechanical shattering, and loss is reduced to 15-20 percent range. The longer forage lays in the field, the greater the risk of rain (Mayer, 1999).

Rainy days postpone the harvest of the forage. This gives more time for the plants to mature, increasing the amount of indigestible matter and decreasing the protein and energy content. Also, the more time the cut forage spends on the ground waiting to get dry and baled, the greater the opportunity for field losses (NRCS, 2000). The superior quality of LRBS under these circumstances can clearly be demonstrated. NRCS (2000)

studies showed that LRBS has higher or equal levels of energy and higher percentage of protein than hay. McCormick et al., (1998) showed that when cows ate higher proportions of LRBS they produced more milk; the cows that ate hay increased their grain consumption compared to those that ate LRBS. Large round bale silage had more energy and protein than the hay thus reducing the need for grain. A previous study demonstrated that feeding LRBS to Holstein cows on pasture permitted a 35-40 percent reduction in grain supplementation without a reduction in dairy milk production (NRCS, 2000).

According to Clarke (2001), the biggest advantage offered by storing ensiled forage as individually wrapped LRBS is the potential to minimize spoilage. Dry matter losses in hay range between 20 and 25 percent (Coblentz, 2005). Losses in LRBS usually do not exceed 5 percent, provided moisture levels at baling are correct and the plastic wrap is applied and maintained correctly (Clarke, 2001; Coblentz, 2005). Large round bale silage can provide an economical and quality forage product, especially for farmers who already own a big round baler (Mayer, 1999).

A few disadvantages of feeding LRBS are readjusting daily feeding requirements, presence of *Clostridium botulism* (which may be caused by an incomplete fermentation process), and risk of spoilage if integrity of wrap is not maintained (Noeller and Thomas, 1985; Morse and Sedivec, 1990; Wright, 1999; Stocks, 2003).

The starting point for high quality LRBS is high quality parent forage. The recommended growth stage for harvest is a compromise between increasing yield and declining quality as the crop matures (Burns et al., 2005). Stage of maturity at the time of

harvest is the single most important factor influencing the feeding value of LRBS. This is especially true for first cutting of grass forages (Jones et al., 2004). Forage quality begins to decline as soon as forages start to regrow caused by the accumulation of stems and deposition of lignin in both leaves and stems. Summer regrowth may have lower quality because high temperature increases lignin deposition, and high rainfall increases growth rates and maturation (Adesogan et al., 2006). Plants continue to respire after they are cut. Fiber and lignin concentrations in the whole plant increase, while protein and energy decrease. Digestibility of fiber also declines as the concentration of lignin increases (Jones et al., 2004). Each day harvest is delayed the plant matures and increases indigestible matter and decreases in nutritional value (Quinn, 1995). The increase in plant fiber as the crop matures results in lowered digestibility and forage intake. Feeding forage cut at later stages of maturity can easily result in up to 180 kg of milk loss per cow per lactation (Quinn, 1995).

The interval between baling and wrapping or bagging is critical to the success of the ensiling process and should be as short as possible. Increases in internal bale temperature, associated with excessive delay between wrappings, lead to lower forage quality (due to heat damage) and greater mold growth (Henning et al., 2001; Undersander et al., 2003). Prior to wrapping, high moisture forage is subject to high respiration rates and growth of undesirable microorganisms (Henning et al., 2001). Respiration typically increases neutral detergent fiber (NDF) and acid detergent fiber (ADF) and decreases net energy for lactation of LRBS. These changes reduce forage quality. Respiration not only depletes plant sugars, but the heat produced can limit the activity of lactic acid bacteria

and cause protein to bind to lignin (Jones et al., 2004). Respiration reduces forage quality by consuming readily digestible carbohydrates (Henning et al., 2001).

Fermentation Process

Large round bale silage is the result of fermentative reactions; also known as the ensilage process. The basic fermentation conditions (i.e., low pH and anaerobic condition) are difficult to achieve in LRBS because the forage is not chopped prior to baling resulting in slow oxygen removal and a restricted release of nutrients necessary for acid producing bacteria (Moshtaghi and Wittenberg, 2000). As a result, there is generally less fermentation in LRBS than in chopped silage (Macaulay, 2003). Also, a low concentration of water soluble carbohydrates (sugars) at initiation of ensiling will extend the initiating fermentation phase thus causing the pH to drop too slowly (Etchebarne, 2001).

The primary objective of ensiling is to achieve anaerobic conditions (Nash, 1985). The plastic wrap keeps out air, allowing anaerobic microorganisms to ferment carbohydrates to lactic acid, which inhibits the growth of other detrimental microorganisms (Henning et al., 2001). According to Bagg (2002), when lactic acid bacteria multiply they produce acetic acid, which lowers the pH from approx 6 to 5, while the production of ammonia tends to raise the pH. The production of ammonia increases the amount of time it takes to reach a stable pH. However, the beneficial bacteria lower the pH to around 4 and the acidity inhibits the growth of any other bacteria leaving LRBS in a stable condition (Kung, 2003). Because of the high moisture level and

airtight environment, the forage ferments and is preserved by acid production during fermentation (Spivey and Nix, 1998; Kung, 2003).

The second objective of ensiling is to prevent the growth of saccharolytic and proteolytic bacteria (Nash, 1985) and fungi (Kung and Shaver, 2001). Too much water in the plant reduces the concentration of water-soluble carbohydrates in the plant cells. High moisture will induce the growth of butyric acid producing bacteria and molds that lower the quality of the LRBS (Etchebarne, 2001). Wet LRBS that improperly ferments can lead to botulism poisoning caused by *Clostridium botulism* (Nash, 1985; Henning et al., 2001; Bagg, 2002). According to Rankin (2000), *Clostridium* fermentation results in excessive DM and energy losses in forage with a high pH (typically over 5.0). Where weather permits, wilting forage above 30-35 percent DM prior to ensiling can reduce the incidence of clostridia because these organisms are not very osmotolerant, they do not tolerate dry conditions (Kung, 2000). Exposure to oxygen results in the growth of yeast, molds, and aerobic microorganisms (Bagg, 2002) and leads to deteriorated LRBS and animal toxicity (Henning et al., 2001). Excess oxygen can cause unwanted protein breakdown, excessive heating, and growth of undesirable bacterial microbes and molds (Kung, 2003). Oxygen must be eliminated before an optimal fermentation can take place.

Acetic acid can be an indicator of a slow, inefficient fermentation driven by heterofermentative lactic acid bacteria. This type of fermentation can result in the production of other products in the LRBS that can depress intake and waste energy. However, acetic acid can be produced efficiently by homofermentative bacteria, and by the anaerobic conversion of lactic acid to acetic acid. In these situations the fermentation

is efficient and the potential intake depressing compounds are not produced (Charley, 2006).

According to Seglar (2003), the low levels of propionic acid produced during fermentation assist in maintaining aerobic stability. Propionic acid is effective in reducing yeast and mold growth which is responsible for aerobic deterioration in silages. The antimycotic effect of propionic acid is enhanced as pH declines, making it an ideal candidate for improving the aerobic stability (Kung, 2003). The aerobic stability of LRBS during the winter months, when most of this product is fed remains unclear (Rhein et al., 2005). Most silage contains very low concentrations of propionic acid (<0.2 to 0.3 percent) unless the silage is very wet (Kung and Shaver, 2001).

The DM content of the forage can also have major effects on the ensiling process via several different mechanisms. Drier silages do not pack well, and it is difficult to exclude all of the air from the forage mass (Kung, 2000). As the DM content increases, growth of lactic acid bacteria is curtailed and the rate and extent of fermentation is reduced (Kung, 2000; Hall, 1994). Bales with higher moisture content are more likely to freeze or have more effluent that collects at the bottom of the silage bags. These problems are apt to occur as moisture levels increase above 50 percent, and during extremely cold winters (Sullivan and McKinlay, 1998). Too low a moisture level may lead to an unstable forage mass with yeast and mold problems (Hall, 1994).

Heat is essential to successful silage fermentation. When microbial growth occurs in silage, there is a rise in temperature (Macaulay, 2004). The rate of acidification is greater when silage temperatures are higher and the onset of fermentation is earlier (Weinberg et

al., 2001). Macaulay (2004) indicates temperatures in the 15°C to 25°C range have been shown to allow growth of the more important lactic acid producing species of bacterial while inhibiting the undesirable clostridial species.

Internal bale temperatures which are higher than the optimum temperature destroy forage by overheating (Macaulay, 2004). Heating causes plant sugars and proteins to combine and form indigestible compounds. Heating will form indigestible products that lower protein and energy values (Morse and Sedivec, 1990). Too much heat may lead to spontaneous combustion. Heat damage may lower forage quality (House, 1998) or cause spoilage. Although animals eat damaged feed, the nutritional value is reduced. Higher temperatures encourage the growth of undesirable clostridia (Weinberg et al., 2001). Weinberg et al. (2001), and Rodríguez et al. (1998), demonstrated that these higher temperatures negatively affect the fermentation process and aerobic stability.

Temperatures lower than optimal near the center of the bale do not favor proper fermentation (Macaulay, 2004). Ensiling conditions are not ideal during the fall (low temperatures and low populations of ensiling bacteria), thus fall produced LRBS should be fed first during the winter (Henning et al., 2001). At low temperatures the primary end product of fermentation is butyric acid (Morse and Sedivec, 1990).

Large round bale silage should have a clean, pleasant, acidic odor, be uniformly green to brownish in color and feel moist, but not mushy and slimy. Dark brown, caramelized, charred-looking, or tobacco-smelling LRBS is a sign that excessive heating occurred during fermentation, while black patches indicate it is rotten (Spillers, 2003). A vinegar odor is indicative of excess acetic acid caused by low plant sugars or poor fermentation.

A rancid odor is due to butyric acid from *Clostridium* fermentation caused by excessive moisture. An alcohol odor indicates yeast fermentation caused by slow feed-out (not consumed quickly enough by the animal), oxygen, or low lactic acid bacteria (Bagg, 2002).

Baling Compaction

The key to good LRBS is the exclusion of oxygen quickly and completely (Sullivan and McKinlay, 1998). Compaction of forage when baled is an important factor for exclusion of air (Morse and Sedivec, 1990). Bales should be formed as tightly as practical (Morse and Sedivec, 1990; Henning et al., 2001; Undersander et al., 2003). The compaction provided by high density baler limits the amount of oxygen in the bale (Macaulay, 2003), which reduces possible spoilage or heat damage. It is extremely critical that plant respiration be stopped as soon as possible after harvest. This is achieved by making firm, dense bales that are then wrapped air-tight. The drier the forage, the more dense and firm the bale should be in order to avoid air pockets (Moshtaghi and Wittenberg, 2000). If air gets into the system during the anaerobic phase, mold will develop (Sullivan and McKinlay, 1998). Bales which are packed too loosely usually have high NH_3-N concentrations (Zimmerman, 2002).

A slow tractor speed helps make tight bales (Garthe and Hall, 1992; Sullivan and McKinlay, 1998) and should be lower than the speed used in making field-cured hay. Downshifting one gear should help to guarantee a tighter denser bale (Henning et al., 2001), which will reduce chances of bale spoilage (Garthe and Hall, 1992). Also, picking up forage directly from the windrow that hasn't been raked will make bales tighter

(Sullivan and McKinlay, 1998). Henning et al. (2001), recommend using mower-conditioners because they concentrate the cut forage into a narrow swath. These narrow swaths allow baling without raking. If raking is required to allow faster drying, a wide windrow should be maintained (Sullivan and McKinlay, 1998). Bale density should be in the range of 160-192 kg/m^3, this equates to a weight between 544 kg and 703 kg in a typical 1.2 x 1.2 m or 1.2 x 1.5 m round bale at 50-60 percent moisture (Sullivan and McKinlay, 1998; Henning et al., 2001; and Coblentz, 2005).

Plastic Wrap

Bales should be moved to the wrapping and storage area immediately after baling. If left too long they will begin to heat and lose feed value (Sullivan and McKinlay, 1998) as well as bale roundness, which is important when wrapping (Garthe and Hall, 1992). High-moisture bales will lose shape making them more difficult to wrap. The sun may also evaporate moisture on the outside of the bale making stems brittle (Sullivan and McKinlay, 1998). Wrapping should be complete within 12 hours after baling (Sullivan and McKinlay, 1998; Moshtaghi and Wittenberg, 2000). Fermentation is most affected by the moisture content at wrapping, not at baling. Any delay between baling and wrapping increases the exposure to oxygen and the risk of unfavorable fermentation (Jones et al., 2004).

Most LRBS is wrapped in plastic stretch film (White, 2003). Damage to plastic wrap must be minimized to maintain an anaerobic environment and prevent mold growth. Wrapping bales in the field increases the opportunity for damage to the plastic wrap because of wildlife piercing the plastic wrap before the bales are removed from the field,

and physical damage to the wrap while the wrapped bales are being transported to the storage area (White, 2003).

Undersander et al. (2003) found different levels of plastic thickness had an effect on the bale internal temperatures. Bales with 4 mils or less of plastic wrap had a temperature between 41° and 43°C, indicating oxygen was leaking through the plastic to support continued microbial activity. These bales also had significant mold throughout when opened for feeding. When bales were wrapped with a minimum of 6 mil plastic, the temperature of the bale immediately began to decline and fell to ambient temperature in 8-9 days. Kunkle (2003), also recommends 6 mils of plastic wrap due to problems with air entry and spoilage. Air entry was usually traced to too few layers of stretch wrap, inappropriate stretching of the film (50-60 percent usually suggested), or reprocessed resins used in manufacturing of stretch wrap.

The objective of experiments by O'Kiely et al. (2002) was to determine effects of varying plastic wrap thicknesses and color, on bale preservation, gas composition, and mold growth. Plastic wrap color did not have a significant effect however, increased plastic thicknesses (6 mils) significantly increased DM digestibility, and decreased pH, NH_3-N, and visible mold. Plastic film must have a 50 percent stretch factor, be resistant to ultra-violet light, have good tear strength, and be able to adhere well to the bale. White plastic is used for high sunlight areas and black for lower sunlight areas (Moshtaghi and Wittenberg, 2000) because black plastic may allow greater absorption of solar radiation, in turn increasing the internal temperature of LRBS during curing (Morse and Sedivec, 1990).

Stacking wrapped bales has been tried but it is not recommended for most situations. Forage baled when too wet often shrink and change shape after a few months of storage. Stacking bales can result in additional shape distortion causing air leakage and bales falling off the pile (Kunkle, 2003), any shift of the bales may tear or rip the plastic (Clarke, 2001). Bales should be stacked in a wind-sheltered area to reduce wind damage to the plastic. Wind whip can quickly wear holes in the plastic, and act as a bellows to pump air into the bale. Rows should be set up, with ends in a north-south direction. If they are set in an east-west direction, the sun's warmth on the side expanse of southern exposure in the winter can cause moisture to migrate to the north side of the bale (Vough, 1995). Solar heating of the material inside the plastic appears to be the cause of much of the deterioration of silage from early summer cuttings stored outside until winter (González and Rodríguez, 2003). Diurnal variations in temperature cause a migration of moisture from the tops and south-facing sides of bales to the bottoms and north-facing sides (Coblentz, 2005). Direct solar radiation increases temperature within the plastic during the day and vaporizes water, which then condenses primarily on the cooler north sides and bottoms of the bales at night. The warm south side will attract rodents, as well (Vough, 1995).

Additives

Additives increase dry-matter recovery, improve animal performance (milk production, weight gain, body condition, reproduction) by decreasing heating and molding during storage and feed out (Kung, 2003). Additives are classified into various categories that generally include 1) stimulants of fermentation (microbial inoculants,

enzymes, and fermentable substrates), 2) inhibitors of fermentation (acids, other preservatives) and 3) nutrient additives (Bates, 1998; Kung, 2003). Bacterial inoculants contain lactic acid bacteria (LAB) that enhance fermentation (Bagg, 2002) and acid production (Noeller and Thomas, 1985). Mineral acid additives lower the pH immediately, while organic acids have a limited effect on lowering pH; both reduce proteolysis and limit microbial growth. Propionic acid appears to reduce mold growth and temperature in LRBS with 40-60 percent DM (Noeller and Thomas, 1985). However, results of additives in LRBS have been variable and inconsistent (Johnson, 1972; Noeller and Thomas, 1985; Quinn, 1995; Kung, 2003).

Silage inhibitors hinder either aerobic or anaerobic processes. These include propionic acid and anhydrous ammonia. Inhibitors of aerobic processes suppress the growth of yeast, molds, and aerobic bacteria. Benefits are most likely in excessively wilted forages, which are more likely to have heat-damaged protein, storage losses, molding, and aerobic deterioration at feedout. Inhibitors of anaerobic processes tend to restrict undesirable bacteria (clostridia), plant enzymes (proteases), and possibly lactic acid bacteria. Acids reduce pH of the forage at the time of application (Shaver, 2002).

There are two important potential problems with the production of LRBS: 1) growth of molds, which produce mycotoxins and 2) growth of *Clostridium* bacteria, which produce botulism toxins (Nash, 1985; Wright, 1999). Excessive moisture and a lack of colonizing fermentation bacteria (Nash, 1985; Rankin, 2000) exacerbate both conditions. One technique for ensuring an adequate number of fermentation bacteria is spraying LRBS with an inoculum during the harvest (Morse and Sedivec, 1990; Stocks, 2003).

Preservatives can reduce storage losses and improve feed quality under certain conditions (Yu and Thomas, 1975; Walton, 1983; Kung, 2003).

Propionic acid-based additives have been used to inhibit yeasts that assimilate lactic acid when silages are exposed to air and thus improve aerobic stability (Woolford, 1975). Preservative additives, which are usually propionic acid based, can help keep LRBS fresher longer (Balbian, 1999). Some producers have applied both buffered propionic acid additives and microbial inoculants on the same forage, but there is no published information to support this practice (Kung et al., 2004). Yu and Thomas (1975) conducted a two year study to evaluate propionic acid (0.4 and 0.8 percent), ammonium isobutyrate (AIB) (0.5 and 0.1 percent), an AIB mixture (0.5) and formaldehyde (1.25 of a 37 percent solution) in preserving forage. Treatments had no marked effect on pH or acetic acid concentration but decreased lactic acid concentration. Propionic acid and AIB were equally effective in reducing total fungal counts. All treatments reduced ADF, cell walls, crude fiber, ash, lignin and acid detergent insoluble nitrogen (ADIN) when compared to control forages.

Nutritional Value

Nutritional value of LRBS affects the rates of weight gain, milk production, and reproduction in livestock. It thereby affects the farmer's profits (Klebesadel, 1983; Quarberg, 1993; Ball et al., 2001). Nutritional value and quality varies greatly among and within forage crops, and nutritional needs vary among and within ruminants and horses (Ball et al., 2001). Analyzing LRBS forages for nutrient content can be used to determine whether quality of LRBS is adequate for livestock. Forages should at least be

analyzed for DM, CP, NDF and ADF, lignin, digestible energy (DE), and ADIN (Weiss et al., 1999).

Nutrients and other feed characteristics are typically reported on a DM basis to eliminate the dilution effect of moisture and to allow more direct comparison of feeds and easier formulation of diets. Excessively low moisture (below 45 percent) can indicate heat damage, while high moisture (above 70 percent) can indicate poor fermentation and potential intake problems (Ball et al., 2001). Moisture levels in bales change throughout the day; bales made early in the day likely contain more moisture than those at the end of the day. Crop variation exists within each field as well as among fields, and in LRBS that variation may be concentrated into individual bales (Jones et al., 2004). Moisture is a measure of the amount of water in the feed on an "as is" or "as fed" basis, and is important because moisture dilutes the concentration of all nutrients. When a feed sample is placed in an oven (at 105°C overnight) the water evaporates and the residual dry feed is called DM (Walton, 1983; Makoni, 2003).

Plant cells are composed of cell walls (cellulose, hemicellulose, lignin, silica, insoluble crude protein, and ash) and the contents within the cell walls. The intracellular contents can be assumed to be near 100 percent digestible, and digestibility does not change as the plant ages or grows. Conversely, the chemical makeup of cell walls changes as the plant grows. With aging, the fiber content increases as a percent of the total plant biomass. However, there are several types of fibers in plants, and they can vary greatly in digestibility (Schroeder, 2004).

Fiber analysis is one measure of forage quality. Van Soest et al. (1991) sequential fiber analysis determines amounts of NDF, ADF, and lignin content in plant tissues. Neutral detergent fiber is composed of all cell wall components according to Belyea and Ricketts (1993) because it measures the structural part of the plant including lignin, cellulose and hemicellulose. Neutral detergent fiber values are indicators of feed bulk and are used to predict feed intake in ruminants (Ball et al., 2001). Because forage fiber is bulky, there is a limit to the amount of NDF that will fit into a cow's rumen. When that limit is reached, she will stop eating. There is no more room until a significant portion of the fiber in the rumen is digested and or passes on to the lower gut (Belyea et al., 1999).

Acid detergent fiber is the cell wall content minus hemicellulose and is an indicator of digestibility. Plant cell walls are much less digestible than the intracellular contents. As the proportion of cell wall increases with maturity, the digestibility or quality of the forage decreases (Walton, 1983; Shirley, 1986; Pinkerton and Cross, 1992). Therefore, forage with a low NDF or ADF content is higher in quality than one with a high NDF or ADF content. Neutral detergent fiber is closely associated with total potential intake of the forage by an animal while ADF is more closely related to digestibility of the forage (Pinkerton and Cross, 1992). Acid detergent fiber values are used to calculate total digestible nutrients value (Walton, 1983; Shirley, 1986).

With advancing growth and maturity, forage cells insert a non-carbohydrate material known as lignin, into the primary and secondary walls. This complex compound gives the plant additional tensile strength and rigidity (Schroeder, 2004). Lignin is one of the

least digestible parts of the plant (Walton, 1983; Belyea and Rickets, 1993), and its presence will inhibit the availability of the cellulose and hemicellulose portion of the forage (Schroeder 2004).

Digestible energy is a measure of the solar energy captured by the plant which can be digested by the animal for use in maintenance and in making products (such as milk) (Rayburn, 2001). Digestible energy of a feed is gross energy less the energy contained in the feces that result from any particular input of that feed (Shirley, 1986; Makoni, 2003). Digestible energy is measured as total digestible nutrients, or as net energy lactation, or as net energy maintenance and net energy gain (Rayburn, 2001). Digestible energy can be calculated from the amount of digestible DM which can be estimated from ADF concentration.

Crude protein is the proportion of nitrogen found in the dried sample multiplied by 6.25 (Van Soest, 1985). The value 6.25 is a generalized proportion of elemental nitrogen to plant protein, taking into account the fact that the forage material contains ammonia, nitrate and amides (Walton, 1983). Much of the protein in feeds for ruminants is broken down by rumen bacteria and used by them in digestion of carbohydrates (cellulose, sugars, and starches) in the forage (Rayburn, 2001). In general, as CP increases in forage, livestock performance improves and weight gain increases. Thus, there is a reasonably good relationship between forage quality and CP content. Although protein content of forages is important, energy is often more of a concern (Pinkerton and Cross, 1992). Crude protein is assumed to be totally digestible, but a certain amount is completely unavailable to the herbivore. Unavailable protein apparently is bound to fiber

and actually may not be true protein (Belyea and Ricketts, 1993). True protein reflects only the nitrogen associated with protein and does not include the nitrogen from non-protein sources, which is composed of urea and other low molecular weight nitrogen containing compounds such as creatine and creatinine (Barbano and Lynch, 1999).

Acid detergent insoluble nitrogen is the nitrogen remaining in the ADF residue and, while some occurs naturally in all plant material, is generally considered to be an estimate of heat damage occurring during storage or processing. Generally, the large amounts of unavailable protein are caused by too much oxygen in LRBS. The resulting forage turns brown to black depending on severity of overheating, when the temperature of the LRBS exceeds 40°C (Bagg, 2002; Macaulay, 2004) and it has an odor that ranges from sweet caramelized to tobacco-like. Cows often relish overheated forage because the sugars become condensed and turn into syrup (Belyea and Ricketts, 1993; Bagg, 2002; Macaulay, 2004). High ADIN indicates excessive heating during early fermentation and during storage by aerobic activity of yeast, molds, and especially *Bacillus*, of which some species are highly thermophilic (Seglar, 2003). Protein and energy digestibility decreases significantly as ADIN increases (Weiss et al., 1999). The protein that is bound in this process is largely indigestible to the rumen microorganisms and is unavailable to the animal (Macaulay, 2004). The protein in fresh forage typically has a true digestibility of approximately 90 percent, regardless of the forage source. Excessive heating can reduce this digestibility to 30 percent or less (Macaulay, 2004).

Fermentation analysis is another measure of forage quality. A fermentation analysis determines the amounts of lactic acid and each important volatile fatty acid (VFA), which

includes acetic, propionic, and butyric acids produced during the ensiling process. Normally lactic acid is the predominate acid in silages, and is normally responsible for decreasing pH level (Kung and Shaver, 2001; Zimmerman, 2002; Macaulay, 2004). Fermentations that produce lactic acid result in the lowest loss of DM and energy from the crop during storage (Kung and Shaver, 2001). Some reasons for low lactic acid content are: 1) restricted fermentation due to dry forage (greater then 50 percent DM); 2) ensiling during cold weather; 3) sampling after air exposure has degraded lactic acid; and 4) bales high in butyric acid are usually low in lactic acid (Kung and Shaver, 2001; Zimmerman, 2002).

Large round bale silage put up too wet or mature, or having inadequate lactic acid bacteria numbers present for the last phase of fermentation, can lead to elevated acetic acid levels (Etchebarne, 2001). Acetic acid has a strong ability to prevent growth of yeasts and mold and so should ideally be present in silages at a reasonable level to prevent heating and spoilage (Hutjens, 2002; Charley, 2006). High acetic levels increase as DM content drops (Coblentz, 2005), and reduce palatability. Acetic acid alone is not harmful to the animal because in the rumen, this acid is the primary VFA source of energy for the cow (Etchebarne, 2001).

Excessive amounts of acetic, propionic, or butyric acids as well as ethanol indicate a poor quality fermentation process resulting from microbes that are not exclusively lactic acid-producing bacteria (Van Saun, 2000). Acetic acid is often produced if lactic acid production is not rapid enough to inhibit acetic acid production by bacteria (Zimmerman, 2002), which normally occurs during first 2-3 days of ensiling (Kung, 2003). High acetic

acid levels suggest inefficient (slow or prolonged) fermentation (Kung and Shaver, 2001; Zimmerman, 2002) and very high levels may decrease DM intake (Zimmerman, 2002). In such LRBS, energy and DM recovery are probably less than ideal. High acetic acid levels may be due to: 1) wet forage (DM less than 25 percent); 2) prolonged fermentation; 3) loose compaction; and 4) forage treated with ammonia.

Most silages contain very low concentrations of propionic acid (<0.2 to 0.3 percent) unless the silage is very wet (Kung and Shaver, 2001; Zimmerman, 2002). Propionic acid is a liquid fatty acid, found naturally in sweat, milk products, rumen, and as a product of bacterial fermentation. The acid has a sharp, sweet smell and taste. Propionic acid can be produced in the LRBS by fermentation of sugars and/or lactic acid by propionic acid producing bacteria and/or as a co-product in the conversion of lactic acid to acetic acid by *Lactobacillus bunhner* (Charley, 2006). Propionic acid reduces molding, heating, and aerobic deterioration, which is most important in surface layers (Kunkle et al., 2006).

Butyric acid which is produced by the anaerobic bacteria, C*lostridium*, which are present on the crop in relatively small numbers at harvest (Charley, 2006) and proliferate if the silage is harvested too wet (<30 percent DM), indicates LRBS has undergone poor fermentation (Kung and Shaver, 2001; Hutjens, 2002). Large round bale silage high in butyric acid is usually low in nutritive value and has high ADF and NDF levels because many of the soluble nutrients have been degraded (Kung and Shaver, 2001; Charley, 2006). Butyric acid is an undesirable VFA produced during poor silage fermentation (Hutjens, 2002). Clostridia numbers in the ensiled forage can be dramatically increased

by the inclusion of soil, picked up either by cutting the crop too low or during raking (Charley, 2006), or from manure that was applied too close to the harvest date.

The fermentation analysis also measures the pH and ammonia concentration. The pH is a measure of acidity and a function of lactic acid content in silage (Van Saun, 2000), which ultimately stops the fermentation process (Macaulay, 2004). The key to high quality LRBS is getting a rapid pH decrease (Zimmerman, 2002). For grass forages, pH should fall into a range between 4.0 and 5.1 (Van Saun, 2000; Kung and Shaver, 2001; Zimmerman, 2002; Macaulay, 2004). A high pH due to clostridia is a definite indicator of an undesirable fermentation that has led to poor quality forage. A high pH due to restricted fermentation is not always indicative of poor fermentation or poor LRBS, but, LRBS from a restricted fermentation usually is unstable when exposed to air because insufficient amounts of acid were produced to inhibit secondary microbial growth (Kung and Shaver, 2001).

Ammonia is another component which is measured in the fermentation analysis. High levels of NH3-N show that there has been excessive protein degradation, either due to prolonged wilting or due to microbial activity (Hall, 1994; Kung and Shaver, 2001; Zimmerman, 2002; Charley, 2006). High amounts of NH_3-N may also imply the presence of amines and amides (protein breakdown products) which are toxic (Hall, 1994). Ensiled forages with high NH_3 -N levels may have high metabolic energy contents, but are unpalatable and have reduced production potential because of low intake (Roenfeldt, 1999; Burns et al., 2005).

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Chapter 2 Fiber Analysis of Large Round Bale Silage as Affected by Compaction, Color of Wrap, or Preservative in Southcentral Alaska

ABSTRACT

Large round bale silage (LRBS), fermented hay, baled at 45-65% moisture content might be a better product than air-dried hay for farmers and ranchers in Southcentral Alaska. Variable weather and sometimes unfavorable conditions for drying hay to the required 18% moisture content makes high quality hay production unpredictable. Our study was designed to determine what practices might produce the highest nutritional quality LRBS. Treatments included using black and white plastic bale wrap, two different baler compaction levels, and application of a buffered propionic acid preservative. The study used four different forage fields over a two year period. Three fields were harvested on each cutting date. We measured dry matter (DM), neutral detergent fiber (NDF), acid detergent fiber (ADF), lignin, acid detergent insoluble nitrogen (ADIN), crude protein (CP), and digestible energy (DE). Highly compact bales contained significantly higher bound protein than less compact bales. Color of plastic wrap (black or white) did significantly affect LRBS fiber concentrations. Overall, treatment with buffered propionic acid preservative did not significantly affect nutritional quality. However, in one case, the high moisture content bales (above 70%), from the June 2005 harvest had higher nutritional quality when the preservative was applied.

Lussier, Charlotte and Harris, Norman. 2007. Fiber Analysis of Large Round Bale Silage as Affected by Compaction, Color of Wrap, or Preservative in Southcentral, Alaska. Prepared for submission to Agronomy Journal.

Other variables such as the number of core samples taken from each bale, significantly decreased nutritional values with storage time; and delay of harvest also significantly decreased nutritional quality.

Ensiling of green forage is a traditional way to conserve animal feed and is replacing hay production and direct feeding of green forage. The technology is simple and includes compression of the forage, followed by airtight sealing (Danner et al., 2003). Large round bale silage techniques offer the potential for storing high-quality forages without prolonged periods of field-drying. This approach may also allow a regular second harvest of cool-season grass crops before the summer dormancy period begins (Coblentz, 2005).

Relatively short growing seasons at subarctic latitudes require maximum efficiencies in production of forages during the brief growing period. Forages in Alaska are used in several ways including a) usually two harvests per year for preservation as silage, LRBS, or hay, b) more frequent harvests for green-chop feeding, and c) pasturing rotationally or continuously. Various forage crop species differ in growth characteristics as well as in their responses to various harvest procedures and schedules; therefore a number of species can be advantageously employed for forage production in Alaska (Klebesadel, 1992). Timothy (*Phleum pretense* L.) and smooth bromegrass (*Bromus inermis* Leyss) are the most commonly harvested grasses in Southcentral Alaska (Benz et al., 2005). However, the grasses in this study were quackgrass (*Elymus repens* L. Beauv.) and smooth bromegrass. Quackgrass was the dominant grass in all the fields of the study area except for one field where smooth bromegrass was grown.

Quackgrass does not tolerate long hot summers. Optimum temperatures for growth are between 20-25°C. Rhizome growth is favored by low temperatures (10°C) and long days (18 hours). Early spring fires generally increase quackgrass cover, flowering, and biomass. Quackgrass has been rated fair in energy value and poor in protein value (Snyder, 1992). Christen et al. (1990) reported quackgrass has been used in ruminant feeding but, information on its nutritive value is limited. They compared timothy and quackgrass and found the nutritive value similar except for crude protein (CP). Higher CP content of quackgrass resulted in a higher availability of this nutrient to the animal. They suggested that producers should take advantage of quackgrass when it is present in the grassland.

Smooth bromegrass is cold hardy, and cultivars have been bred for nutritional quality and adaptation to selected climates. Early growth of smooth bromegrass is highly palatable to grazing animals. Palatability and nutritional quality decrease rapidly after flowering. Early spring fire can increase smooth bromegrass productivity (Howard, 1996). Klebesadel (1992) found smooth bromegrass in Southcentral Alaska favored only two harvests per year. The first cuttings yielded greater DM production than the second harvest when the first harvest was relatively late (Klebesadel, 1994). Previous studies by Klebesadel (1992) indicate more than two cuttings per year of Alaskan tall forage grasses results in low forage dry-matter yields. Large round bale silage is a perishable product and will deteriorate quickly if it is exposed to air (Burns et al., 2005).

Large round bale silage quality is affected by several variables, including an air-tight environment, which is influenced by compaction of bales, thickness of plastic wrap,

moisture content of the ensiled materials, the heat or temperature at which the LRBS is allowed to cure, and the addition of additives such as preservatives or inoculants. If forage is too dry, more open spaces exist, allowing oxygen to fill these areas. The integrity of the plastic wrap is a major component in creating an air tight environment.

Preservatives can reduce storage losses and improve feed quality under certain conditions (Yu and Thomas, 1975; Walton, 1983; Kung, 2003). Preservative additives, which are usually propionic acid based, can help keep LRBS fresh longer (Balbian, 1999). Buffered propionic additives are added to silages to improve the stability of silages when they are exposed to air (Kung et al., 2004).

We found no literature to indicate that any plastic color is better than another as far as LRBS quality is concerned. However, black plastic has an ultraviolet inhibitor, called carbon black, which limits plastic degradation under sunlight; thus, white and green plastics degrade quicker (Garthe and Hall, 1992). The deterioration of plastic can allow air into the bales, thus greater chances of spoilage.

To determine nutritional value of LRBS and hay in Southcentral Alaska, we measured dry matter (DM), neutral detergent fiber (NDF), acid detergent fiber (ADF), lignin, crude protein (CP), acid detergent insoluble nitrogen (ADIN), and digestible energy (DE). The objectives were to determine if compaction, color of plastic wrap, or preservative impacted the nutritional quality of LRBS.

MATERIALS AND METHODS

Site Description

The study area consisted of four hay fields, each between 15-25 hectares in size, at the University of Alaska Fairbanks (UAF) Matanuska Experiment Farm (61°33′57″ N lat; 149°14′39″ W long), 16 km southwest of Palmer and 56 km northeast of Anchorage, Alaska. Fields 1, 2 and 3 were cut and baled once in 2004. Fields 1, 2 and 4 were cut and baled twice in 2005. Field 3 was not available for harvest in 2005. Air dried hay was also baled from each field, except for the September 2005 cutting when inclement weather prevented drying of the forage to acceptable moisture content for hay.

Field History

The fields were burned on 12 and 13 April 2004, and 24 March 2005. Approximately two weeks after burning, approximately 89 kg of phosphate (P_2O_5), 106 kg of ammonium sulfate ($(NH_4)_2SO_4$), 136 kg of urea, 77 kg of potash (K_2O) and 17 kg of lime filler per hectare was broadcast. Approximately two weeks after the first cutting, fields were fertilized with 185 kg ha^{-1} of urea (84 kg N ha^{-1}). Harvests dates were weather dependent. The first cutting occurred 9 June 2004, at which time the plant stage was mid-vegetative for Fields 1 and 2, and boot stage for Field 3. Above normal temperatures and inadequate precipitation prevented sufficient regrowth for a second harvest in 2004 Figure 2-1) (Benz et al., 2005). The first cutting for 2005 was 1 June 2005, at which plant stage was mid-vegetative for Fields 1, 2, and 4. The second 2005 cutting was delayed to 19 September 2005 due to above normal precipitation, at which plant stage was mature.

Experimental Design

This study is a two-level factorial experiment for three treatments. Each of the fields received a combination of the three treatments: compaction level (loose or tight), color of plastic wrap (black or white), and a preservative (with or without), resulting in eight LRBS from each field (24 bales each harvest), for all three cuttings June 2004, 2005 and September 2005 (total of 72 LRBS). One hay bale was also harvested from each field, except during the September 2005 harvest (6 total hay bales). Hay bales were analyzed and compared to other hay bales with similar climatic conditions as found in Southcentral Alaska.

Harvest Equipment

Grass swards were cut with a mower conditioner set to place wide windrows on the stubble. These windrows were tossed and raked with an H&S® (H&S Manufacturing Co., Inc., Marshfield, WI) bifold rake with seven wheels and a Tonutti® Model V1-2 (Tonutti USA, Memphis, TN) with eight wheels after 24 hours wilting. Before baling, grass was tested for moisture content via microwave drying (Staples, 1998) for 2004 harvest. A vortex forage and biomass sample dryer (Buckmaster, 2005) was used to test moisture content prior to baling for both 2005 harvests. A preservative, Baler's Choice® (The Profitable Farming Co. Ltd., Devon, UK), Buffered Acid (75% ammonium salt of propionic acid, propionic acid, citric acid and surfactants; 25% deionized water, T-DET DD-5) was added at 107 kg ha^{-1} during baling process with a Harvest TEC® Model 441 (Harvest TEC, Hudson, WI), 25 gallon preservative applicator sprayer.

Thirty six tightly compacted (approximately 500 kg m^{-3}) bales were baled with a Vermeer® Model 504 L-series (Vermeer Manufacturing Co., Pella, IA) baler, and 36 loose compacted (approximately 450 kg m^{-3}) bales and the 6 hay bales were baled with an New Holland Model 848 (Pioneer Equipment Inc., Palmer, AK) baler. The bales in our study were transported approximately 2 km to a storage area, 3-6 hours after baling for the June 2004 and September 2005 harvests and 24 hours after baling for the June 2005 cutting. LRBS was wrapped in plastic 5-10 hours after baling for the June 2004 and September 2005 harvests, and 25-32 hours after baling for June 2005 harvest. The June 2004 hay bales were baled 5 days after cut (9 June 2004) and the June 2005 bales were baled 7 days after cut (1 June 2005).

The LRBS was weighed on a Paul® Model 310-3000 (WW Paul Scales, Duncan, OK) livestock scale and then wrapped in white or black plastic. Bales were wrapped with a Vermeer® Model SW2500 (Vermeer Manufacturing Co., Pella, IA) wrapper. Thirty-six bales were wrapped with two layers of 2-ply AEP Black (B) AB-30100M Sunfilm® (Wheat-Belt Industries, Balzac, Alberta, Canada) Silage Wrap (750mm x 1500m x 1 mil). The other 36 bales were wrapped with two layers of 2-ply AEP White (W) RT-30100 Sunfilm® Silage Wrap (750mm x 1500m x 1 mil). Bale height and diameter were measured to calculate density.

Bale Temperature Measurement

We inserted Optic Stowaway® (Onset Computer Corp., Pocasset, MA) self-recording thermistors, with 8k of memory, into bales to monitor internal temperature near the center of the bale. Core holes were drilled at a right angle to outside circumference of bales

with a 56 cm coring probe. Thermistors were inserted 56 cm into cored holes, near center (NC) and 12 cm below surface (BS) edge of bale. Temperature measurements were recorded every ½ hour for 168 days (24 weeks). To record plastic surface temperature Onset Computer Corporation, Hobo® (Onset Computer Corp., Pocasset, MA) outdoor/industrial 4-channel thermistors leads were inserted between ply on selected white and black plastic bales. Four tripods containing thermistors were set around the bales to record ambient temperature every ½ hour for 168 days (24 weeks).

Sampling Method

Before harvest, 10 stratified random (encompassing all grass types, heights, and density for an accurate representation of the fields) plots from each field, 0.6 m x 0.6 m, were clipped, dried and analyzed for fiber sequential analysis, CP, DE, and ADIN, just prior to cutting and baling. The plots represent time zero for core sample analysis.

Samples were cored from hay and LRBS at 2, 4, 12 and 24 week intervals after baling. The heavy-ply plastic encasing bales required the cutting of a small hole in the side of the bale, and coring with a 56 cm long probe inserted at a right angle to the outside circumference of the bales. Two samples were taken from each bale. Argon, an inert gas, was used to displace the air that entered the bale during coring. The holes in the bag were taped shut immediately after samples were withdrawn, reducing potential damage to the contents.

Each sample was thoroughly mixed, divided into a fiber analysis and a fermentation product sample, and weighed. The fiber analysis sample was placed in a paper bag, dried at 55°C for 96 hours, and then weighed again to determine dry matter and moisture

content of the bales. The dried samples were ground with a Wiley® (Wiley Corp, Hoboken, NJ) grinder to pass through a 1mm mesh screen.

Chemical Analysis

For LRBS and hay bales, the nutritional indicators measured were DM, NDF, ADF, lignin, CP, ADIN and DE. The Van Soest et al. (1991) procedures for sequential fiber analysis were used to determine NDF, ADF, and lignin.

Tissue nitrogen (N) was measured using LECO® CHN-1000 (LECO Corp., St. Joseph, MI) Elemental analyzer. The analyzer is a non-dispersive, infrared, microcomputer based instrument, designed to measure the carbon, hydrogen, and nitrogen content in a wide variety of organic compounds. Crude protein concentration was determined by multiplying tissue N concentration by 6.25.

Acid detergent insoluble nitrogen was determined by measuring the N content of the ADF residue with a LECO® CHN-1000 Elemental analyzer in the same matter described above to determine the CP.

Digestible energy was determined using Oregon State University chemical analysis calculated values formula for DE. Digestible DM (DDM) was calculated:

$$DDM=88.9-(0.779*ADF),\quad DE=10.027+(0.0428*DDM).$$

Digestible energy is the energy availability estimate from forage test results and can be used to balance rations.

Statistical Analysis

Analysis of variance (ANOVA) and general linear model (GLM) (SAS Institute Inc., 2004) were used to test for significance. The highest level of interaction used as the error

term for all main effects and lower order interactions. Differences were considered to be statistically significant at $P<0.10$. Results were presented as treatment means or least squares means. Differences among treatment means were presented as least significant differences with ANOVA models and as Tukey honest significant differences with GLM.

RESULTS AND DISCUSSION

Compaction

The loose bales averaged 72 kg m^{-3} less than the tight bales (Table 2-1). The tight bales were significantly denser than the lose bales (Tables 2-1 and 2-2) overall, and the June 2004 tightly compacted bales had significantly higher levels of bound protein compared to the loose bales. The higher bound protein in the compact bales infers a greater internal temperature or higher moisture content (Coblentz et al., 2000; Turner et al., 2002).

The June 2005 bales were the densest, and had the lowest DM content, because of high moisture content (73%) when harvested. The September 2005 bales were the least dense due to maturity of plants at harvest, and had the overall lowest nutritional values.

Fields

Field 2 had the most compact/densest (527 kg m^{-3}) bales, while Field 3 had the lowest density (481 kg m^{-3}) bales. Field 2 had the highest overall nutritional quality, with the lowest NDF, ADF, and lignin percentages and the highest DE. Field 3 had the lowest overall nutritional quality, which can be explained by the fact this field was cut only once (June 2004) and, Field 3 consisted of a more mature stage forage, than Fields 1 and 2 at the time of cutting.

Plastic Wrap Color

The color of plastic wrap had no significant bearing on the quality of the fiber analysis (Table 2-1). However, color of plastic wrap had significant differences between harvests (Table 2-3). The June 2004 bales, wrapped in black plastic had significantly lower NDF, and ADF; and significantly higher DE than bales wrapped in white plastic.

The bales wrapped in black plastic were significantly denser than the bales wrapped in white plastic (Table 2-1). A closer look at where these bales were on the field, the type of grass, and the biomass of the forage stand may lead to a more defined explanation of large difference in densities between the colors of plastic wrap.

Bales wrapped in black plastic had significantly ($p<0.001$) higher NC (11°C), BS (11°C) and plastic surface (10°C) temperatures than those bales wrapped in white plastic (9°C, 8°C, and 8°C) respectively (Figures 2-2 and 2-3).

We expected a significant effect from wrap color on ADIN because when excessive heating occurs, a portion of the crude protein becomes unavailable (Schroeder, 2004). Since all of our samples were taken on the north sides of bales, we may not have received a true representation of heat damage as it occurred on the sun-exposed south side of the bales. Also our samples were composites of forage extracted from exterior to the interior of the bale and the surface effects of heat damage might be sufficiently diluted by the process to become undetectable. The southern exposure of bales wrapped in black plastic tended to have a darkened surface of caramelized forage. Most bales wrapped in black plastic showed effects of caramelizing on the surface, but the heat damage only affected 2-3 mm layer of forage. A Dow Chemical Company (2002) study showed an average

wastage of almost 9% of the total fresh weight of bales wrapped with 4 mils of black plastic; wrapping bales with 6 or 8 mils reduced wastage to less than 1%. O'Kiely et al. (2002) conducted several experiments to determine impact of color and thickness of plastic bale wrap and concluded the thickness of plastic around the bales, rather than the color of plastic wrap significantly affected forage preservation, mold development, and gaseous composition. Undersander et al. (2003) also found when bales were wrapped with 6 mils or more of plastic; the temperature of the bale immediately began to decline and fell to ambient temperature in eight to nine days. They also found that bales with less than 4 mils of plastic wrap had higher levels of ADIN.

Preservative

Overall, the buffered propionic acid preservative had no significant effect on the forage (Table 2-1). However, the preservative had significant differences between harvests (Table 2-4). The high moisture content (above 70%) bales from the June 2005 harvest which had the preservative applied had higher nutritional quality. June 2005 bales with applied preservative were significantly lower in NDF, and ADF content, and had significantly higher DE than bales without the preservative. The June 2005 bales without the preservative had significantly higher CP than bales with the preservative.

The bales treated with preservative had a significantly ($p<0.001$) lower temperature (9.2°C) recorded in the outer portion of the bale.

CONCLUSION

An interaction between the color of plastic and DM might have occurred. When harvest was 36-37 % DM the bales wrapped in black plastic had significantly less NDF

percentage. When harvest was 27% DM bales wrapped in black plastic had significantly higher CP. Overall the color of plastic wrap did not have a significant bearing of the forage quality. The use of the buffered propionic acid preservative positively affected the outcome of nutritional value of the LRBS, when bales contained <30% DM, with lower NDF, ADF, and lignin percentages. Denser bales appeared to provide higher nutritional quality. Further study of bales with varying dry matter content with treatments of plastic wrap color and preservative are recommended.

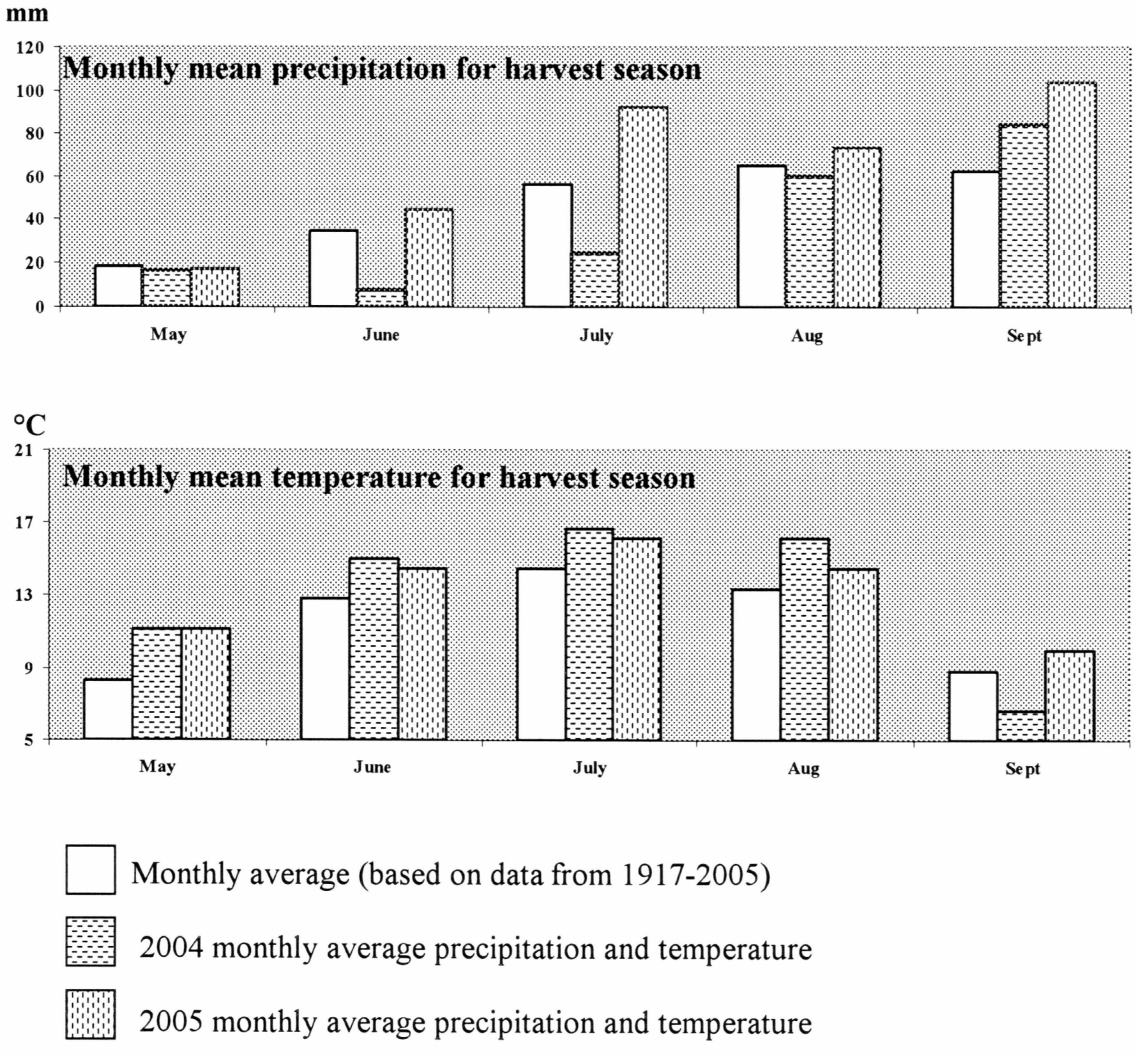

Figure 2-1: Eighty-eight year mean, 2004 and 2005 monthly precipitation and temperature during the harvest season (May-September). Harvest season for 2004 had below average precipitation and above normal temperatures. Harvest season for 2005 had higher than 88-year monthly average precipitation and temperatures.
Source: Western Regional Climate Center, Desert Research Institute, Alaska Climate Summaries.

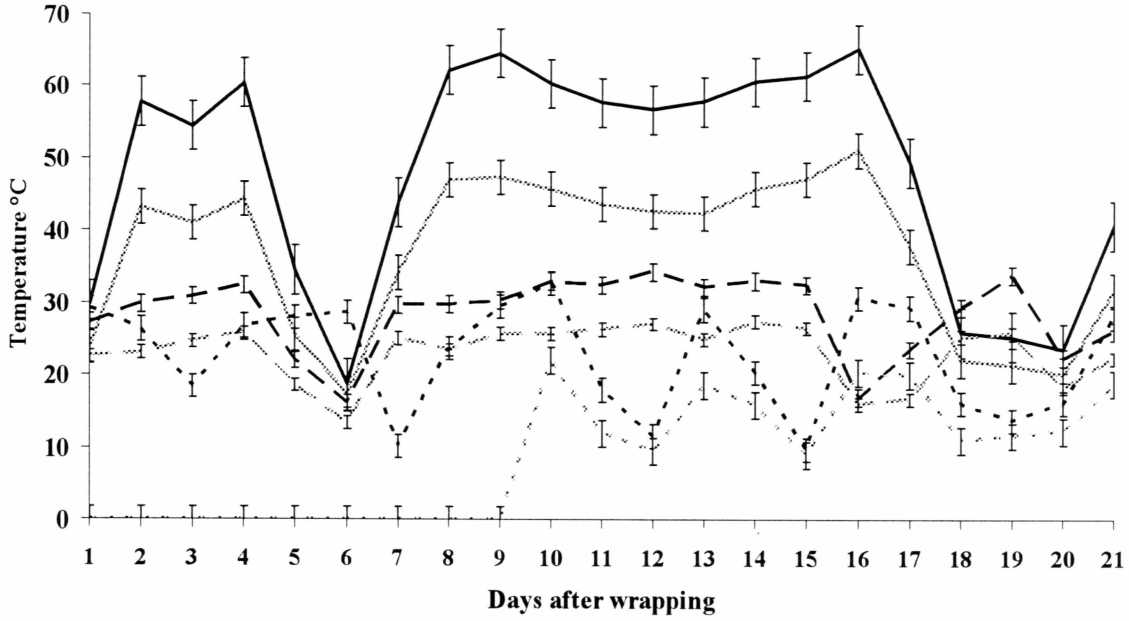

Figure 2-2: Surface temperature of large round bale silage wrapped in black and white plastic wrap for first 21 days of each harvest. Specific harvest and bale color wrap are represented as follows: heavy solid line, June 2004 bales wrapped in black plastic; light solid line, June 2004 bales wrapped in white plastic; heavy long dash line, June 2005 bales wrapped in black plastic; light long dash line, June 2005 bales wrapped in white plastic; heavy short dash line, September 2005 bales wrapped in black plastic; light short dash line, September 2005 bales wrapped in white plastic. Bales wrapped in black plastic had warmer ($p<0.001$) bale surface than bales wrapped in white plastic. Surface temperature for September 2005 bales wrapped in white plastic were unavailable due to equipment failure during the first 9 days of recording.

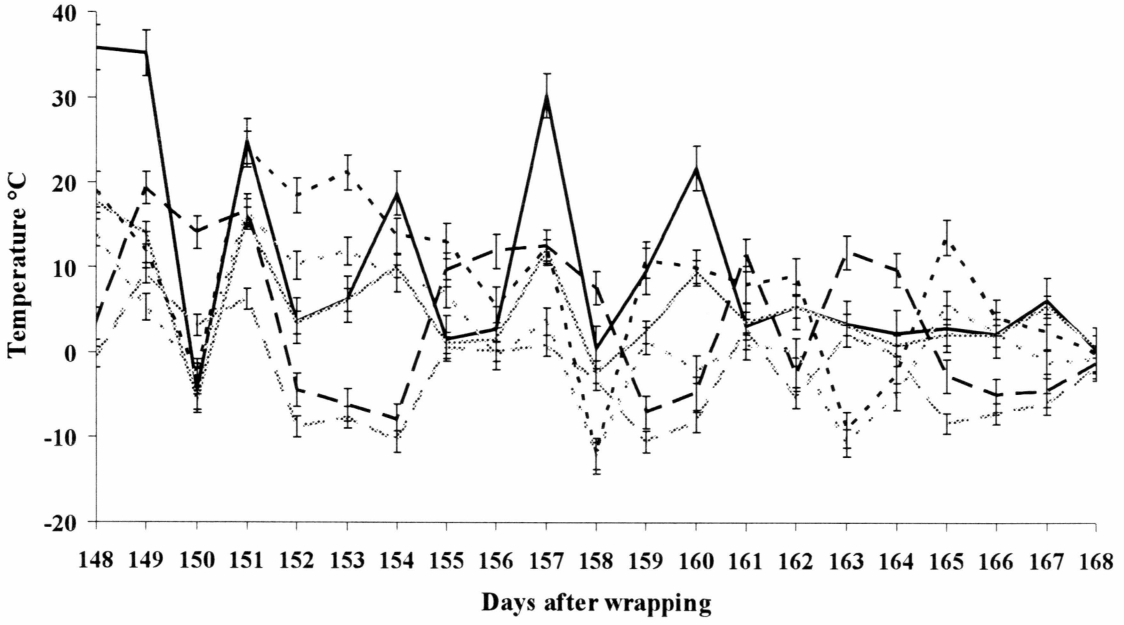

Figure 2-3: Surface temperature of large round bale silage (LRBS) wrapped in black and white plastic wrap for last 21 days of each harvest. Specific harvest and bale color wrap are represented as follows: heavy solid line, June 2004 bales wrapped in black plastic; light solid line, June 2004 bales wrapped in white plastic; heavy long dash line, June 2005 bales wrapped in black plastic; light long dash line, June 2005 bales wrapped in white plastic; heavy short dash line, September 2005 bales wrapped in black plastic; light short dash line, September 2005 bales wrapped in white plastic. Bales wrapped in black plastic continued to be warmer than bales wrapped in white plastic throughout the 168 days, except for June 2004 bales. During the last week of storage the June 2004 bales wrapped in white plastic were warmer than LRBS is wrapped black plastic.

Table 2-1: Fiber, protein, and energy characteristics of large round bale silage (LRBS) with three treatments consisting of bale compaction, plastic wrap color, and preservative after 168 d.†

Treatment	df	NDF	ADF	Lignin	ADIN	CP	DM	DE	Density
		%DM						Mcal kg^{-1}	kg m^{-3}
Treatment means‡									
Compaction									
Loose		56	29	3.8	.40b§	11	33	12.86	441b
Tight		56	29	3.8	.42a	11	33	12.87	513a
Wrap Color									
Black		55	29	3.8	.41ab	12	33	12.87	484ab
White		56	29	3.8	.41ab	11	33	12.86	467b
Preservative									
Yes		56	29	3.8	.41ab	11	33	12.87	477ab
No		56	29	3.8	.41ab	11	33	12.86	476ab
SEM¶		39	13	1.5	0.007	9	29	0.015	15
				GLM					
Source of Variation									
Compaction (C)	1	NS#	NS	NS	††	NS	NS	NS	***
Wrap Color (W)	1	NS	NS	NS	NS	NS	NS	NS	**
Preservative (P)	1	NS	NS	NS	NS	NS	NS	NS	NS
C x W	3	NS	NS	NS	NS	NS	NS	NS	***
C x P	3	NS	NS	NS	NS	NS	NS	NS	***
W x P	3	NS	NS	NS	NS	NS	NS	NS	NS
C x W x P	5	NS	NS	NS	NS	NS	NS	NS	***

** Significant at the 0.01 probability level.

*** Significant at the 0.001 probability level.

† NDF, neutral detergent fiber; ADF, acid detergent fiber; ADIN, acid detergent insoluble nitrogen; CP, crude protein; DM, dry matter; DE, digestible energy.

‡ Overall mean of treatments for LRBS.

§ Within columns, means followed by the same letter are not significantly different according to Tukey HSD (0.10).

¶ Standard error of the treatment mean.

Nonsignificant effect ($P>0.10$).

†† Significant at the 0.10 probability level.

Table 2-2: Fiber, protein, and energy characteristics of large round bale silage (LRBS) at two compactions, loose and tight, for three harvests, after 168 d.†

Compaction	df	NDF	ADF	Lignin	ADIN	CP	DM	DE	Density
		%DM						Mcal kg^{-1}	kg m^{-3}
Harvest‡									
Compaction means§									
1-Loose		55b¶	28b	3.6b	0.38b	13a	37a	12.8b	465d
1-Tight		54b	28b	3.6b	0.44a	13a	36ab	12.8b	537b
2-Loose		51c	26c	2.6c	0.40b	13a	27c	12.9a	488c
2-Tight		50c	25c	2.7c	0.38b	13a	27c	12.9a	556a
3-Loose		63a	33a	5.1a	0.43a	8b	36ab	12.7c	369f
3-Tight		64a	33a	5.1a	0.43a	8b	35b	12.7c	445e
SEM#		9	4	0.4	0.006	3	9	0.005	5
				GLM					
Source of Variation									
Harvest (H)	2	***	***	***	**	***	***	***	***
Compaction (C)	1	NS††	NS	NS	‡‡	NS	NS	NS	NS
H x C	5	***	***	***	***	***	***	***	***

** Significant at the 0.01 probability level.
*** Significant at the 0.001 probability level.
† NDF, neutral detergent fiber; ADF, acid detergent fiber; ADIN, acid detergent insoluble nitrogen; CP, crude protein; DM, dry matter; DE, digestible energy.
‡ Harvests: 1, June 2004; 2, June 2005; 3, September 2005.
§ Compaction means.
¶ Within columns, means followed by the same letter are not significantly different according to Tukey HSD (0.10).
# Standard error of the compaction mean.
†† Nonsignificant effect ($P>0.10$).
‡‡ Significant at the 0.10 probability level.

Table 2-3: Fiber, protein, and energy characteristics of large round bale silage (LRBS) wrapped in black and white plastic, for three harvests, after 168 d.†

Wrap Color	df	NDF	ADF	Lignin	ADIN	CP	DM	DE	Density
		%DM						Mcal kg^{-1}	kg m^{-3}
Harvest‡									
Wrap Color means§									
1-Black		53c¶	27c	3.6b	0.40ab	12a	37a	12.89b	507b
1-White		55b	29b	3.7b	0.41ab	13a	36a	12.86c	497b
2-Black		50d	26d	2.7c	0.39b	13a	27b	12.98a	536a
2-White		50d	25d	2.7c	0.38b	12a	27b	12.98a	510b
3-Black		63a	33a	5.1a	0.43a	8b	36a	12.74d	419c
3-White		64a	33a	5.1a	0.43a	8b	35a	12.74d	395c
SEM#		9	3	0.4	0.007	3	9	0.005	10
		ANOVA							
Source of Variation									
Harvest (H)	2	***	***	***	††	***	***	***	***
Wrap Color (W)	1	NS‡‡	NS	NS	NS	NS	NS	NS	*
H x W	5	***	***	***	*	***	***	***	***

* Significant at the 0.05 probability level.

*** Significant at the 0.001 probability level.

† NDF, neutral detergent fiber; ADF, acid detergent fiber; ADIN, acid detergent insoluble nitrogen; CP, crude protein; DM, dry matter; DE, digestible energy.

‡ Harvests: 1, June 2004; 2, June 2005; 3, September 2005.

§ Color of plastic wrap means.

¶ Within columns, means followed by the same letter are not significantly different according to LSD (0.10).

Standard error of the plastic wrap color mean.

†† Significant at the 0.10 probability level.

‡‡ Nonsignificant effect ($P>0.10$).

Table 2-4: Fiber, protein, and energy characteristics of large round bale silage (LRBS) applied with buffered propionic acid preservative for three harvests, after 168 d.†

Preservative	df	NDF	ADF	Lignin	ADIN	CP	DM	DE	Density
		%DM						Mcal kg^{-1}	Kg m^{-3}
Harvest‡									
Preservative means§									
1-Yes		54b¶	28b	3.7b	0.41ab	12.7ab	36b	12.8c	502b
1-No		54b	28b	3.5b	0.41ab	12.5b	37a	12.8c	502b
2-Yes		49d	25d	2.5c	0.39b	12.5b	28c	12.9b	516ab
2-No		51c	26c	2.7c	0.39b	13.3a	26d	13.0a	527a
3-Yes		63a	33a	5.1a	0.43a	7.5c	35b	12.7d	414c
3-No		63a	33a	5.2a	0.43a	7.6c	36b	12.7d	400c
SEM#		9	3.4	0.4	0.007	2.6	9	0.005	10
		ANOVA							
Source of Variation									
Harvest (H)	2	***	***	***	††	***	***	***	***
	1	NS‡‡	NS	NS	NS	NS	NS	NS	*
Preservative (P)									
H x P	5	***	***	***	*	***	***	***	***

* Significant at the 0.05 probability level.
*** Significant at the 0.001 probability level.
† NDF, neutral detergent fiber; ADF, acid detergent fiber; ADIN, acid detergent insoluble nitrogen; CP, crude protein; DM, dry matter; DE, digestible energy.
‡ Harvests: 1, June 2004; 2, June 2005; 3, September 2005.
§ Forage applied with (Yes), and without (No) preservative means.
¶ Within columns, means followed by the same letter are not significantly different according to LSD (0.10).
# Standard error of the preservative mean.
†† Significant at the 0.10 probability level.
‡‡ Nonsignificant effect ($P>0.10$).

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Chapter 3 Fermentation Characteristics of Large Round Bale Silage as Affected by Compaction, Color of Wrap, or Preservative in Southcentral Alaska

ABSTRACT

Fermentation analysis (volatile fatty acid (VFA) profile) using high performance liquid chromatography (HPLC), was completed on large round bale silage (LRBS) harvested at three different dates over a two year period. Bale treatments included two different baling compaction levels, black and white plastic wrap, and use of a buffered propionic preservative. The denser bales, as well as bales wrapped in black plastic and those treated with preservative produced higher quality forage. Dense bales had lowest dry matter (DM) and pH and the most lactic acid. Bales with <35% DM had the highest lactic acid content and the lowest pH. June 2005 harvest had lowest DM and pH, with the densest bales, and had the highest concentration of lactic acid, VFAs, and ammonia (NH_3-N). Ammonia levels declined when moisture content decreased.

Preserving and storing an adequate, nutritionally suitable winter feed supply is an essential part of livestock production. With feed costs making up a major portion of total livestock industry expenses, it is essential that the most efficient and effective method be used. Large round bale silage (LRBS) offers the opportunity of consistently putting up high quality feed with a minimum of harvesting losses despite weather. Timely harvesting will minimize losses resulting in a high quality feed. The ensiling process itself does not affect the quality of the feed (Macaulay, 2003b).

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A fermentation analysis determines the amounts of each important volatile fatty acid (acetic, propionic, and butyric), as well as lactic acid produced during the ensiling process. Normally lactic acid is the predominate acid in silages, and is usually responsible for decreasing pH levels (Kung and Shaver, 2001; Zimmerman, 2002; Macaulay, 2003a). Under normal conditions, acetic acid producing bacteria are predominant during the aerobic phase that occurs during the first 2-3 days of ensiling. If successful, they will drive the pH down and create a favorable anaerobic environment for the lactic acid bacteria that finalize the fermentation process over the next 2-3 weeks (Coblentz, 2005). However, management factors such as baling speed, pack density, type of additive used, storage, and management during feed-out can also affect fermentation analyses. In some cases, fermentation analyses can qualitatively explain poor silage nutritive value or low intakes, but they cannot be used to balance diets for livestock. Thus, they should always be used in conjunction with other standard chemical analyses (i.e. acid detergent fiber, neutral detergent fiber, crude protein, lignin, and digestible energy) (Kung and Shaver, 2001).

Few controlled studies have been undertaken to characterize fermentation of forage ensiled as LRBS. The work of Nicholson et al. (1991) identified an opportunity to improve utilization of long fiber silage through improvements in ensiling of large round bales. González and Rodríguez (2003) reported LRBS in the tropics generally results in poor fermentation, and is susceptible to aerobic deterioration with low nutritive value. Moshtaghi and Wittenberg (2000) found the process of fermentation in LRBS is longer than that typically reported for chopped silage. The basic fermentation conditions (i.e.,

low pH and anaerobic condition) are difficult to achieve in LRBS because the forage is not chopped prior to baling resulting in slow oxygen removal and a restricted release of nutrients necessary for acid producing bacteria (Moshtaghi and Wittenberg, 2000; Macaulay, 2003a; Jones et al., 2004).

The key to good LRBS is the exclusion of oxygen quickly and completely. This indicates starting with a very compact bale to reduce air pockets. Tight bales are made by reducing the tractor speed and picking up forage directly from the windrow that hasn't been raked. The compaction provided by high density balers limits the amount of oxygen in the bales. The conditions create an anaerobic state, which can limit mold growth (Macaulay, 2003a).

Sealing the bales with plastic within a few hours of baling will prevent secondary air movement into the bales (Macaulay, 2003a). Moshtaghi and Wittenberg (2000) found that delaying bale wrapping time to the next day results in forage temperature, ADIN, NH_3 and pH higher than observed for 2 hour and 10 hour delayed bale wrapping. González and Rodríguez (2003) indicated plastic wrap of bales deteriorated after long periods of storage, promoting secondary fermentation in the aerobic phase. Henning et al. (2001) reported unprepared holes or having too few layers of stretch wrap plastic can lead to oxygen infiltration of the bales. The exact effect of plastic color on fermentation is unknown. A study by Dow Chemical Company (2004) found use of black plastic wrap had decreased because lighter color plastic wrap keeps the near center (NC) bale temperatures lower, minimizing nutrient loss. However Dow Chemical Company (2005) reports black plastic wrap is the most popular.

Ensiling bales at 45-55% moisture provides adequate moisture for fermentation. Forages baled at lower moisture levels may have minimal fermentation, resulting in higher pH values (Macaulay, 2003a). Nicholson et al. (1991) found that alfalfa-grass forage baled at 39% DM had less desirable fermentation compared to similar forage chopped and compacted in a plastic tube. Fermentation is most affected by the moisture content at wrapping, not at baling. Any delay between baling and wrapping increases the exposure to oxygen and the risk of unfavorable fermentation (Jones et al., 2004). A moisture error in either direction (either too wet or too dry) can lead to a poor fermentation with the resulting poor quality feed. Zimmerman (2002) lists the four keys to good quality LRBS as: 1) harvest at the correct moisture; 2) use of a good quality inoculant and/or preservative; 3) baling slowly enough to have a tightly packed bale; and 4) wrapping the bales as soon as possible, 4-8 hours given Southcentral Alaska diurnal temperatures (Moshataghi and Wittenberg, 2000).

Propionic acid can be produced in the silage by fermentation of sugars and/or lactic acid by propionic acid producing bacteria and/or as a co-product in the conversion of lactic acid to acetic acid by *Lactobacillus bunhner* (Charley, 2006). Propionic acid reduces molding, heating, and aerobic deterioration (Kung, 2003), which is most important in surface layers (Kunkle et al., 2006). Chemical additives containing propionic acid are more effective than acetic or citric acids at increasing the concentration of propionic acid in silages (Kung and Shaver, 2001; Zimmerman, 2002). According to Seglar (2003), the low levels of propionic acid produced during fermentation assist in maintaining aerobic stability. The antimycotic effect of propionic

acid is enhanced as pH declines, making it an ideal candidate for improving the aerobic stability (Kung, 2003). The aerobic stability of LRBS during the winter months, when most of the LRBS is fed remains unclear (Rhein et al., 2005). Aerobic inhibitors suppress the growth of yeast, molds, and aerobic bacteria. Aerobic inhibitors include propionic acid and anhydrous ammonia. Benefits are most likely in excessively wilted forages, which are more likely to have heat-damaged protein, storage losses, molding, and aerobic deterioration at feed out. Acids reduce pH of the forage at the time of application. Buffered acid products, such as ammonium propionate, are more commonly used (Shaver, 2002).

Heat is essential to successful silage fermentation, but too high a temperature reduces forage quality, while too low a temperature does not favor proper development of fermentative microorganisms. Weinberg et al. (2001) and Rodríguez et al. (1998) demonstrated that higher temperatures promote microbial activities and negatively affect the fermentation process and aerobic stability. The rate of acidification is greater when silage temperatures are higher and the onset of fermentation is earlier. Higher temperatures encourage the growth of undesirable clostridia that result in increased butyric acid and NH_3-N formation, which is detrimental to quality. Macaulay (2004) indicates temperatures in the 15°C to 25°C range allows growth of the more important lactic acid producing species of bacteria while inhibiting the undesirable clostridial species. Ensiling conditions are not ideal during the fall (low temperatures and low numbers of ensiling bacteria), and fall LRBS should be fed first during the winter (Henning et al., 2001). McDonald et al. (1996) and Weinberg et al. (2001) found that in

most grass silages which were warmed between 37°C and 42°C, less lactic acid was produced and the pH remained high compared with silages fermented less than 28°C.

The DM content of the forage can also have major effects on the ensiling process via several different mechanisms. Dry forages do not pack well and thus it is difficult to exclude all of the air forage mass. As the DM content increases, growth of lactic acid bacteria is curtailed and the rate and extent of fermentation is reduced (Hall, 1994; Kung, 2000). Undesirable bacteria called clostridia tend to thrive in wet LRBS and can result in excessive protein degradation, DM loss, and production of toxins (Kung, 2000). Bales with high moisture content are more likely to freeze or have more effluent that collects at the bottom of the silage bags. These problems are apt to occur as moisture levels increase above 50% and during extremely cold winters (Sullivan and McKinlay, 1998). Where weather permits, wilting forage above 30-35% DM prior to ensiling can reduce the incidence of clostridia because these organisms are not very osmotolerant, they do not thrive in dry conditions (Kung, 2000).

The aim of this two-year study was to examine methods of bale compaction, the color of plastic wrap, and use of a preservative to determine, measure, and assess the effects these treatments have on the fermentation process and the nutritional value of the LRBS. Fermentation analysis measured DM; lactic acid; three volatile fatty acids (VFAs), acetic, propionic, and butyric acids; pH; and ammonia (NH_3), in LRBS. These production techniques could lead to improved quality and marketability of Southcentral Alaskan LRBS.

MATERIALS AND METHODS

Site Description

The study area consisted of four hay fields, each between 15-25 hectares in size, at the University of Alaska Fairbanks (UAF) Matanuska Experiment Farm (61°33′57″ N lat; 149°14′39″ W long), 16 km southwest of Palmer and 56 km northeast of Anchorage, Alaska. Fields 1, 2 and 3 were cut and baled once in 2004. Fields 1, 2 and 4 were cut and baled twice in 2005. Field 3 was not available for harvest in 2005. Air dried hay was also baled from each field, except for the September 2005 cutting when inclement weather prevented drying of the forage to acceptable moisture content for hay.

Field History

The fields were burned on 12 and 13 April 2004, and 24 March 2005. Approximately two weeks after burning, approximately 89 kg of phosphate (P_2O_5), 106 kg of ammonium sulfate ($(NH_4)_2SO_4$), 136 kg of urea, 77 kg of potash (K_2O) and 17 kg of lime filler per hectare was broadcast. Approximately two weeks after the first cutting, fields were fertilized with 185 kg ha^{-1} of urea (84 kg N ha^{-1}). Harvests dates were weather dependent, to ensure sufficient time for forage to reach appropriate moisture content prior to baling. The first cutting occurred 9 June 2004 at which time the plant stage for Fields 1 and 2 was mid-vegetative, and for Field 3 was boot stage. Above normal temperatures and inadequate precipitation prevented sufficient regrowth for a second harvest in 2004 (Benz et al., 2005). The first cutting for 2005 was 1 June 2005, at which plant stage was mid-vegetative for Fields 1, 2, and 4. The second 2005 cutting was delayed to 19 September 2005 due to above normal precipitation, at which plant stage was mature.

Experimental Design

This study is a two-level factorial experiment for three treatments. Each of the fields received a combination of the three treatments: compaction level (loose or tight), color of plastic wrap (black or white), and a preservative (with or without), resulting in eight LRBS from each field (24 bales each harvest), for all three cuttings (total of 72 LRBS). One hay bale was also harvested from each field, except during the September 2005 harvest (6 total hay bales). Hay bales were analyzed and compared to other hay bales with similar climatic conditions as found in Southcentral Alaska.

Harvest Equipment

Grass swards were cut with a mower conditioner set to place wide windrows on the stubble. These windrows were tossed and raked with an H&S® (H&S Manufacturing Co., Inc., Marshfield, WI) bifold rake with seven wheels and a Tonutti® Model V1-2 (Tonutti USA, Memphis, TN) with eight wheels after 24 hours wilting. Before baling, grass was tested for moisture content via microwave drying (Staples, 1998) for 2004 harvest. A vortex forage and biomass sample dryer (Buckmaster, 2005) was used to test moisture content prior to baling for both 2005 harvests. A preservative, Baler's Choice®, (The Profitable Farming Co. Ltd., Devon, UK). Buffered Acid (75% ammonium salt of propionic acid, propionic acid, citric acid and surfactants; 25% deionized water, T-DET DD-5) was added at 107 kg ha^{-1} during baling process with a Harvest TEC® Model 441 (Harvest TEC, Hudson, WI), 25 gallon preservative applicator sprayer.

Thirty six tightly compacted (approximately 500 kg m^{-3}) bales were baled with a Vermeer® Model 504 L-series (Vermeer Manufacturing Co., Pella, IA) baler, and 36

loose compacted (approximately 450 kg m^{-3}) bales and the 6 hay bales were baled with an New Holland Model 848 (Pioneer Equipment Inc., Palmer, AK) baler. The bales in our study were transported (approximately 2 km) to a storage area, 3-6 hours after baling for the June 2004 and September 2005 harvests and 24 hours after baling for the June 2005 cutting. LRBS was wrapped in plastic 5-10 hours after baling for the June 2004 and September 2005 harvests, and 25-32 hours after baling for June 2005 harvest. The June 2004 hay bales were baled 5 days after cut (9 June 2004) and the June 2005 bales were baled 7 days after cut (2 June 2005).

The LRBS was weighed on a Paul® Model 310-3000 (WW Paul Scales, Duncan, OK) livestock scale and then wrapped in white or black plastic. Bales were wrapped with a Vermeer® Model SW2500 (Vermeer Manufacturing Co., Pella, IA) wrapper. Thirty-six bales were wrapped with two layers of 2-ply AEP Black (B) AB-30100M Sunfilm® (Wheat-Belt Industries, Balzac, Alberta, Canada) Silage Wrap (750mm x 1500m x 1 mil). The other 36 bales were wrapped with two layers of 2-ply AEP White (W) RT-30100 Sunfilm® Silage Wrap (750mm x 1500m x 1 mil). Bale height and diameter were measured to calculate density.

Bale Temperature Measurement

We inserted Optic Stowaway® (Onset Computer Corp., Pocasset, MA) self-recording thermistors, with 8k of memory, into bales to monitor internal temperature near the center of the bale. Core holes were drilled at a right angle to outside circumference of bales with a 56 cm coring probe. Thermistors were inserted 56 cm into cored holes, near center (NC) and 12 cm below surface (BS) edge of bale. Temperature measurements were

recorded every ½ hour for 168 days (24 weeks). To record plastic surface temperature Onset Computer Corporation, Hobo® (Onset Computer Corp., Pocasset, MA) outdoor/industrial 4-channel thermistors leads were inserted between ply on selected white and black plastic bales. Four tripods containing thermistors were set around the bales to record ambient temperature every ½ hour for 168 days (24 weeks).

Sampling Method

Before harvest, 10 stratified random (encompassing all grass types, heights, and density for an accurate representation of the fields) plots from each field, 0.6 m x 0.6 m, were clipped, dried and analyzed for fiber sequential analysis, CP, DE, and ADIN, just prior to cutting and baling. The plots represent time zero for core sample analysis.

Samples were cored from LRBS at 2, 4, 12 and 24 week intervals after baling. The heavy-ply plastic encasing bales required the cutting of a small hole in the side of the bale, and coring with a 56 cm long probe inserted at a right angle to the outside circumference of the bales. Two samples were taken from each bale. Argon, an inert gas, was used to displace the air that entered the bale during coring. The holes in the bag were taped shut immediately after samples were withdrawn, reducing potential damage to the contents. Each sample was thoroughly mixed and placed in a plastic bag, placed in a cooler, packed in ice, and then transferred to a freezer.

Chemical Analysis

Sample tissue was mixed in a blender with deionized water, and then vacuum filtered through 2 micron filter. An Orion® ROSS® combination pH electrode (Model 815600, Thermo Fisher Scientific Inc., Waltham, MA) was placed in a blended, filtered aqueous

solution to measure LRBS pH. Ammonia was determined by the AOAC 920.03 method, using Kjeltec™ system 1002 (Foss Tecator, Sweden).

Samples were sent to Dairyland Laboratories, Inc.® for VFA profile analysis via HPLC using a BioRad® Aminex Ion Exclusion HPX-87H (300x7.8mm) column, at 42°C, mobile phase 0.015N H_2SO_4 plus 0.25 mM EDTA (acid free) at 0.6 ml min^{-1} flow rate, and 220 nm UV detection.

Statistical Analysis

Analysis of variance (ANOVA) and general linear model (GLM) (SAS Institute Inc., 2004) was used to test for significance. The highest level of interaction used as the error term for all main effects and lower order interactions. Differences were considered to be statistically significant at $P<0.10$. Results were presented as treatment means or least squares means. Differences among treatment means were presented as least significant differences with ANOVA models and as Tukey honest significant differences with GLM.

RESULTS AND DISCUSSION

Compaction

The tighter compact bales had significantly higher concentrations of propionic acid (Table 3-1). The higher density bales (Table 3-2) had significantly ($p<0.001$) lower DM (less than 30%) and pH (4.47). In general, the higher the DM content in the crop, the higher the pH will be when anaerobic stability is reached (Macaulay, 2004). The dense, wet bales also had significantly ($p<0.001$) higher levels of lactic acid (1.9%). Lactic acid is a stronger acid than acetic, propionic, and butyric acids, and therefore is usually

responsible for most of the drop in silage pH (Kung and Shaver, 2001). Lactic acid content did not reach the desirable level (3-14 % DM) (Van Saun, 2000; Kung and Shaver, 2001; Zimmerman, 2002; Macaulay, 2003a), indicating a poor fermentation (McCullough, 1984; González and Rodríguez, 2003). Furthermore, fermentations that produce more lactic acid result in the lowest losses of DM and energy from the crop during storage. Some common reasons for low lactic acid content include (Kung and Shaver, 2001): 1) Restricted fermentation due to high DM content; 2) Sample taken after considerable aerobic exposure that has degraded lactic acid; 3) Silages high in butyric acid (clostridial silages); and 4) Restricted fermentation due to cold weather.

For both 2005 harvests propionic acid was significantly less in the less compact bales (Table 3-3). The wet, dense bales also had significantly higher levels of propionic ($p<0.05$) and butyric ($p<0.10$) than drier, less compact bales. High butyric acid levels can be caused by ensiling a forage too wet (<30% DM) (Zimmerman, 2002). Acetic acid was significantly less in the loosely compact bales than the tighter bales in June 2004 harvest (Table 3-3). The butyric acid was significantly higher in less compact bales than the tight bales in June 2005 harvest. Ensiled bales containing high levels of butyric acid are usually low in energy and have undergone extensive protein degradation resulting in large increases in the soluble protein fraction (NH_3-N, nitrate, nitrite, free amino acids, amines, amides, and peptides) and losses of dry matter (Jones et al., 2004; Charley 2006). The wet, dense bales also had significantly higher ($p<0.001$) levels of NH_3-N (14%). High levels of NH_3-N (>12-15% of crude protein) can indicate that extensive protein

degradation has occurred. High NH_3-N concentrations can occur in LRBS that has been stored too wet (Zimmerman, 2002).

Plastic Wrap Color

Most differences between the colors of plastic were not significant. Overall, and for the June 2004 harvest, the black-wrapped bales had significantly lower acetic acid concentrations than the white bales (Tables 3-1 and 3-4). Bales in black plastic had a significantly ($p<0.10$) higher concentrations of butyric acid than the bales in white for the June 2005 harvest. The June 2005 harvest had significantly lower DM than the June 2004 and September 2005 harvests. High butyric acid levels can result from Clostridial fermentation when forages are ensiled too wet (Zimmerman, 2002). Higher levels of butyric acid in the black bales may be caused by higher temperatures increasing the permeability of the plastic wrap, thereby enabling oxygen to enter the bale and leading to a more variable fermentation. The black plastic wrapped bales had significantly ($p<0.001$) higher temperatures during first 21 days of fermentation, and the remaining days of bale storage (Figure 3-1).

Plastic wrap deteriorates after long periods of storage, which promotes secondary silage fermentation in the aerobic phase. The storage of round bales under direct sunlight could be a contributing cause of deteriorated silage during fermentative process, aerobic exposure, and animal utilization (González and Rodríguez, 2003). Vough and Glick (1993) believe that this deterioration is caused by the movement of humidity through the bale; the water evaporates during the day, and condenses on the top and external surfaces at night. Wrapping bales with 6 mils of plastic wrap instead of 4 mils could make a

better oxygen barrier. Stackyard (2005), at ADAS Pwllpeiran Research Centre, Wales found bales wrapped in green film had a significantly higher ratio of lactic to acetic acid than those wrapped in black plastic film. This may have been due to higher temperatures causing increased permeability of the black wrap thereby enabling oxygen to pass into the bale converting some of the lactic acid to undesirable acetic acid.

All of our bales had less acetic acid than usually found as a fermentation end product. However, we found the bales wrapped in white plastic had significantly ($p<0.05$) higher percentages of acetic acid (0.29) than the black-wrapped bales (0.18). Acetic acid is often produced if lactic acid production is not rapid enough to inhibit acetic acid production by bacteria. High levels (>3%) suggest inefficient LRBS fermentation. High acetic acid silage can be due to 1) wet silages (<25% DM), 2) prolonged fermentations; 3) loose packing, and 4) silages treated with NH_3-N, where fermentation is slowed by NH_3-N (Kung and Shaver, 2001; Zimmerman, 2002).

Several factors affect the fermentation process: the amount of air, the compactness of material, solar radiation of containment, and the season. An increase in temperature is usually prompt and rapid, with the maximum being reached within one or two weeks. Coupled with the rise in temperature is an increase in acidity. The maximum acidity is normally reached within 14 days, often before (Bushnell and Hunter, 1916). The temperatures recorded during the ensiling process are indicative of different types of fermentations occurring. In our study, bales wrapped in black plastic (June 2004 and 2005) and bales in white plastic (June 2004, only) had prolonged fermentation as evidenced by the temperature data. According to Berlodo (2006) very wet silages

experience prolonged fermentation and high acetic acid concentrations, which was the case for our June 2005 harvests. The June 2005 black-wrapped bales had a peak NC temperature on day 17 (22.79°C), then declined until day 23 (21.75°C). They then began to rise again and had a final peak on day 42 (24.76°C). The June 2005 bales in white plastic also had a fluctuating pattern with a NC temperature peak on day 7 (19.61°C), then declining to (18.79°C) on day 13. They then reached to the highest peak 20.24°C on day 42. The June 2005 harvests had higher levels of acetic acid (0.26) and the lowest DM (27.02) percentages. Acetic acid is needed for stable feeding characteristics, but prolonged fermentation depletes silage energy value and reduces dry matter intake (Beck, 2001; Summer, 2002).

The highest NC bale temperature should occur on the second day of fermentation (Bates, 1998; Schroeder, 2006). Ensiling temperature generally is 7°C degrees higher than ambient (Schroeder, 2006). The ambient temperature was consistently lower than the NC, BS, and surface temperatures (Figure 3-1). The NC of the June black-wrapped bales remained 7°C above ambient temperature throughout the ensiling process. However, the June white-wrapped bales had a 7°C or greater temperature difference between ambient and NC after day 14, as did all the September bales.

The September harvest was the only harvest which followed the cited bale NC temperature pattern indicting good fermentation. During fermentation, peak temperatures occurred on 4th day for black-wrapped bales, and the 3rd day for white-wrapped bales. The temperatures recorded during the ensiling process of the September harvest are indicative of complete and efficient fermentation.

One interesting discovery in the June bales occurred on day 118 of storage when the NC temperature of the June bales wrapped in white plastic (12.37°C) exceeded the NC temperature of the bales in black plastic (12.20°C). The June bales wrapped in white plastic continued to have higher NC temperatures than the black-wrapped bales through the end of the 168 day experiment.

Preservative

Bales sprayed with the buffered propionic acid preservative had a significantly ($p<0.05$) lower pH than bales which were not sprayed (Tables 3-1 and 3-5). The application of the preservative appears to have helped drive the pH down indicating more stable, efficient fermentation occurring in those bales (Kunkle et al., 2006). The best single indicator of the nutritive value of high moisture silage is pH. In general the lower the pH the better, since it indicates that a lactic acid type of fermentation has occurred (Macaulay, 2003a). Bales with preservative had significantly ($p<0.05$) higher NH_3-N levels then those bales without preservative. The higher level of NH_3-N in the bales with the preservative is hard to explain. High levels of NH_3-N usually show that there has been excessive protein degradation caused either by prolonged wilting or microbial activity. One would expect to see higher levels of butyric acid with the higher NH_3-N levels, which was not the case here.

Propionic acid reduces molding, heating, and aerobic deterioration, which is more important in surface layers (Kunkle et al., 2006). Propionic acid-based additives have been used to inhibit yeasts that assimilate lactic acid when forages are exposed to air and thus, they improve aerobic stability (Kung et al., 2004). Yeasts and molds are considered

to be the primary cause of aerobic deterioration in LRBS (Summer, 2002). Mold prefers moisture levels greater than 12%, temperatures above -5°C, at least 0.5% oxygen, and moderate pH. Ensiled forage usually meets those temperature and moisture requirements; therefore, eliminating oxygen is the key to restricting mold growth in LRBS (Jones et al., 2004). Each of our core samples offered air an opportunity to infiltrate the bales even though argon was used to displace the oxygen.

If LRBS has not properly fermented or contains high populations of yeast and/or mold, oxygen entering the bale will quickly deteriorate the LRBS. According to Berlodo (2006), dry forages do not support either good or harmful fermentation, but may enhance mold growth and lead to an unstable forage mass with yeast problems (Hall, 1994). The June 2004 harvest had the greatest DM (36.57%), and more molds were observed and noted on these bales, than on the bales from June 2005 and September 2005 harvests. The acids produced by fermentation are volatile and thus may migrate from the bale if air enters, or may also be leached with moisture migration. This leaves high pH areas where molds may establish. Molds can produce toxins that cause feed refusal, vomiting, and estrogen production in livestock (Sullivan and McKinlay, 1998; Van Saun, 2000). *Fusarium* L. (filamentous fungi) grows at 4-16°C; but *Aspergillus* L. and penicillin grow at 18-35°C. As ambient temperatures rise, the temperature of the material will rise into these ranges (Sullivan and McKinlay, 1998), which we observed in many of the 2004 bales, some in the June 2005 harvest, and few in the September bales.

The June 2005 bales had higher moisture content than the other two harvests. These bales, with the preservative applied, had fewer molds on them than the June 2005 bales

without the preservative. Fewer of the September preservative bales showed mold compared to the bales without a preservative, which may be attributed to the lower temperatures of the bales (Figure 3-2). Vermeer® (2001), manufacturer of plastic wrapper, provides a checklist to reduce mold growth which includes: using 8 mils of plastic wrap, dense bales, wrapping within 4 hours, harvesting at proper maturity and moisture content, verifying plastic is properly stretched and sealed. Undersander et al. (2003) found that when bales were wrapped with six mils or more of plastic they had only a little white mold on the exterior of the bales. Our bales were wrapped in 4 mils of plastic, and we found some of the mold on our bales was so extensive after 168 days that the bales were discarded as unfit for animal consumption. However, other bales looked and smelled good. Since mold detection was not part of this experiment, no mold or yeasts counts were conducted nor statistical analysis preformed. Further study in this area is needed.

CONCLUSION

Fermentation analysis provides a look back at what happened during fermentation of the forage. With the information in hand, producers can learn to improve LRBS production and make better feeding decisions (Roenfeldt, 1999). Our three treatments: compaction, plastic color wrap, and preservative, had less than optimal concentrations of lactic, acetic and butyric acids but had optimal concentrations of propionic acid and NH_3-N range. The use of a preservative assisted in lowering pH level. Fermentation occurred in the recommended temperature range of 15-25°C (Macaulay 2004) for all three harvests. Various fermentation types occurred during this experiment, producing some

high quality LRBS as well as some less than favorable bales. Overall the densest bales, wrapped in black plastic with a preservative had highest nutritional value. The bales harvested in June, wrapped in black plastic had prolonged fermentation; however the cause for the prolonged fermentation is not clear. The dry 2004 harvest led to unstable fermentation products allowing considerable amounts of mold with high internal bale temperatures which often indicate restricted fermentation caused by high DM content. The September harvest had the ideal fermentation, however the maturity of grass when cut decreased the overall quality (Lussier and Harris, unpublished).

This two year experiment encountered what hay producers in Southcentral Alaska encounter on a regular basis, where weather can prohibit harvesting forage at its optimum. Based on this data, we recommend Southcentral Alaska farmers put up LRBS instead of hay, because decreased curing time reduces the risk of rained on hay. The same baler used for harvesting hay can be used for harvesting LRBS, and decreased raking results in fewer lost leaves, so LRBS will be slightly higher in quality and more palatable than dry hay.

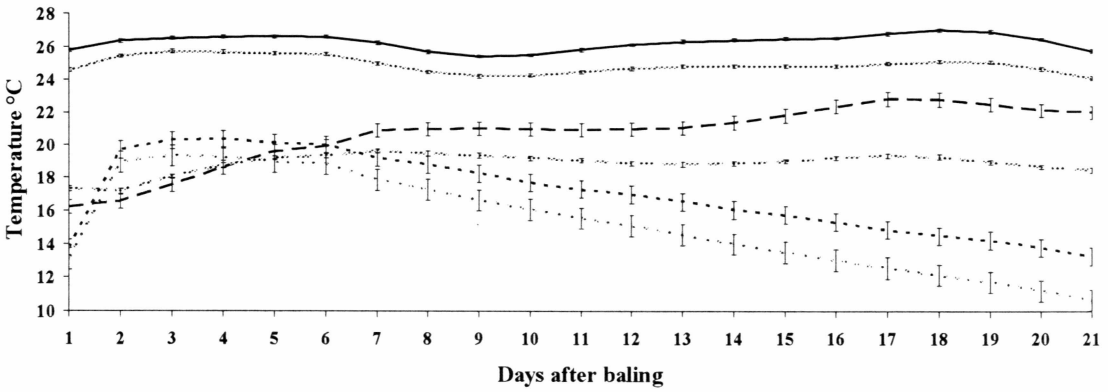

Figure 3-1: Temperatures of large round bale silage near the center (56 cm) of bales wrapped in black and white plastic for first 21 days (expected fermentation duration) after baling. Specific harvest and bale color wrap are represented as follows: heavy solid line, June 2004 bales wrapped in black plastic; light solid line, June 2004 bales wrapped in white plastic; heavy long dash line, June 2005 bales wrapped in black plastic; light long dash line, June 2005 bales wrapped in white plastic; heavy short dash line, September 2005 bales wrapped in black plastic; light short dash line, September 2005 bales wrapped in white plastic. Bales wrapped in black plastic had warmer internal temperatures ($P > 0.0001$) than bales wrapped in white plastic. The curve June 2004 bales (wrapped in black and white plastic), and the June 2005 bales wrapped in black plastic lines indicate prolonged fermentation. Near center bale temperatures were at least 7°C higher than ambient temperatures and ranged between 15-25°C, indicating ideal environment for acid producing bacteria to ensure a good fermentation (Macaulay 2004).

Table 3-1: Fermentation profile characteristics of large round bale silage (LRBS) with three treatments consisting of bale compaction, plastic wrap color, and preservative after 168 d.†

Treatment	df	Lactic	Acetic	Propionic	Butyric	pH	%NH_3	Density
		%DM						kg m^{-3}
Treatment means‡								
Compaction								
Loose		1.0	0.20ab§	0.03b	0.04	5.1ab	11ab	441b
Tight		1.0	0.27a	0.19a	0.02	5.0b	12a	513a
Wrap Color								
Black		1.1	0.18b	0.10a	0.05	5.0b	11ab	484ab
White		1.0	0.29a	0.12a	<0.01	5.1ab	11ab	467b
Preservative								
Yes		1.0	0.22ab	0.21a	0.02	4.9b	12a	477ab
No		1.0	0.24ab	0.03b	0.04	5.2a	10b	476ab
SEM¶		0.95	0.07	0.05	0.02	0.5	20	17
				GLM				
Source of Variation								
Compaction (C)	1	NS#	NS	***	NS	NS	NS	***
Wrap Color (W)	1	NS	*	NS	††	NS	NS	††
Preservative (P)	1	NS	NS	***	NS	*	***	NS
C x W	3	NS	††	**	††	NS	NS	***
C x P	3	NS	††	***	NS	*	***	***
W x P	3	NS	NS	***	NS	**	**	NS
C x W x P	5	NS	††	***	NS	*	***	***

* Significant at the 0.05 probability level.
** Significant at the 0.01 probability level.
*** Significant at the 0.001 probability level.
† NH_3, ammonia percentage of crude protein; DM, dry matter.
‡ Overall mean of treatments for LRBS.
§ Within columns, means followed by the same letter are not significantly different according to Tukey HSD (0.10).
¶ Standard error of the treatment mean.
# Nonsignificant effect ($P>0.10$).
†† Significant at the 0.10 probability level.

Table 3-2: Fermentation profile characteristics of large round bale silage (LRBS) at four different moisture levels for 168 d.†

Variable	df	Lactic	Acetic	Propionic	Butyric	pH	%NH_3	Density
		%DM						kg m^{-3}
Dry matter means‡								
<30%		1.9a§	0.26	0.18a	0.07	4.5c	14a	515a
30-35%		0.68b	0.23	0.08b	<0.01	5.2ab	10b	473b
36-40%		0.3c	0.20	0.06b	<0.01	5.4a	10b	438b
>40%		0.2c	0.27	0.04b	<0.01	5.6a	7c	429b
SEM¶		0.34	0.07	0.04	0.02	0.3	14	10
				GLM				
Source of Variation								
Dry matter (DM)	3	***	NS#	*	NS	***	***	***
Harvest (H)	2	***	NS	***	NS	***	***	***
DM x H	9	***	††	***	NS	***	***	***

* Significant at the 0.05 probability level.
*** Significant at the 0.001 probability level.
† NH_3, ammonia percentage of crude protein; DM, dry matter.
‡ Dry matter means.
§ Within columns, means followed by the same letter are not significantly different according to Tukey HSD (0.10).
¶ Standard error of the dry matter mean.
# Nonsignificant effect (P>0.10).
†† Significant at the 0.10 probability level.

Table 3-3: Fermentation characteristics of large round bale silage (LRBS) tightly and loosely compacted after 168 d.†

Compaction	df	Lactic	Acetic	Propionic	Butyric	pH	%NH_3	%DM	Density
		%DM							kg m^{-3}
Harvest‡									
Compaction means§									
1-Loose		0.4bc¶	0.1b	<0.01d	<0.01c	5.5a	12b	37a	467b
1-Tight		0.3c	0.3a	<0.01d	<0.01c	5.7a	12b	36a	537a
2-Loose		2.0a	0.2ab	0.06c	0.10a	4.5c	14a	27b	490ab
2-Tight		1.9a	0.3a	0.40a	<0.03b	4.4c	14a	28b	554a
3-Loose		0.5b	0.3a	0.03c	<0.01c	5.3ab	7c	36a	362c
3-Tight		0.6b	0.2ab	0.12b	<0.01c	5.0b	8c	36a	444b
SEM#		0.36	0.08	0.04	0.02	0.3	15	9	6
				ANOVA					
Source of Variation									
Harvest (H)	2	***	NS††	***	‡‡	***	***	***	***
Compaction (C)	1	NS	NS	***	NS	NS	NS	NS	***
H x C	5	***	‡‡	***	‡‡	***	***	***	***

* Significant at the 0.05 probability level.
*** Significant at the 0.001 probability level.
† NH_3, ammonia percentage of crude protein; DM, dry matter.
‡ Harvests: 1, June 2004; 2, June 2005; 3, September 2005.
§ Loose and tight compaction means.
¶ Within columns, means followed by the same letter are not significantly different according to LSD (0.10).
# Standard error of the compaction mean.
†† Nonsignificant effect (P>0.10).
‡‡ Significant at the 0.10 probability level.

Table 3-4: Fermentation characteristics of large round bale silage (LRBS) wrapped in black and white plastic after 168 d.†

Wrap Color	df	Lactic	Acetic	Propionic	Butyric	pH	%NH_3	%DM	Density
		%DM							kg m^{-3}
Harvest‡									
Wrap Color means§									
1-Black		0.3c¶	0.1b	<0.01c	<0.01b	5.5a	11c	37a	507b
1-White		0.3c	0.3a	<0.01c	<0.01b	5.7a	12bc	36a	497bc
2-Black		2.1a	0.3a	0.21a	0.13a	4.4c	14a	27b	532a
2-White		1.9a	0.2ab	0.25a	<0.01b	4.5c	13ab	27b	513b
3-Black		0.6b	0.2ab	0.07b	<0.01b	5.2b	8d	36a	413d
3-White		0.5b	0.3a	0.08b	<0.01b	5.1b	8d	36a	394e
SEM#		0.36	0.07	0.06	0.08	0.30	15.7	9.3	10.8
				ANOVA					
Source of Variation									
Harvest (H)	2	***	NS††	***	‡‡	***	***	***	***
Wrap Color (W)	1	NS	*	NS	‡‡	NS	NS	NS	‡‡
H x W	5	***	#	***	**	***	***	***	***

* Significant at the 0.05 probability level.
** Significant at the 0.01 probability level.
*** Significant at the 0.001 probability level.
† NH_3, ammonia percentage of crude protein; DM, dry matter.
‡ Harvests: 1, June 2004; 2, June 2005; 3, September 2005.
§ Black and white plastic wrap means.
¶ Within columns, means followed by the same letter are not significantly different according to LSD (0.10).
# Standard error of the wrap color mean.
†† Nonsignificant effect (P>0.10).
‡‡ Significant at the 0.10 probability level.

Table 3-5: Fermentation characteristics of large round bale silage (LRBS) with and without preservative after 168 d.†

Preservation	df	Lactic	Acetic	Propionic	Butyric	pH	%NH_3	%DM	Density
		%DM							kg m^{-3}
Harvest‡									
Preservative means§									
1-Yes		0.47c¶	0.20b	<0.01c	<0.01c	5.5a	13a	36a	502b
1-No		0.22d	0.21b	<0.01c	<0.01c	5.7a	11b	37a	502b
2-Yes		1.80a	0.15c	0.46a	0.04b	4.4b	14a	28b	518a
2-No		2.21a	0.36a	<0.01c	0.10a	4.4b	13a	26b	525a
3-Yes		0.61b	0.32a	0.09b	<0.01c	4.9b	9c	35a	414c
3-No		0.50bc	0.16c	0.06b	<0.01c	5.3ab	7d	36a	394d
SEM#		0.34	0.72	0.04	0.02	0.3	15	9	11
				GLM					
Source of Variation									
Harvest (H)	2	***	NS††	***	*	***	***	***	***
Preservative (P)	1	NS	NS	***	NS	**	***	NS	NS
H x P	5	***	*	***	‡‡	***	***	***	***

* Significant at the 0.05 probability level.
** Significant at the 0.01 probability level.
*** Significant at the 0.001 probability level.
† NH_3, ammonia percentage of crude protein; DM, dry matter.
‡ Harvests: 1, June 2004; 2, June 2005; 3, September 2005.
§ Forage applied with (Yes), and without (No) preservative means.
¶ Within columns, means followed by the same letter are not significantly different according to Tukey HSD (0.10).
# Standard error of the wrap color mean.
†† Nonsignificant effect (P>0.10).
‡‡ Significant at the 0.10 probability level.

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Chapter 4 Nutritional Quality of Large Round Bale Silage as Affected by Compaction, Color of Wrap, or Preservative in Southcentral Alaska

CONCLUSION

Our three treatments, compaction, plastic color wrap, and preservative, produced various types of fermentation during this experiment, producing some high quality LRBS as well as some less than optimal bales. Overall, the densest bales that were wrapped in black plastic with a preservative had the highest nutritional value. The denser bales provided higher nutritional quality, with lower NDF and ADF percentages and higher DE, as well as a greater concentration of lactic acid.

Bales wrapped in black plastic tended to be a marginally higher quality feed, with lower percentages of ADF, lignin, ADIN, acetic and propionic acids and a lower pH. The black-wrapped plastic bales had greater levels of DE, CP and lactic acid. The bales wrapped in black plastic in June had prolonged fermentation. The cause for the prolonged fermentation is not clear.

The use of the buffered propionic acid preservative did not have an overall significant affect on the nutritional value of the LRBS. However, significantly low pH indicates a complete fermentation occurred in bales with preservative. The dry 2004 harvest led to unstable fermentation products causing considerable amounts of mold with high internal bale temperatures which often indicates a restricted fermentation caused by high DM content. The September harvest had ideal fermentation, however the maturity of grass when cut, decreased the overall quality.

This two year experiment encountered what hay producers in Southcentral Alaska encounter on a regular basis, where weather can prohibit harvesting forage at its optimum. We recommend Southcentral Alaska farmers put up LRBS instead of hay, because decreased curing time reduces the risk of rained on hay. The same baler used for harvesting hay can be used for harvesting LRBS, and decreased raking results in fewer leaves that are lost, so LRBS will be slightly higher in quality versus dry hay, as well as higher palatability. Wrapping with at least 6 mils of plastic wrap may ensure minimal spoilage and weathering of the LRBS.