FERMENTATION CHARACTERISTICS AND NUTRITIONAL VALUE OF DIFFERENT PROPORTIONS OF ALFALFA AND WHEAT STRAW ENSILED WITH AND WITHOUT DIFFERENT ADDITIVES

by

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(ABSTRACT)

Experiments were conducted to investigate the fermentation characteristics and nutritional value of mixtures containing different proportions of alfalfa (*Medicago sativa L.*) and wheat (*Triticum aestivum L.*) straw ensiled with and without molasses, microbial inoculant and molasses + microbial inoculant. In experiment 1, chopped alfalfa harvested at 1/10 bloom and chopped wheat straw were ensiled in the following proportions (DM basis): 0:100, 25:75, 50:50, 75:25, 100:0, 0:100 (urea-treated), with 0 and 5% dry molasses, and 0 and .1% microbial inoculant (*Lactobacillus plantarum* and *Streptococcus faecium*) in a 6 x 2 x 2 completely randomized design with a factorial arrangement. Each mixture was ensiled in 3.8-liter cardboard containers double lined with polyethylene. The pH values for the ensiled mixtures of 0:100, 25:75, 50:50, 75:25 and 100:0 alfalfa:straw without additives were 4.70, 4.76, 4.65, 4.76 and 4.82, respectively. Urea treatment of the 0:100 mixture (wheat straw) increased ($P < .01$) pH to 8.84. Overall lower pH ($P < .01$) occurred when molasses was added, compared to untreated and inoculated silages. Lactic acid concentration decreased (P < .01) linearly with decreased level of alfalfa, over all additives. Molasses increased (P < .01) lactic acid concentration. Overall, water soluble carbohydrates (WSC) in pre-ensiled mixtures increased (P < .01) linearly with increases in alfalfa. The WSC decreased (P < .01) after ensiling. Microbial inoculant did not affect pH or lactic acid content in the silages. In vitro dry matter digestibility (IVDMD) increased (P < .01) linearly with level of alfalfa, and molasses increased (P < .01) IVDMD. In experiment 2, chopped alfalfa (1/10 bloom, third cutting) and wheat straw were ensiled in the following respective proportions (DM basis): 0:100, 25:75, 50:50, 75:25, 100:0, 100:0 + 5% dry molasses, and 0:100 (urea-treated) in 210-liter metal drums double lined with .08 mm polyethylene bags. Increased proportions of wheat straw to alfalfa increased (P < .01) DM content and lactic acid concentration, and decreased pH and total VFA content. The CP, Ca, P, Mg and K contents decreased (P < .01) with increases in wheat straw. Addition of molasses to alfalfa increased (P < .01) WSC and lactic acid, and decreased (P < .01) pH and total VFA. Urea treatment of wheat straw increased (P < .01) pH and acetic acid, and decreased (P < .01) lactic acid, compared to untreated wheat straw. The NDF (P < .05) and hemicellulose (P < .01) were decreased with urea treatment. Two metabolism trials were conducted, each with 21 crossbred wethers. The diets were alfalfa and wheat straw silages made in 210-liter metal drums described above. Wheat straw ensiled alone was supplemented with soybean meal because of insufficient consumption when the straw was fed alone. Linear increases

($P < .01$) in DM, OM, and CP digestibilities were observed with increased level of alfalfa. Adding molasses increased ($P < .05$) DM digestibility. A linear increase ($P < .01$) in N retention was observed with increasing alfalfa level. Ruminal NH_3-N and blood urea-N increased ($P < .01$) with increased proportion of alfalfa. Feeding urea-treated straw increased ($P < .01$) ruminal NH_3-N and blood urea-N, compared to untreated wheat straw. A palatability trial was conducted with 42 sheep fed the same diets as in the metabolism trials. Daily DM intake increased linearly ($P < .01$) with increased proportion of alfalfa. It is concluded that ensiling cereal crop residues with leguminous forage has potential in improving fermentation characteristics and nutritional value of alfalfa silage and improving the nutritional value and utilization of cereal crop residues.

DEDICATION

I dedicate this humble effort, the fruit of my thoughts and study, to my father, Iqbal Mohammad Rana, my wife, Perveen Akhtar, my daughter, Shazia Rehman Rana, and my sons, Mazhar Ali Rana, Shafiq-ur-Rehman Rana and Zia-ur-Rehman Rana for their quiet and patient support.

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CHAPTER I.

INTRODUCTION

Cereal crop residues represent a major potential feed source in the United States, Pakistan and other parts of the world. Wheat (*Triticum aestivum L.*) is the most commonly grown cereal crop for human consumption. For each ton of grain, a similar amount of residue is available. Wheat straw, like other crop residues, is low in CP, high in lignocellulosic compounds, and low in palatability and digestibility. Various chemical treatments, such as alkali, urea and ammonia have been used to improve the nutritional value of cereal straws. These chemical treatments are expensive and not readily available in developing countries. Development of a less expensive process than chemical treatments is a major concern, and ensiling of dry cereal crop residues with fresh green forages offers some possibilities (Singh et al., 1984).

Jayasuriya and Perera (1982) reported that urea can be used as a source of ammonia in treating straw, and treatment improves voluntary intake and digestibility of the straw. Treating straw with NH_3 released via the hydrolysis of urea is comparatively new. Urea is preferred over other chemicals, because it is easier to handle than anhydrous NH_3, comparatively cheap and easily available.

Leguminous green forages, such as alfalfa (*Medicago sativa L.*), also called lucerne, and berseem (*Trifolium alexandrinum L.*) are difficult to ensile because of high moisture content, low level of water soluble carbohydrates (WSC) and high buffering capacity (McDonald and

Whittenbury, 1973). Additionally, they are high in protein and minerals, which raise their ability to resist pH change (Lassiter et al., 1982).

Study of fermentation characteristics is very important, because proper preservation of crops depends upon production of sufficient quantities of acids, preferably lactic acid, which helps in lowering the pH of ensiled materials to inhibit undesirable microbial activity and catabolic processes. For silages of high-protein forages, it is important that the decrease in pH be rapid to prevent proteolysis (McDonald, 1981). The bacteria responsible for production of high quality silages are lactic acid producing. Addition of *Lactobacillus sp.* to fresh forage has been recommended to control the fermentation.

The DM concentration in the fresh green forage is not sufficient to avoid seepage and effluent losses. The DM can be increased by wilting or by addition of dry roughages, such as straws. Wilting has limitations and is not always feasible under farm conditions. Direct cut forage choppers have advantages to reduce extra field operations. The present study was designed to study the possibility of making good quality silage from leguminous forage (alfalfa) in combination with crop residue (wheat straw) with and without molasses and microbial inoculant, and to study the nutritional value and utilization of the ensiled mixtures.

CHAPTER II.

LITERATURE REVIEW

Crop Residues

Crop residues are portions of crops normally left in the field following harvesting (Ensminger et al., 1990). Crop residues from cereal grains are potential feed sources in the U.S. (Males, 1987). In U.S. cereal crop residues are the principal crop residues (Ensminger et al., 1990). Corn stover, wheat straw and soybean (*Glycine max L.*) residues account for more than 80% of the estimated 500 million tons of residues produced annually. Worldwide, more than 2.2 billion tons of crop residues are produced annually. Crop residues form the major part of livestock feed in southeast Asia and other developing countries (Jackson, 1977). Klopfenstein (1978) reported that for each kilogram of cereal grain produced an equal quantity of residue is obtained.

Nutritive Value of Crop Residues. Cereal crop residues are low in nutritive value because they are low in CP (Wanapat, 1986; Males, 1987) and high in lignocellulose fractions (Wanapat, 1986; Males, 1987). The voluntary intake and digestibility of these forages are low (Anderson, 1978; Klopfenstein, 1978; Males, 1987). It is known that diets with less than 7% CP are not readily consumed by ruminants (Trung, 1986). An inadequate supply of N retards microbial growth and thereby impedes degradation of cell wall components. The primary limitation to the intake of low quality roughage is rumen fill (Weston, 1983), high lignin content, and the manner in which lignin is bound to the digestible cellulose and hemicellulose (Klopfenstein, 1978).

Wheat straw is poor quality straw, barley straw is slightly better and oat straw appears to have higher nutritive value (Anderson, 1978).

Voluntary consumption of low-quality roughages can be increased by physical processing (Beardsley, 1964; Campling and Freer, 1966) or by chemical treatments (Horton, 1978; Klopfenstein, 1978; Horton and Steacy, 1979).

Lesoing et al. (1981b) reported that the relatively low available energy value of wheat straw has restricted use of wheat straw for gestating beef cows and finishing cattle. Its use is minimal in the diet of growing calves because the calves cannot consume enough straw to meet their energy needs. For wheat straw to be more fully utilized, its energy availability must be improved.

Treatment of Crop Residues. Physical, chemical and biological treatments have been developed to improve the nutritive value of crop residues (Klopfenstein, 1978) Four chemicals are being routinely used in experimentation with animals, NaOH, NH_4OH, $Ca(OH)_2$ and KOH (Klopfenstein, 1978). The concept of chemical treatment is based mostly on the hydrolysis of lignocellulosic bonds and the oxidation of lignin compounds.

Sodium hydroxide and anhydrous and aqueous NH_3 treatments have been investigated and are effective in improving feed intake, digestibility and performance by ruminants (Klopfenstein, 1978).

Treatment with NaOH has been effective in improving digestibility of cereal grain straws (Ololade et al., 1970; Rexen and Thomson, 1976). Lesoing et al. (1981a) reported that lambs fed NaOH and CaOH-treated wheat straw gained faster and more efficiently. Daily DM intake was more than for lambs fed untreated wheat straw. They also reported that chemical treatment of wheat straw increased DM, OM, cellulose and hemicellulose digestibilities in lambs.

Verma and Jaiswal (1981) reported that NaOH spray treatment of wheat straw increased digestibility of crude fiber, water intake and urine volume in Sahiwal steers as compared with untreated wheat straw. Similar results were reported by Rehman (1985) with NaOH-treated rice (*Oryza sativa L.*) straw.

Treatment with NaOH results in solubilization of cellulose and increased extent and rate of cellulose and hemicellulose digestion (Klopfenstein and Owen, 1981). Research data suggest that NaOH is the most effective alkali for straw treatment (Klopfenstein, 1978; Trung, 1986). It improves DM digestibility by 12 to 25 percentage units and voluntary intake (Klopfenstein, 1978). However, the treatment may result in accumulation of Na and creates difficulties in processing and handling of treated straw. Straw treatment with NaOH has not gained acceptance mainly because of high cost, in addition to hazard of handling the chemical (Klopfenstein, 1978; Trung, 1986).

Ammoniation of low quality roughages by anhydrous and aqueous NH_3 has been proposed by Sundstol et al. (1978), as it adds nonprotein nitrogen (NPN) to the ruminant diet. The most commonly used method is the anhydrous NH_3 procedure of Sundstol et al. (1978), however, the problems associated with its handling and high cost have limited its use (Sundstol and Coxworth, 1984). The other procedure is the wet method that involves addition of water to straw at the time of ammoniation with either anhydrous or aqueous ammonia (Males and Gaskins, 1982; Streeter and Horn, 1984). Recent research (Oji and Mowat, 1977; Jayasuriya and Perera, 1982; Hadjipanayiotou, 1982) has shown that urea can be used as a source of ammonia.

Jackson (1978) recommended 3.5 kg NH_3/100 kg straw and 8 wk of treatment time for winter and 4 wk in summer. He further observed that IVDMD was increased by 15 percentage units with 5 kg NH_3/100 kg of barley straw. Sundstol et al. (1978) found that the energy value of cereal straws and stovers was increased by 70 to 80% and N content of material was increased by .8 to 1.0 percentage unit with ammoniation.

Lawlor and O'Shea (1979) treated barley straw with 3.3% (w/w) anhydrous NH_3 for 56 d. The CP content of the straw increased from 3.1 to 7.6% and IVDMD increased by 15 percentage units.

Kiangi et al. (1981) studied the effect of different sources of NH_3 (anhydrous and aqueous NH_3 and urea). They reported that anhydrous NH_3 was most effective in improving the IVDMD of corn stover, anhydrous and aqueous NH_3 had similar effects on rice straw and urea was least effective but promising. Highest response in IVDMD was observed with rice straw, then wheat straw, and lastly corn stover.

Rehman (1985) fed four diets containing 25% untreated, 3.5% NH_3-treated, 4% NaOH-treated, 4% NaOH + NH_3-treated rice straw to 24 Sahiwal male calves (9 to 12 mo) and observed that both NH_3 and NaOH + NH_3 treatments improved the nutritive value of rice straw, as was reflected in increases in weight gain and improved feed efficiency. The digestibilities of DM, CP, EE and CF were increased by ammoniation, NaOH treatment and NaOH + NH_3 treatment of rice straw. No toxic effect was observed on the health of the calves fed experimental diets. The lowest feed cost per unit of weight gain was for the ammoniation treatment.

Wheat (*Triticum aestivum*) is the most commonly grown crop on a worldwide basis for human consumption. For each kilogram of grain, a similar amount of residue is available. As the demand for grain for human consumption increases, alternate energy sources, such as wheat straw, will be used in ruminant diets (Lesoing et al., 1981a).

Solaiman et al. (1979) reported an increased N content and IVDMD from treatment of wheat straw with 3.3% NH_4OH. Ammonium hydroxide treatment decreased hemicellulose and NDF fractions and increased digestibility of NDF, ADF and cellulose. Herrera-Saldana et al. (1982) treated wheat straw under ambient conditions (mean temperature 6 C for 44 d) with 5% NH_3. Ammoniation increased the CP content of wheat straw from 3.6 to 8.1%. Voluntary intake of DM, OM, and gross energy (GE) in cattle was improved by NH_3 treatment. Digestibility of DM and OM did not differ ($P < .05$) among diets, but apparent CP, ADF and GE digestibilities were increased ($P < .05$) by NH_3 treatment. Plasma urea N and rumen NH_3 concentrations were lower for cattle fed untreated wheat straw diet. They suggested that supplemental energy may be required to maximize the utilization of added N.

Birkelo et al. (1986) reported that 7% anhydrous NH_3 treatment of wheat straw, DM basis, raised the N content from .49 to 1.59% and DM intake 1.0 to 1.3% of body weight in cattle. The higher net energy value of the ammoniated wheat straw diet (1.45 vs 1.26 Kcal/g, DM) was due mainly to decreased fecal loss and slight decline in urinary loss. Schneider and Flachowsky (1990) reported increased N content of wheat straw from ammoniation, depending on NH_3 level, moisture and temperature. A maximum N value of 2.9% was reached with 4.5% NH_3, 45% moisture of the straw and temperature 20° C.

Zorilla-Rios et al. (1985) reported increased CP (9.3 vs 4.6%) and IVDMD (47.6 vs 37.3%) from ammoniation of wheat straw (35 g/kg of DM of straw). Steers fed ammoniated straw tended to have higher concentrations of ruminal NH_3-N, but no differences were found in ruminal pH. Ammoniation of low quality roughages can increase intake through chemical effects on the forage. Also, added NH_3 serves to supplement the diet with N (Zorilla-Rios et al., 1991).

The indirect method of ammoniation from hydrolysis of urea has been tested by Oji and Mowat (1977), Hadjipanayiotou (1982), and Jayasuriya and Perera (1982). This procedure is gaining popularity in developing countries (Saddullah, 1985). Urea is preferred over other chemicals, because it is easier to handle than anhydrous NH_3, comparatively cheap and farmers are familiar with it. Williams and Inness (1982) reported that the effectiveness of urea was related to the degree of urea hydrolysis and that NH_3 from urea hydrolysis increased straw degradability significantly.

Oji and Mowat (1977) reported that urea rapidly hydrolyzed to ammonia. They observed that after 48 h of treatment, 70% of the added urea was broken down to NH_3 and was completely decomposed by d 20. Henning et al. (1990) reported that 56 and 91% of the incorporated urea hyrolyzed by 4 and 14 d after baling of tall fescue (*Festuca arundinacea schreb.*) hay, respectively. Williams et al. (1984a) reported that the degree of hydrolysis was significantly affected by the concentration of moisture in the straw. When urea was applied at 7.5% level, the degree of hydrolysis (in 6 wk) was 100 and 36.5% when the straw moisture was 55 and 25%, respectively.

Ground soybeans appeared to be satisfactory source of urease (Jayasuriya and Pearce, 1983). Tetlow (1983) reported that urea added to mature perennial ryegrass hydrolyzed rapidly to NH_3 and there was no benefit from an additional supply of urease enzyme. Williams and Innes (1982) reported that urease has no significant effect on the rate of urea hydrolysis in barley straw. Williams et al. (1984b) compared the rate of hydrolysis of urea alone, urea + soybean meal, urea + soybean meal + 15 g/kg NaOH and urea + molasses and observed that rate of hydrolysis of urea was decreased by urea + soybean meal with NaOH treatment of barley straw, but increased by molasses addition, compared with straw treated with urea alone. The addition of soybean meal as source of urease had no effect.

Cloete and Kritzinger (1984) reported that temperature, moisture level and treatment period significantly affected NH_3 release from urea. The efficiency of ammoniation was accordingly affected. Ammoniation was accelerated at higher temperatures, especially at higher moisture. Comparable IVOMD values were obtained at 2-wk treatment period at 35° C and 6-wk at 24° C. In the second phase of the same study, Cloete and Kritzinger (1985) reported physical form, moisture level and treatment period significantly affected NH_3 release from urea. Ammonia release was slower in long wheat straw, compared to chopped straw. Ammoniation was accelerated at the two higher moisture levels (37.5 and 50%), compared to lower (25%) moisture level. The IVOMD of wheat straw increased substantially up to treatment period of 8 to 12 wk.

Jayasuriya and Perera (1982) reported that use of urea as a source of NH_3 in treating straw improved voluntary intake and digestibility of the straw. They treated rice straw with 0, 20, 40, 60, 80 or 100 g urea in 1 liter of water per kilogram of chopped straw, and ensiled it in polyethylene bags for periods varying from 1 to 6 wk. They found that IVDMD increased with increasing levels of urea, and ensiling beyond 3 to 4 wk had no further effect. The optimum level was 4 g urea per 100 g straw DM with an ensiling period of 3 to 4 wk.

Oji and Mowat (1977) treated corn stover with a 50% solution of urea (equal to 3% NH_3) and reported that after 48 h of treatment, 70% of the added urea was broken down to the NH_3 and was completely decomposed by d 20. Doulberg et al. (1981) reported increased intake, in vivo and in vitro DM digestibilities from urea treatment of wheat straw. They observed further that high moisture could enhance urea hydrolysis.

Hadjipanayiotou (1982) reported that maximum IVDMD was reached in 45 d post-treatment of barley straw with 4% urea. The overall increase in digestibility was 11 percentage units. Voluntary intake and crude fiber and DM digestibilities of urea-treated straw were increased when urea-treated straw was fed to wethers. Feeding urea-treated straw resulted in an increase of ruminal NH_3-N concentration without any change of ruminal pH. They observed that ammoniation using urea requires more time than direct ammoniation for maximum effect on digestibility.

Mbatya (1983) studied the effect of ensiling straw treated with urea. Barley straw was fed to two groups of lambs, either freshly prepared or after ensiling for 30 d. Ensiling the straw increased the DM intake and DM digestibility.

Ibbotson (1983) studied the effectiveness of urea as an NH_3 source. They observed that improvement in OM digestibility of barley straw was consistently higher at 40 g/kg urea, compared to 20 g/kg urea, and increased with increasing moisture. At 37° C, maximum improvement occurred at all moisture levels (20, 30 and 40%), at 4 wk post treatment. Wanapat (1986) reported that treatment with 5% urea (w/w) has great potential. By treating the rice straw with a solution containing urea at 1:1 to 1:1.2 and ensiling for 2 to 3 wk, the CP and DM digestibility increased by 5 to 7 and 10 to 12%, respectively.

Yadav and Yadav (1986) fed untreated or 4% urea-treated wheat straw with different amounts of concentrates to crossbred calves (1 yr old). They reported increased apparent digestibility of OM, DM, hemicellulose crude fiber, NDF, ADF, lignin and cellulose. Similar responses were reported with urea-treated tall fescue (*Festuca arundinacea*) hay by Henning et al. (1990).

Naseer (1990) reported that urea and NH_4OH treatment increased CP and decreased NDF and hemicellulose content of barley straw, compared to the untreated straw. The ash content of the treated and untreated barley straw was similar. Gupta et al. (1985) found that treatment with 5% urea and storage for 4 wk is an effective way of increasing the nutritive value of rice straw.

Ibrahim et al. (1986) treated rice straw with 4% urea (w/w) dissolved in water, resulting in straw to water ratios of 1:1, 1:0.3 and 1:0.1. They reported that use of a straw to water ratio of 1:0.3 was as effective as 1:1 ratio in enhancing N content and IVOMD. Increased IVOMD and N content were also reported by Jayasuriya and Pearce (1983) with urea treatment of the straw.

Dias-Da-Silva and Sundstol (1986) studied the effect of urea treatment on nutritive value of wheat straw. Treating straw by ensiling with urea raised OM digestibility and digestible OM intake, compared to untreated straw. Digestibility of cell wall constituents was enhanced by urea treatment. Urea treatment of stacked straw was less effective than urea treatment of ensiled straw. Feeding anhydrous NH_3 and urea treated straw by ensiling resulted in similar levels of DOM intake. It was concluded that urea can be an effective source of NH_3 for straw treatment by ensiling.

Yadav and Yadav (1988) conducted an experiment with untreated or urea-treated wheat or paddy straws in the diet. They reported increased concentration of total ammonial protein and NPN of strained ruminal liquor in animals fed ammoniated straws, as compared to controls. There were also significant increases in serum protein and serum-urea N and NH_3-N. They concluded that feeding of ammoniated straws increased nitrogenous constituents in rumen and blood metabolites.

Orskov et al. (1981) studied the utilization of NH_3 and urea-treated barley straw as the only feed for dairy heifers. Barley straw was treated with anhydrous NH_3 and urea at 3.5% NH_3 and was fed to Friesian heifers. The DM intake, OM digestibility and weight gain were lower for animals fed urea-treated straw than straw treated with NH_3. They concluded that nutritive value of straw was not improved by treatment with urea. Benahmed and Dulphy (1985) reported that urea gave lower NH_3 content in forages than NH_3 treatment.

Alfalfa (*Medicago sativa L.*) Forage

Alfalfa (*Medicago sativa L.*) originated in an area bounded by Asia Minor, Transcancasia, Iran and Turkmenistan (Bolton, 1962). In principal areas where it is now cultivated, the plant is known either as "alfalfa" or "lucerne" (Marble, 1989). Alfalfa is the most important cultivated forage crop in the world. It is well known as high quality forage and serves as a soil-improving crop and N source for other rotation crops.

Alfalfa is a basic forage for maximizing milk production and provides an important source of nutrients for dairy and beef cattle (Conrad and Klopfenstein, 1988). It is a superior pasture legume for many classes of livestock, because of its high yield, forage quality and wide climatic and soil adaptation. Alfalfa is an economical protein source for grazing animals, because it is independent of soil N (Van Keuren and Matches, 1988). It is an excellent source of Ca, Mg, P, and pro-vitamin A (carotene). Intake of alfalfa is usually greater than that of grasses of equal digestibility. Cattle and sheep consuming legumes grow more rapidly than ruminants consuming grass of equal energy digestibility (Rattary and Joyce, 1969; Waldo and Jorgensen, 1981).

Antiquality Factors in Alfalfa. Bloat is an acute, digestive disorder of ruminants, associated with the consumption of lush green leguminous green forage such as alfalfa (Howart, 1988). Lignin content in alfalfa herbage ranges from 5 to 14% with 3 to 8% in leaves and 6 to 15% in stems (Harkin, 1973). Nitrate at prebud stage ranges from .18 to .32% and decreases to .12 to .17% at green pod stage (Howarth, 1988). Forage nitrate concentration of more than .2% is considered as a risk of causing nitrate toxicity in ruminants.

Ensiling

Ensiling is a preservation method involving anaerobic fermentation and is characterized by the production of heat, lactic and acetic acid, followed by a stable phase during which lactic acid concentration remains stable and the pH of the fermented mass becomes constant (Barnett, 1954). Ensiling is the process of making silage and the container is called a "silo". Ensiling is governed by the interaction of three factors: 1) chemical composition of the plant material; 2) the amount of air entrapped or allowed to enter the silage mass and 3) the activity of the bacterial population (McCullough, 1978). Ensiling for adequate preservation depends upon production of sufficient acid to decrease the pH of the ensiled mass to the value that inhibits undesirable microbial activity and catabolic processes (McDonald, 1981). For silage of high protein, it is important that the decrease in pH be rapid enough to prevent proteolysis (McDonald, 1981).

Silage is produced by controlled fermentation of forages of high moisture content (McDonald et al., 1988) and is a product resulting from preserving high moisture, usually green forages, by fermentation (Lassiter and Edward, 1982). Fermentation can be controlled either by encouraging growth of lactic acid-producing bacteria present on the fresh green forage or by restricting fermentation by pre-wilting the crop or by use of chemical additives (McDonald et al., 1988).

There are advantages in ensiling over haymaking, including reduced field losses (20% of those with haymaking) (Waldo, 1977; McCullogh, 1978), less delay at harvest due to bad weather which increases the time for regrowth, adaptation to mechanization, and an extended period of utilization with minimum loss of nutrients after stability of silage is reached (Noller and Thomas, 1985). Good quality silage is a very palatable product, which is well utilized (Hawkin et al., 1970) and excellent results may be obtained with high producing animals such as lactating dairy cows (Church, 1977). The fermentation that occurs during ensiling usually reduces the nitrate content, if present, and other toxic materials such as prussic acid. With legume silage, bloat is less of a problem than with pasture or green chop (Church, 1977; Howarth, 1988).

Chemical Changes During Fermentation. When the crop is ensiled, lactic acid bacteria present on green forage continue to increase in number (McDonald, 1981). The plant carbohydrates are converted through anaerobic fermentation into organic acids, which help in lowering the pH and preserve the forage. Lactic acid-producing bacteria act on the readily available carbohydrates in the forage to produce lactic acid and some acetic, propionic, formic and succinic acids. Lactic acid bacteria can be classified into two groups: 1) homofermentative, and 2) heterofermentative, depending on whether they ferment sugars by the homofermentative or heterofermentative pathway (Seale, 1987). Failure to produce sufficient acid for stable silage results in secondary fermentation involving heterofermentative bacteria, with the conversion of lactic acid to butyric acid. Formation of butyric acid reduces the intake of the silage by the animals. Plant proteins may also be altered during fermentation.

Fresh forage contains 15 to 25% of total N as NPN (Noller and Thomas, 1985). During ensiling, protein is converted to various NPN compounds, hence, 40 to 70% of the total N in the forage mass may be present as NPN (Noller and Thomas, 1985). Ensiling results in catabolism of protein N in the crop, which has been associated with reduced efficiency of utilization of silage N by ruminants (Thomas and Thomas, 1985). Muck (1987) reported that proteolysis was negatively and linearly correlated with the DM content of the herbage and that little proteolysis occurs at 75% DM. Proteolytic activity decreases with time during fermentation in the silo, with little proteolysis activity after 5 d of fermentation.

<u>Factors Affecting Silage Fermentation</u>. Factors affecting silage fermentation are: 1) moisture content of the crop; 2) buffering capacity of the crop; 3) WSC availability; and 4) type of bacteria present and speed of fermentation (McCullough, 1977). Ideal silage fermentation should occur when forage has 28 to 34% DM, 6 to 8% WSC, minimum buffering capacity, a large population of lactic acid-producing bacteria and a temperature and degree of compaction suitable for an immediate bacteria population increase (McCullough, 1977). Dropping pH by fermentation requires anaerobic environment, adequate substrate and a sufficient number of lactic acid bacteria (Muck, 1988). For efficient preservation of crop quality, DM and energy in the silo, it is required that plant proteolytic activity, clostridial activity and aerobic growth be limited (Muck, 1988).

The chopped forage entering the silo continues to respire, using oxygen and sugars and producing CO_2, H_2O and heat (Muck, 1988). This process eliminates O_2 from the silo and aids in establishing an anaerobic environment (Muck, 1988). McDonald (1981) suggested that a silo needs to be filled quickly. Slowly and improperly filled silos result in excessive respiration, which may result in loss of DM and WSC, amounting to a loss in energy value of the crop as well as loss of substrate for lactic acid fermentation. Silages with high moisture and high pH promote growth of undesirable baceria such as clostridia, which produces butyric acid, NH_3 and amines (Noller and Thomas, 1985).

There are two main groups of clostridia: 1) the saccharolytic, which ferment carbohydrate and organic acids, and produce butyric acid, CO_2 and hydrogen; and 2) proteolytic clostridia, which ferment amino acids to organic acids, CO_2, NH_3 and amines (McDonald, 1981).

Activity of plant proteases is affected by, pH, time, DM of the herbage and temperature (Muck, 1988). Plant proteolytic activity in legumes (white clover [*Trifolium repens*], red clover [*Trifolium pratense*], alfalfa [*Medicago sativa*], and birdsfoot trefoil [*Lotus corniculatus*]) has been reported to be optimum at a pH of 6.0, with activity declining between pH 4 and 6 (Brady, 1961; Finely et al., 1980; McKersie, 1985).

<u>Problems Associated with Ensiling Legumes</u>. Leguminous forages are nutritious, but leguminous green forages such as alfalfa (*Medicago sativa*) and berseem (*Trifolium alexandrium*) are difficult to ensile because of high-moisture content, low level of WSC, high protein and high buffering capacity (McDonald and Whittenbury, 1973; Weissbach et al., 1974; Wilkinson, 1983a).

Wilkinson (1983a) observed that tropical grasses and legumes have lower levels of WSC than temperate crops. He reported that crops harvested with low DM and WSC are at risk with regard to secondary fermentation during ensiling.

Weissbach et al. (1974) observed that as the ratio of WSC to buffering capacity decreased, the minimum DM required to achieve satisfactory fermentation increased. The higher ratio was found for maize (*Zea mays*) forage and lowest for legume crop, particularly alfalfa.

Legumes are high in protein content, and high protein forages are more dificult to ensile. Similarly, high mineral contents in plants tend to restrict the decrease in pH. Corn (*Zea mays*) forage with low mineral content is easy to ensile (Noller and Thomas, 1985).

The DM concentration in fresh green leguminous forages is not sufficient to avoid seepage and effluent losses (Miller and Clifton, 1965). The proteolysis during ensiling was negatively and linearly correlated with DM content of alfalfa (Muck, 1987). The DM can be increased either by wilting or addition of cereal crop residues (Catchpoole and Henzell, 1971).

Wilting. Grass and legume forage harvested and stored without field drying may have more than 70% moisture (Noller and Thomas, 1985). Field wilting involves mowing and subsequently picking the cut swath up with the forage harvester (Wilkinson, 1983b). Partial removal of H_2O has the effect of increasing the WSC content in the crop, restricting the extent of fermentation and reducing the incidence of secondary fermentation (Wilkinson, 1983b). Reducing the moisture content of the crop retards the activity of all micro-organisms, especially clostridia and to lesser extent, heterofermentive organisms (Thomas and Thomas, 1985).

Catchpoole and Henzell (1971) concluded that tropical crops ensiled without wilting are likely to ferment during ensiling to give relatively high content of acetic acid, unless additional fermentable carbohydrate, such as molasses, is added. McCormick et al. (1988) studied the effect of wilting interval and microbial inoculation on ensiling characteristics and nutrient utilization by lambs. They reported that wilting interval had no effect on ensiling pH (mean 4.30) but increasing wilting time reduced ($P < .05$) silage soluble carbohydrate and increased NDF content.

Inhibition of proteolysis in silages can be achieved by wilting (Merchen and Satter, 1983) and the use of acid additives (McDonald et al., 1983). With the advent of the direct cut forage chopper, the wilting procedure lost favor because of the extra field operation involved in harvesting wilted silage (Noller and Thomas, 1985). Peoples and Gordon (1989) reported that wilted silage had a higher digestibility than the unwilted material and animals offered wilted silage consumed .18 kg more silage DM/day and produced 1.6 MJ/day more milk energy output than those offered unwilted silage. Animals given wilted silage consumed 13.5 MJ more metabolizable energy (ME) per day than those offered unwilted silage.

Many direct cut hay crop silages contain low levels of WSC and desirable bacterial fermentation for proper preservation is difficult to obtain. Clostridial type organisms tend to predominate, using protein as a source of energy which leads to a low-quality product (Lusk, 1978). On the other hand, excessive wilting of forage usually results in heat damaged silage and low protein digestion. In addition, added field operations are required to wilt the forage. Marsh (1979) reviewed the effects of wilting on fermentation in the silo and nutritive value of silage. He reported that wilting increases both fermentation quality and intake; increasing intake outweighed the possible disadvantage of lowering digestibility coefficients. Therefore, wilting prior to ensiling is recommended.

Gordon (1980) reported that wilting increased the pH of grass silage from 3.9 to 4.6 and depressed milk yield (24.8 vs 22.7 kg/day for unwilted and wilted materials, respectively). Wilting had no effect on live weight or body condition. Gordon (1981) reported the wilting of herbage (ryegrass) prior to ensiling increased DM intake by British Friesian cows.

Flynn (1981) reported that the reason for reduction in output of animal product in response to raising forage DM content by wilting remains unresearched and unresolved. The slight reduction in digestibility due to wilting and possible higher energy value of unwilted silage may be the reason. It is possible that differences in composition of wilted and unwilted silage can result in a different rumen fermentation pattern, which in turn may result in slight differences in efficiency of wilted silages.

Singh and Rekib (1986) ensiled berseem for 60 d after 0, 2, 4 and 5 h of wilting and oat after 0, 2 and 3 h of wilting, alone and in mixtures at 2:1, 1:1 and 1:2 ratios. They found a positive correlation between DM content of the forage and lactic acid content of the silages. Negative correlations between DM of the forage and pH, NH_3-N (% of total N) and VFA content were observed.

Ensiling Leguminous Green Forage in Combination with Crop Residues. The DM concentration in fresh green forage is not sufficient to avoid seepage and effluent losses (Miller and Clifton, 1965). The DM can be increased by wilting or by addition of straws. Wilting is not always feasible under farm conditions. Cereal straws are readily available in developing countries and can be incorporated with green forages for making silage, especially leguminous green forages (Lal and Mudgal, 1967). They reported that combined ensiling of cereal straws with legumes helps to improve the palatability and digestibility of the straws. They observed an increase of 10 to 12 percentage units in crude fiber digestibility from ensiling of paddy straw with green berseem, compared to paddy straw alone. Narang and Pradhan (1973) observed an increased intake of wheat straw when ensiled with cowpea (*Vigna unguiculata*).

Soliman et al. (1978) found that berseem preserved poorly when ensiled alone, but preserved well when ensiled in a mixture (70:30) with ryegrass (*Lolium perenne*), barley (*Hordeum vulgare*) or maize with the addition of 20 kg molasses per ton. Kamra et al. (1983) studied the process of ensiling fresh maize (15% DM), wilted maize (18 and 24% DM) and maize mixed with 5 to 20% wheat straw (18, 25, and 29% DM) and observed that silages with 24% DM were preserved better than those with lower DM. There was a significant decline in VFA and NH_3 production and a significant increase in soluble sugar in silages made after wilting. A significant decrease in VFA production and NH_3-N and a significant increase in pH were found in silage of maize mixed with wheat straw. In the second experiment, the effects of urea and molasses on wheat straw + maize (15:85) silage with initial DM of 31 to 34% were studied. Three levels of molasses (0, 3 and 6% of fresh weight) and two levels of urea (0 and .5% of fresh weight) were used. Urea treatment with 3% molasses produced the best silage characteristics.

Gupta and Pradhan (1985) reported that good quality silage can be prepared from wheat straw when ensiled for 60 d with either green alfalfa or urea-molasses. Singh et al. (1984) studied ensiling of combinations of leguminous green forage and dry roughage in laboratory silos. The effect of addition of molasses at different levels (0, 5, 10%, fresh basis) was also studied on a combination of green berseem and wheat straw (80:20, fresh basis). They reported significant decreases in pH, NH_3-N, total VFA, DM disappearance and number of coliform bacteria, and a significant increase in titratable acidity and lactic acid by the addition of 5% molasses. There was no significant difference in the quality of silage at the 5 and 10% levels of molasses or after 40 or 80 d of fermentation.

Singh and Pandita (1985) ensiled chopped berseem wilted to about 30% DM and unwilted, mixed with wheat straw or paddy straw in the proportion of 4:1, on fresh weight basis, all combinations with 0 and 1% molasses, in 500 ml flasks. Water soluble carbohydrates in wilted berseem, fresh berseem + wheat straw, and fresh berseem + paddy straw mixture were 5.2, 3.8 and 4.9%, respectively. Higher pH values and acetic acid concentration were recorded for wilted silage. Lactic acid production was similar for wilted and berseem + paddy straw, and was lower for berseem + wheat straw. This indicated that paddy straw with comparatively higher WSC produced more lactic acid.

Gampawar and Kakde (1986) ensiled wheat straw and berseem in 2:5 proportion (w/w) with two levels of molasses (4 and 6%) and two levels of formic acid (.2 and .3%). They reported that ensiling of wheat straw with berseem in 2:5 proportion (w/w) after enriching with 4% molasses in combination with .2% formic acid improved the utilization of wheat straw in ruminants, compared to control consisting of wheat straw and fresh berseem 2:5 (w/w). Voluntary feed consumption and weight gains were significantly higher.

Mosi and Butterworth (1985) studied voluntary intake and digestibility of combinations of cereal crop residues and legume hay for sheep. They reported that benefits obtained by supplementation of crop residues with legume hay were comparable to those expected from treatment of cereal crop residues with strong alkali. They indicated that legume supplementation is more appropriate to conditions encountered on small mixed farms in Africa.

Kamra et al. (1989) fermented cattle waste using four different treatments. The ingredient composition of mixtures was wheat straw, cattle dung, berseem and sugar cane molasses in the ratios of 20:0:75:5, 20:25:50:5, 20:50:25:5 and 20:75:0:5, respectively. The DM in the premix varied between 32 and 34%. They reported a decline in soluble sugar, lactic acid and VFA with the increasing level of waste in the premix. However, the ratio of lactic acid to VFA increased. They concluded that cattle waste can be included in berseem silage at levels of 13 to 26% of the total DM without adversely affecting silage characteristics.

Chauhan et al. (1987) studied the utilization of berseem and wheat straw silage by growing buffalo calves. Berseem (fourth cut) was wilted for 24 h in the field and then berseem and wheat straw were chopped and mixed in the ratios 7:1 and 5:1. The mixtures were sprayed with 1.5% molasses (wet basis) and ensiled for 3 mo. Fifteen buffalo calves (1 year old) were fed three diets. Animals in control group were fed 1.5 kg concentrate mixture, ad lib wheat straw and .5 to 1.0 kg green berseem. For the other two diets berseem and wheat straw silages (7:1 and 5:1) were fed ad libitum. The apparent digestibility of DM, CP, EE and NFE of the control diet (concentrate + wheat straw + .5 to 1 kg berseem fed) was higher ($P < .05$) than for berseem-wheat straw (5:1) silage. The crude fiber digestibility of control and mixed silages was similar. They concluded that a good quality silage from berseem and wheat straw can be prepared in 5:1 or 7:1 ratios by spraying 1.5% molasses and these silages provide complete maintenance and part of the growth requirements for growing buffalo calves.

One of the major problems in utilization of ensiled plant materials as feed for ruminant animals is reduced voluntary DM consumption, as compared to forage preserved in another manner (Gordon et al., 1960). Daily DM intake is positively associated with silage DM, over a wide range of silage DM (Gordon et al., 1961, 1965). Cattle and sheep consumed more DM as hay than as silage, but the performance was not greater with hay (Thomas et al., 1969). Dry matter from silage contained more energy, ether extract and less hemicellulose than DM for hay, and the energy from silage was slightly more digestible. The digestible energy concentration, DM basis, for silages was 1.24 times that of hay. The DM intake was positively and linearly related to the DM content of the silage (Hawkins et al., 1970). When crops are ensiled in well sealed silos, the digestibility of DM and OM in the ensilage is similar to the crop before ensiling (Harris and Raymond, 1963). Wilkins (1981) stated that it might be expected that ensiling would result in increased metabolizable energy.

Wilkins et al. (1971) studied the voluntary intake by sheep of 70 different silages and reported that DM voluntary intake was positively correlated with the DM, N and lactic acid as percent of the total acid.

Silage Additives

The objective of using additives is to ensure that lactic acid bacteria dominate fermentation, resulting in well-preserved silage (McDonald, 1981). Additives are used in silage mainly to prevent secondary fermentation of lactic acid to butyric acid by clostridial bacteria (Wilkison, 1987). The secondary fermentation can be checked by wilting or use of different additives.

Silage additives can be classified into two main types: stimulants, such as inoculants, and sugars, which encourage the growth of lactic acid bacteria; and inhibitors such as acids and formalin (McDonald et al., 1988).

In recent years, a number of commercial inoculants containing freeze-dried cultures of homofermentative lactic acid bacteria have become available. Mostly, they contain *Lactobacillus plantarum* and other organisms such as *Pediococcus acidilactici*. The success in using these inoculants depends upon the inoculation rate, which should be 10^6 organism/g fresh forage and presence of an adequate availability of readily fermentable carbohydrates (McDonald et al., 1988).

Molasses, a by-product of sugar cane (*Saccharum officinarum*) or sugar beet industries, was one of the earliest silage additives. Molasses has a WSC content of about 700 g/kg DM and the additive has been shown to increase the DM and lactic acid contents, and reduce the pH and NH_3 in treated silage (McDonald et al., 1988).

A large number of chemical compounds have been tested as potential fermentation inhibitors. They include mineral acids, HCl and H_2SO_4 (McDonald et al., 1988). In recent years, formic acid has largely replaced mineral acid and this organic acid, which is less corrosive, has been accepted as an additive (McDonald et al., 1988). The recommended rate is 2.7 kg/ton fresh crop. The beneficial effect of formic acid on fermentation characteristic of difficult crops (legumes) with low WSC has been established. Formalin, a 40% solution of formaldehyde in water is also used as an additive (McDonald et al., 1988). Acids (mainly formic and sulfuric) and salts (mainly calcium formate and sodium nitrate) are the most common types of additives used to reduce the risk of secondary fermentation (Wilkinson, 1987). Acid additives can also help in inhibition of proteolysis in silages (McDonald et al., 1983).

Molasses. Molasses is extremely palatable and an excellent source of energy (Ensminger et al., 1990). The energy value of molasses is 75 to 100% hat of corn grain (NRC, 1984). There are several sources of molasses used in livestock feeds. The most common results from the processing of sugar cane (*Saccharum officinarum*). There are also considerable amounts of citrus, beet and wood molasses used in livestock diets (Huber, 1981).

Molasses contains more than 50% sucrose and is commonly used as an additive (Thomas, 1978). Addition of sugar in the form of molasses stimulated the lactic acid fermentation and produced good silage (McDonald and Purves, 1956). Molasses provides energy for the growth of lactic acid bacteria (Thomas, 1978). The presence of sufficient quantities of readily fermentable carbohydrate in the silage suppresses production of deaminating enzymes (Thomas, 1978).

Lanigan (1961) reported that the ensiling of alfalfa in laboratory silos with large amounts of molasses resulted in lower pH, increased lactic acid content and decrease in DM loss. Reed and Fitch (1971) found that molasses-treated alfalfa silage was consumed in greater quantities by steers than alfalfa treated with wheat straw. Andrighetto et al. (1987) reported formation of large quantities of volatile compounds, with significant loss in OM when molasses was used at 4% in ensiled *Lolium multiforum*.

Microbial Inoculant. The bacteria responsible for production of high quality silage are lactic acid-producing (McDonald, 1981). Addition of *Lactobacillus sp.* to fresh forage has been recommended to control fermentation (Seale, 1986). In the past few years, due to safety considerations, interest has been focused in the use of biological additives as an alternative to chemical additives for silage (Seale, 1987). Formation of lactic acid is a basic process in preservation of ensiled forage (Ohyama et al., 1975).

Inteaz Alli and Baker (1982) studied the effect of additives on lactic acid production and WSC in chopped corn and alfalfa. They reported that during a 48 h fermentation, incorporation of *Lactobacillus plantarum* culture increased rate of lactic acid production by 70%, as compared to the control.

Waldo and Goering (1976) reported average DM digestibilities for untreated and inoculant treated silages were 48.2 and 59.2% for alfalfa, 53.7 and 55.2 for orchardgrass (*Dactylis glomerata*) and 68.5 and 69.2% for corn (*Zea mays*) forages, respectively. Microbial inoculant improved DM digestibility of alfalfa but not of orchardgrass or corn. Ely et al. (1981) reported lower pH, higher lactic acid concentration and greater DM recovery in alfalfa and wheat straw silage mixtures inoculated with *L. plantarum*. However, addition of inoculant to corn or sorghum (*Sorghum bicolor*) mixtures did not show any positive effect.

Wittenberg et al. (1983) reported no improvement in the preservation of DM, CP, ADF and gross energy when corn silage was treated with *L. plantarum*. Lactic acid concentration and pH levels were similar for the control and inoculated silages. Hinds et al. (1985) studied the effects of molasses/urea and bacterial inoculant additives on silage quality, DM recovery and feeding value for cattle. They reported that treated silage had higher pH, total N, NH_3-N and DM loss from the silos. Treated silage, when compared to the control, had higher lactic acid and lower acetic acid contents, which gave higher lactic acid to acetic acid ratios.

Cho et al. (1989) studied the effect of lactic acid bacteria (*Lactobacillus plantarum*) inoculation and supplementary molasses on fermentation of silage containing poultry manure. Silage consisted of rice straw treated with NaOH, wheat bran, and poultry manure in the ratio of 50:30:20 on DM basis. They reported that lactic acid bacteria or molasses added separately were not as effective as in combination. Silages containing molasses were better digested than those without molasses.

Ely et al. (1982) used *Lactobacillus acidophillus* and *Candida sp.* as microbial inoculants for alfalfa, corn and sorghum silages. When silages were fed to sheep at 2% of body weight, no significant effects were found from adding the inoculants. Ohyama et al. (1973) reported that inoculation with *L. plantarum* did not affect silage quality. Luther (1986) concluded that in most large silo ensiling processes, the use of inoculant has not shown any significant improvement in the fermentation characteristics. Lesins and Schultz (1968) reported that inoculation of ensiled materials with lactic acid-producing bacteria may or may not influence the characteristics of silage.

Dellaglio and Torriani (1985) reported that adding a suspension of lactic acid bacteria containing 15% *Lactobacillus plantarum* and 85% *Pediococcus acidilacti* accelerated the drop in pH after only 4 d of ensiling and resulted in two to five times higher counts of lactic acid bacteria than untreated silage or silage treated with formic acid.

Seale (1986) reviewed use of microbial inoculants as silage additives and concluded that inoculants are desirable as additives because they are safe to handle, cheap to produce and act by aiding natural fermentation.

Muck et al. (1988) reported that number of lactic acid bacteria required for an immediate decrease in pH is approximately 10^8 per gram of crop. Because this concentration is much greater than that supplied by inoculants, the most important characteristic for an inoculant is fast growth rate in the silo environment. Also, inoculant success depends on adequate substrate and its population relative to the natural one.

Kent et al. (1988) harvested lucerne (alfalfa) at bud stage, wilted to 45% DM, chopped to .95 cm and ensiled under pressure in sealed polyethylene bags, untreated or after adding an inoculant of *Lactobacillus plantarum* and *Pediococcus acidilactia*. There was no significant difference between silages in composition, but pH was lower in treated silage. In vitro DM disappearance tended to be higher and NH_3-N content was lower in treated silages, but differences were nonsignificant. Acetate production was higher for treated silage. Daily DM intake and milk yield were similar.

McCormick et al. (1988) studied the effect of wilting interval and microbial inoculation on alfalfa ensiling characteristics and nutrient utilization by lambs. They reported that wilting interval had no effect on silage pH, but increasing wilting time reduced silage soluble carbohydrates and increased NDF content. Inoculation reduced ($P < .05$) the pH. Fish et al. (1988) reported that silage inoculation caused a rapid fermentation and produced a greater production response when fed with a bypass protein.

Rust et al. (1989) reported that corn silage treated with microbial inoculant had higher lactic acid level. The inoculated silage deteriorated at a faster rate upon exposure to air than control silage. When fed to steers, weight gain and DM intake were similar for both silages. They concluded that inoculating maize silage did not affect its nutritive value but appeared to lower the stability of maize silage to air exposure.

Steen et al. (1989) tested a bacterial inoculant containing *Lactobacillus plantrum*, to treat grass silage, compared with untreated and formic acid-treated silages. They concluded that silage fermentation and ME content were similar for the untreated and inoculant-treated silage, but silage DM intake and weight gain were greater for inoculant-treated than for untreated silage. Dry matter intake was higher for formic acid-treated silage, however, liveweight gains tended to be higher on inoculant-treated perennial ryegrass silage.

Gordon (1989) made silage from perennial ryegrass (*Lolium perenne*), treated either with bacterial inoculant, formic acid or no additive (control). He found that bacterial inoculation resulted in improved animal performance over untreated and formic acid-treated silages.

Moon et al. (1980) ensiled wheat (early bloom), alfalfa (40% bloom) and corn forages (early dent) with and without 5 g/kg of a commercial silage additive containing *Lactobacillus acidophilus* and *Candida sp.* In corn silage, lactic acid bacteria population and pH were similar in control and inoculated silage, but lactic acid concentration was higher in inoculated silage. In alfalfa silage, bacterial population and pH were similar between control and inoculated, but fermentation acids were higher in the control.

Shockey et al. (1985) ensiled alfalfa wilted to 45% DM and whole plant corn (40% DM) with and without microbial inoculant in 200 liter metal drums and reported that microbial inoculation did not affect fermentation parameters. The pH declined faster and to a lower level in corn than in alfalfa, even though nearly twice as much acid was produced in alfalfa than corn. Protein degradation, measured by NH_3 and NPN concentration, was more extensive in alfalfa than corn. They concluded that possibly there are differences in metabolic characteristics of microorganisms that develop in different forage crops.

Kung et al. (1987) ensiled field-wilted alfalfa (53 and 57% DM) untreated and microbial inoculant treated in each of 2 yr. In both years treated silage had lower pH and residual WSC and greater lactic acid content than untreated silage. Silage was fed to lactating cows as 60% of the diet DM for 10 wk. In trial 1 more milk was produced by cows fed treated silage, but there was no change in DM intake. In experiment 2 no differences for milk production, milk composition or feed intake were found. Shockey et al. (1988) studied the effects of microbial inoculant on fermentation of poor-quality alfalfa. Inoculant consisted primarily of *Lactobacillus plantarum*, *L. brevis* and *Pediococcus acidilactici*. They reported that inoculation did not affect changes in pH, lactic acid, acetic acid, NPN or NH_3-N.

Hooper et al. (1988) studied the feeding value of ryegrass silage prepared either with or without the use of a lactobacilli inoculant (Pioneer Brand 1177). Silages were prepared in two identical 100-ton capacity bunker silos. Each of the two silages was fed for 100 d to 10 Friesian crossbred steers. They found little differences in chemical composition between the silages. Dry matter intake was similar for both silages. Live weight gain and feed conversion showed a trend in favor of inoculated silage. The digestion coefficients of DM, OM and N were higher for cattle fed inoculated silage.

Petit and Filpot (1990) reported that rumen volume and DM content were higher for sheep fed inoculated long and short-chopped alfalfa-timothy silages. The pH and NH_3-N of the rumen and ruminal dilution rate of liquids and solid were similar for all treatments. Microbial inoculation increased silage intake and silage particle size, modified duodenal flow of N and production of rumen VFA, which might alter performance of the animal. Short chop length decreased the amount of N reaching the duodenum and tended to improve N retention, which could result in higher daily gain of animals. Further, the short chop length decreased the acetate:propionate ratio by lowering rumen acetate concentration.

Availability of Minerals from Alfalfa

Calcium. Hansard et al. (1957) reported that the availability of Ca from common supplemental sources ranged from 37 to 35% in adult cattle. The availability of Ca from alfalfa was 31%. Ward et al. (1972) reported that availability of Ca in alfalfa ranged from 31 to 41%, due to the fact that 20 to 30% of Ca in alfalfa is bound in oxalate crystals, thus unavailable.

Fredeen (1989) compared the availability of Ca in alfalfa hay harvested at vegetative and full bloom with a control diet in which the Ca source was limestone. They reported that Ca absorption rate in goats exceeded 50% of the intake. Maturity of alfalfa did not affect Ca availability. Replacing Ca from limestone with Ca from alfalfa did not alter Ca availability.

Ward et al. (1979) reported that Ca in alfalfa is only 50 to 75% as available to cattle as that from inorganic sources. They suggested that 25 to 50% of Ca in alfalfa be discounted for diet formulation.

Phosphorus. In many plants P is present as phytic acid, hence, not available to nonruminants. It is available to ruminants because rumen microbes produce the enzyme phytase (Ensminger et al., 1990). Lofgreen and Kleiber (1953, 1954) found that true digestibility of P in alfalfa hay by wether lambs was about 90%. Dutton and Fontenot (1967) reported that form of phosphorus in the sheep diet, i.e., organic (phytic acid) vs inorganic (disodium phosphate), did not affect absorption and retention of Mg, Ca nor the absorption of P. However, retention of phosphorus was higher for diets containing inorganic phosphorus.

Magnesium. Generally, the Mg in grains and concentrates is more available than in forage (Peeler, 1972). Magnesium in preserved forage is more available than in pastures. Mg absorption is lowest from young, succulent pastures and increases with maturity (NRC, 1985). Peeler (1972) reported higher Mg absorption in young milk-fed calves than in older calves.

CHAPTER III.

ENSILING CHARACTERISTICS AND IN VITRO DIGESTIBILITY OF ALFALFA AND WHEAT STRAW ENSILED ALONE AND IN DIFFERENT PROPORTIONS WITH AND WITHOUT DIFFERENT ADDITIVES

ABSTRACT

Alfalfa (*Medicago sativa L.*) is a choice forage for maximizing milk as well as beef production. It is difficult to ensile leguminous forage, such as alfalfa, because of high moisture content, low water soluble carbohydrate (WSC) content and high buffering capacity. This study was designed to investigate the ensiling characteristics and in vitro digestibility of alfalfa and wheat straw ensiled alone and in different proportions with and without molasses and a microbial inoculant. Alfalfa harvested at 1/10 bloom and chopped wheat straw were ensiled in different proportions, DM basis: 0:100, 25:75, 50:50, 75:25, 100:0, and 0:100 (urea treated) with 0 and 5% dry molasses and 0 and .1% microbial inoculant (*Lactobacillus plantarum* and *Streptococcus faecium*) in a 6 x 2 x 2 factorial arrangement of a completely randomized design. Each mixture was ensiled in 3.8 liter cardboard containers double lined with polyethylene bags. The pH values for ensiled combinations/ proportions without additives were 4.70, 4.76, 4.65, 4.76, 4.82 and 8.84, respectively. Higher pH ($P < .01$) values were observed with urea-treated straw. Lower pH ($P < .01$) was observed when molasses was used as an additive. When no molasses was used, lactic acid concentration decreased ($P < .01$) linearly with increase in the level of alfalfa. Total VFA content of ensiled mixtures decreased ($P < .01$) linearly with increases in proportion of wheat straw in the mixtures. Water soluble

carbohydrate in pre-ensiled mixtures increased ($P < .01$) linearly with the increase in alfalfa. Addition of molasses increased the WSC in the initial mixtures. The WSC decreased ($P < .01$) during ensiling. Addition of molasses decreased ($P < .01$) the VFA content in the ensiled mixtures. Acetic acid was the major VFA in the silages. Urea treatment of the wheat straw decreased ($P < .01$) lactic acid, but increased ($P < .01$) acetic acid concentation, compared to untreated wheat straw. Microbial inoculant did not significantly affect pH. Average lactic acid content in the silages was lower when inoculant was used in the absence of molasses but was higher in the presence of molasses (molasses x inoculant interaction, $P < .01$). The DM, NDF, ADF, cellulose, and hemicellulose content increased ($P < .01$) linearly with the increase in the level of wheat straw in the mixtures. Ensiling urea-treated wheat straw increased ($P < .01$) the CP content, decreased ($P < .01$) the hemicellulose content and improved the IVDMD by 11 percentage units. In vitro dry matter digestibility increased ($P < .01$) linearly with level of alfalfa, and was enhanced by molasses ($P < .01$). The IVDMD of alfalfa and wheat straw ensiled in 75:25 proportion without additive was equal to urea-treated wheat straw. It is concluded that combined ensiling of alfalfa and wheat straw has potential for improving the fermentation characteristics of alfalfa silage.

(Key Words: Ensiling Characteristics, In Vitro Digestibility, Alfalfa, Wheat Straw, Proportions, Additive.)

INTRODUCTION

Cereal crop residues, such as wheat straw, constitute a major component of livestock feed in developing countries. Chemical treatment to improve the nutritional value of these poor quality roughages is not gaining popularity, because these chemicals are either very expensive or not easily available to small livestock producers in developing countries, such as Pakistan. Jayasuriya and Perera (1982) reported that urea can be used as a source of ammonia in treating straw and it improves voluntary intake and digestibility. There is a need to develop a procedure that is less expensive than chemical treatment, that is effective and is easily understood by small farmers as well as commercial livestock producers. Ensiling of leguminous green forages in combination with cereal crop residues has shown potential in improving the nutritional value and utilization of low quality roughage (Singh et al., 1984; Chauhan et al., 1987).

Leguminous green forages, such as alfalfa (*Medicago sativa L.*) and berseem (*Trifolium alexandrinum L.*), are difficult to ensile because of high moisture content, low level of WSC and high buffering capacity (McDonald and Whittenbury, 1973; Soliman et al., 1978). Various silage additives are used, especially when direct cut green forages are ensiled. The silage additives are of two types, stimulants such as microbial inoculants and sugars such as molasses, which encourage growth of lactic acid bacteria, and inhibitors such as acids and formalin (McDonald et al., 1988). Formation of lactic acid is a basic process in preservation of ensiled forage (Ohyama et al., 1975). Addition of

Lactobacillus sp. to fresh forages has been recommended (Seale, 1986; Fish et al., 1988). The DM concentration in the fresh forages is not sufficient to avoid seepage and effluent losses (Miller and Clifton, 1965) and can be increased either by wilting or addition of crop residues.

This study was designed to investigate the ensiling characeristics and in vitro digestibility of alfalfa and wheat straw ensiled alone and in different proportions, with and without molasses and microbial inoculant as additives.

EXPERIMENTAL PROCEDURE

Alfalfa (4th cutting) was harvested with small forage harvestor at 1/10 bloom stage in September, 1988. Alfalfa and wheat straw were chopped to approximately 1.5 cm in length and were mixed in a small horizontal mixer in proportions (DM basis) and additives as follows: 0:100, 25:75, 50:50, 75:25, 100:0, 0:100 + urea with 0 and 5% dry molasses, and 0 and .1% microbial inoculant. Thus, 24 completely random treatment combinations were used in a 6 x 2 x 2 factorial arrangement. For the urea treatment, 50 g of urea dissolved in .4 liter of water per kilogram of wheat straw DM were added to the straw inside the mixer. Sufficient water was added to wheat straw for the 0:100 treatment to attain a moisture level of about 40%. The microbial inoculant[1] contained *Lactobacillus plantarum* and *Streptococcus faecium.*

After thorough mixing, six laboratory silos per treatment combination were prepared by manual packing of each mixture into 3.8

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[1]Inoculant 1177, Pioneer Microbial Genetics, West Des Moines, IA.

liter cardboard food containers double-lined with polyethylene bags. Samples of ingredients and mixtures were taken for subsequent analysis. The silos were weighed before and after addition of mixtures, and were kept at room temperature for a minimum of 60 d.

After 60 d at room temperature, silos were weighed, opened, and the top 5 cm of ensiled material were discarded prior to sampling, and physical characteristics, such as color, aroma and fungal growth, if any, were recorded.

In Vitro Digestibility. One ruminally cannulated steer was fed wheat straw and alfalfa hay (50:50) ad libitum for 7 d before the collection of ruminal ingesta. Water was supplied at all times except for 2 h prior to collection of ruminal ingesta. The ingesta was collected from the cannula from the steer 2 h after feeding and was strained and filtered through eight layers of cheesecloth into a Thermos bottle and was transported to the laboratory immediately for IVDMD using a two-stage technique for in vitro digestion of forage crops (Tilley and Terry, 1963; as modified by Barnes, 1969).

The samples were ground to pass through a 1 mm sieve. Duplicate air dried samples, .35 g each, were weighed into labeled 50 ml tubes fitted with stoppers equipped with Bunsen valves as described by Tilley and Terry (1963). After rumen fluid reached the laboratory, it was added to the freshly prepared buffer solution (1:4) in a glass bottle fitted with a stopper with two openings (one for passing of CO_2 tube and another for pH meter electrode). Carbon dioxide was passed through the rumen fluid-buffer mixture to adjust the pH to 7.0. Temperature of the mixture was adjusted to 38 to 39° C, 35 ml of the rumen fluid-buffer mixture was added to each tube, and CO_2 was directed in each tube for 15 s to create anaerobic condition. Tubes were fitted with stoppers equipped with Bunsen valves and were kept in a water bath at constant temperature (38 to 39° C). Tubes were swirled at the beginning of the incubation. Two blank tubes and two alfalfa reference standard tubes were incubated and treated similarly. Blank tubes contained only mixed rumen fluid and buffer solution. After 48 h of incubation, tubes were centrifuged at 2500 rpm for 15 min and supernatant was poured off. Twenty-five milliliters acid-pepsin solution (containing 2 g pepsin + 83.3 ml of HCL per liter of solution) were added to each tube and the tubes were placed in the water bath for another 48 h. Tubes were swirled 2, 4, 20 and 28 h after beginning of pepsin incubation. At the end of the 48 h pepsin incubation period, tubes were centrifuged at 2500 rpm for 15 min. The supernatant was poured off and tubes with residue were dried for 24 h at 100° C. After drying, tubes with residue were weighed after cooling in dessicator. Residue was removed from the tubes, and tubes were thoroughly washed, dried, weighed and IVDMD was calculated.

Chemical Analysis. Water extracts of the initial and ensiled (fermented) mixtures were prepared by homogenizing 25 g samples with 225 ml of distilled water in a .5 liter jar in a Waring blender at full speed for 2 min. The homogenates were filtered through four layers of cheesecloth and the filtrates were used for measuring pH (electrometrically) VFA (Varian 6000 gas chromatograph, column packed with 10% SP-1200/1% H_3PO_4 on 80/100 chromasorb WAW), lactic acid (Barker and

Summerson, 1941 as modified by Pennington and Sutherland, 1956) and WSC (Dubois et al., 1956 as adapted to corn plants by Johnson et al., 1966).

Nitrogen content of the ingredients and initial and ensiled mixtures was determined by the Kjeldahl procedure (AOAC, 1984). Dry matter of the initial samples and silages was determined by drying 200 g of samples in a forced draft oven at 60° for 48 h. The samples were allowed to equilibrate and dry weights were recorded. All initial and ensiled samples were ground to pass through 1-mm sieve and were analyzed for DM, ash (AOAC, 1984), NDF (Van Soest and Wine, 1967), ADF (Van Soest, 1963; Goering and Van Soest, 1970), lignin and cellulose (Van Soest and Wine, 1968). The remainder of ground samples were placed in sample jars and were used for determination of IVDMD (Tilley and Terry, 1963, as modified by Barnes, 1969).

Statistical Analysis. Data were statistically analyzed by the General Linear Model (GLM) procedure (SAS, 1985). The experimental design was completely randomized designed with a 6 x 2 x 2 factorial arrangement of treatments. The model included the effects of treatments, molasses, inoculant, treatment x molasses, treatment x inoculant, molasses x inoculant, and treatment x molasses x inoculant. The linear, quadratic and cubic orthogonal contrasts were used to test the effect of proportions of alfalfa and wheat straw. The effect of urea was tested by a single contrast (untreated vs treated straw).

RESULTS AND DISCUSSION

Physical Characteristics of Silage. Silages had pleasant aromas, except the urea-treated wheat straw, which had an ammoniacal smell.

Dias-Da-Silva and Sundstol (1986) reported that urea treatment of either ensiled or stack straw caused an intensive ammonia smell at the time containers were opened. Two silages, 100% alfalfa and 100% alfalfa with molasses, had white mold in about a 1-cm top layer. No mold was detected in untreated and urea-treated wheat straw. Urea-treated wheat straw had a golden color.

Composition of Alfalfa and Wheat Straw. The chemical composition of the two forages, alfalfa and wheat straw, is shown in Table 1. Average DM content was 21.2% for alfalfa, and 91.6% for wheat straw. Higher ($P < .01$) CP content for alfalfa than for wheat straw (22.21 vs 2.31%, DM basis) was recorded. The results are in agreement with those of Weissbach et al. (1974) and Noller and Thomas (1985) that legumes are high in moisture and CP, compared to other forages. Low CP content in cereal crop residues has been reported (Anderson, 1978; Wanapat, 1986; Males, 1987). As shown in the table, wheat straw was higher in NDF, ADF, cellulose and hemicellulose content. Lignin content was lower for wheat straw. Harkin (1973) reported that lignin content in alfalfa ranges from 5 to 14%. High fiber content in crop residue (Anderson, 1978; Males, 1987) and high lignin content (Klopfenstein, 1978) have been reported. The ash content (10.34 vs 3.23) was much higher in alfalfa than wheat straw.

Fermentation Characteristics. Across treatments pH of the initial mixtures (Table 2) was much higher ($P < .01$) than pH of ensiled mixtures (Table 3). The final pH values generally were below 5, except for urea-treated straw. The pH of ensiled mixtures increased linearly ($P < .01$)

TABLE 1. CHEMICAL COMPOSITION OF ALFALFA AND WHEAT STRAW, SMALL SILO STUDY[ab]

Component	Alfalfa	Wheat Straw
	- - - - - - - % - - - - - - -	
Dry matter[c]	21.21	91.57
Crude protein[c]	22.21	2.32
Neutral detergent fiber[c]	44.45	78.97
Acid detergent fiber[c]	36.35	48.31
Lignin[c]	10.37	9.02
Cellulose[c]	24.69	38.20
Hemicellulose[c]	8.10	30.67
Ash[c]	10.36	3.23

[a]Each value represents the mean of six samples.
[b]DM basis, except for DM.
[c]Forages differed ($P < .01$).

TABLE 2. The pH VALUES OF DIFFERENT PROPORTIONS OF ALFALFA AND WHEAT STRAW WITH AND WITHOUT DIFFERENT ADDITIVES (PRE-ENSILED)[a]

Forages		Additives					
Alfalfa	Wheat straw	None	Molasses[b]	Inoculant[c]	Molasses + Inoculant	Average[d]	SE
- - - - - - - - %[e] - - - - - - - -							
100	0	5.92	6.05	6.05	6.05	6.02	.12
75	25	5.97	5.95	6.09	6.05	6.02	.12
50	50	5.97	6.33	6.12	6.07	6.12	.12
25	75	6.13	6.27	6.24	6.21	6.21	.12
0	100[f]	6.52	6.64	6.74	7.60	6.87	.12
0	100 (urea treated)[f]	8.61	8.51	8.56	7.93	8.40[g]	.12
Average		6.52	6.62	6.63	6.65	6.61	

[a]Each value represents the mean of six samples.
[b]Forages x molasses interaction ($P < .01$).
[c]Forages x inoculant interaction ($P < .01$).
[d]Linear effect of proportion of forages ($P < .01$).
[e]DM basis.
[f]Water was added to achieve 60% DM.
[g]Effect of urea ($P < .01$).

TABLE 3. The pH VALUES OF DIFFERENT PROPORTIONS OF ALFALFA AND WHEAT STRAW ENSILED WITH AND WITHOUT DIFFERENT ADDITIVES[a]

Forages		Additives					
Alfalfa	Wheat straw	None	Molasses[bc]	Inoculant[de]	Molasses + Inoculant[f]	Average[g]	SE
- - - - - - - - %[h]	- - - - - - - -						
100	0	4.82	4.23	4.95	4.22	4.56	.16
75	25	4.76	4.38	4.98	4.37	4.62	.16
50	50	4.65	4.33	5.82	4.28	4.77	.16
25	75[i]	4.76	4.45	5.81	4.80	4.95	.16
0	100[i]	4.70	4.83	4.83	5.15	4.88	.16
0	100 (urea treated)[i]	8.84	8.29	8.84	8.38	8.59[j]	.16
Average		5.42	5.08	5.87	5.20	5.39	

[a]Each value represents the mean of six samples.
[b]Forages x molasses interaction ($P < .01$).
[c]Effect of molasses ($P < .01$).
[d]Forages x inoculant interaction ($P < .05$).
[e]Effect of inoculant ($P < .01$).
[f]Molasses x inoculant interaction ($P < .05$).
[g]Linear effect of proportion of forages ($P < .01$).
[h]DM basis.
[i]Water was added to achieve 60% DM.
[j]Effect of urea ($P < .01$).

with the increase in wheat straw level. The effect was especially pronounced when molasses was used alone or in combination with inoculant (molasses x inoculant, $P < .05$). Molasses was effective in lowering the pH of alfalfa and wheat straw ensiled alone and in different proportions. Average reduction was .34 unit. A similar reduction in pH by addition of 5 to 19% molasses in combinations of berseem and wheat straw was reported by Singh et al. (1984). Lanigan (1961) reported that ensiling of alfalfa in laboratory silos with large amounts of molasses resulted in lower pH, compared to alfalfa ensiled alone.

Microbial inoculant resulted in an increase ($P < .01$) in pH of different proportions of alfalfa and wheat straw. Inoculant had a greater effect in the absence of molasses (inoculant x molasses, $P < .05$). Shockey et al. (1988) reported no changes in pH and lactic acid by microbial inoculation of ensiled poor quality alfalfa. The pH values for urea-treated wheat straw were much higher ($P < .01$) than untreated wheat straw. The values for urea-treated straw averaged 8.59, compared to 4.88 for untreated straw. Hinds et al. (1985) reported that NPN silage (sorghum-urea-molasses silage) had higher pH than sorghum silage (no additive). Raymond et al. (1985) reported that in many cases the final pH of the silage with additives was no lower than would have occurred if the crop had been allowed to ferment without the additive, but the early natural fermentation of untreated crops tends to be slower and some proteolytic activity occurs.

Lactic Acid. Overall, the lactic acid content decreased linearly ($P < .01$) with the decrease in alfalfa level (Table 4). Addition of

TABLE 4. LACTIC ACID VALUES OF DIFFERENT PROPORTIONS OF ALFALFA AND WHEAT STRAW ENSILED WITH AND WITHOUT DIFFERENT ADDITIVES[ab]

Forages		Additives					
Alfalfa	Wheat straw	None	Molasses[cd]	Inoculant[ef]	Molasses + Inoculant[g]	Average[h]	SE
- - - - %[b] - - - -		- - - - - - % - - - - - -					
100	0	.93	10.52	.86	11.32	5.91	.22
75	25	.84	8.53	.59	9.08	4.76	.22
50	50	1.20	6.21	.70	7.86	3.99	.22
25	75	3.94	4.72	2.16	4.85	3.92	.22
0	100[i]	1.68	1.96	1.91	3.07	2.15	.22
0	100 (urea treated)[i]	.49	.35	.57	.59	.50[j]	.22
Average		1.51	5.38	1.13	6.13		

[a]Each value represents the mean of six samples.
[b]DM basis.
[c]Forages x molasses interaction ($P < .01$).
[d]Effect of molasses ($P < .01$).
[e]Forages x inoculant interaction ($P < .01$).
[f]Effect of inoculant ($P < .05$).
[g]Molasses x inoculant interaction ($P < .01$).
[h]Linear effect of proportion of forages ($P < .01$).
[i]Water was added to achieve 60% DM.
[j]Effect of urea ($P < .01$).

molasses as an additive increased ($P < .01$) the lactic acid production (Figure 1). The effect decreased as proportion of alfalfa decreased (forage x molasses, $P < .01$). The microbial inoculant alone containing *Lactobacillus plantarum* and *Streptococcus faecium* decreased ($P < .05$) lactic acid content in the silages, compared to untreated silages. The effect of molasses was enhanced by inoculant (molasses x inoculant, $P < .01$). Ely et al. (1981) and Hinds et al. (1985) found that inoculated silages had lower pH and higher lactic acid. Ohyama et al. (1973) reported that inoculation with *L. plantarum* did not affect silage quality. Luther (1986) reported that use of inoculant did not show significant improvement in fermentation characteristics of whole corn plant silage. Steen et al. (1989) reported that silage fermentation was similar between untreated and inoculant (*L. Plantarum*) treated grass silages. Shockey et al. (1988) reported that inoculation did not affect changes in pH or lactic acid of ensiled poor quality alfalfa. Muck et al. (1988) reported that number of lactic acid bacteria required for an immediate drop in pH is approximately 10^8/g of the forage. This concentration is greater than that supplied by the inoculants and inoculant success depends upon adequate substrate. Singh et al. (1984) reported increased lactic acid from addition of 5% molasses to berseem and wheat straw (80:20, fresh basis). Lanigan (1961) reported that ensiling alfalfa in laboratory silos with molasses increased lactic acid content. In the present study urea treatment of wheat straw decreased ($P < .01$) lactic acid. Oji et al. (1977) reported negligible amount of lactic acid was found with ammoniated corn stover.

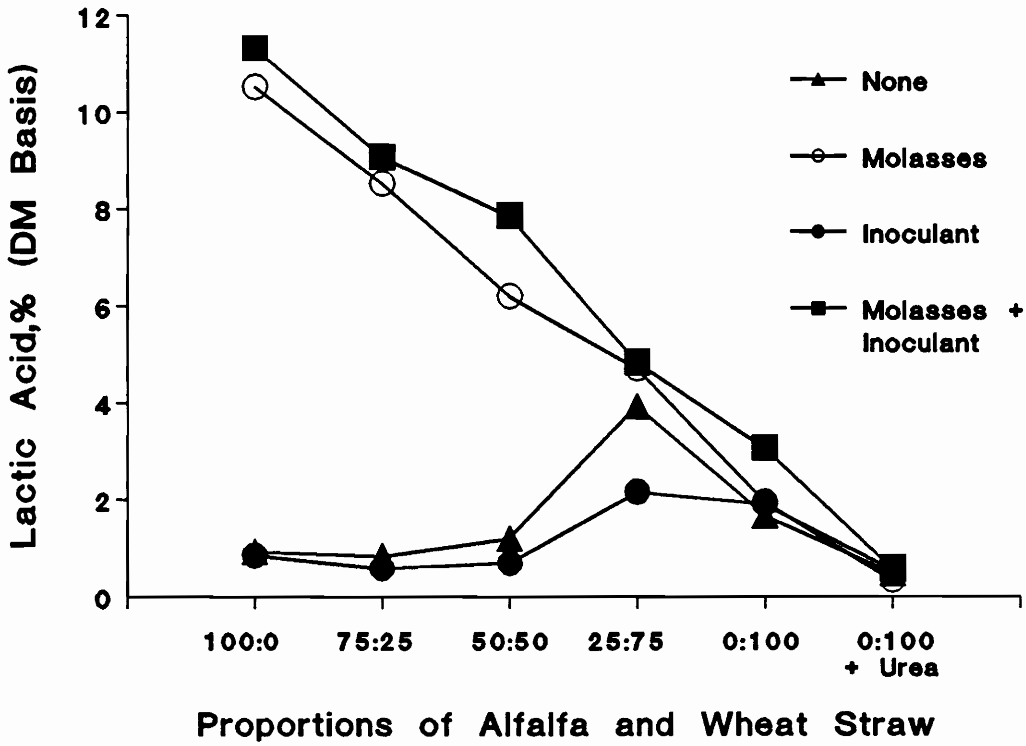

FIGURE 1. LACTIC ACID CONTENT OF DIFFERENT PROPORTIONS OF ALFALFA AND WHEAT STRAW ENSILED ALONE AND WITH DIFFERENT ADDITIVES

Water Soluble Carbohydrates. Water soluble carbohydrate content in initial (pre-ensiled) mixtures increased ($P < .01$) linearly with an increase in alfalfa level (Table 5). Addition of molasses increased ($P < .01$) the WSC content in initial mixtures. The values were within the range of 5.7 to 21.31 and were better than the range of 6 to 8% reported for adequate preservation (McCullough, 1977). In the present study when molasses was added alone the WSC agreed closely to the calculated values. When molasses was added in combination with inoculum, the WSC content differed considerably from the calculated values. On the average, WSC decreased ($P < .01$) after ensiling for all forages except the urea-treated straw (Table 6). The magnitude of decreases agreed generally with the lactic acid levels.

Volatile Fatty Acids. Total VFA content of ensiled mixtures decreased ($P < .01$) linearly with the increase in the level of wheat straw in the mixtures (Table 7). These results agree with the findings of Singh and Rekib (1986) who reported a negative correlation between DM of the ensiled berseem after 0, 2, 4 and 5 h of wilting and oat fodder after 0, 2 and 3 h of wilting ensiled alone and in 2:1, 1:1 and 1:2 proportions. In the present study adding molasses reduced ($P < .01$) total VFA concentration in the silages. The effect was more pronounced with higher proportions of alfalfa (forage x molasses interaction, $P < .01$). There was a forage x inoculant interaction ($P < .05$). The VFA production for urea-treated straw was higher ($P < .01$) than untreated straw; the effect was mostly apparent for the straw to which molasses was added.

TABLE 5. WATER SOLUBLE CARBOHYDRATE CONTENT OF DIFFERENT PROPORTIONS OF ALFALFA AND WHEAT STRAW WITH AND WITHOUT DIFFERENT ADDITIVES (PRE-ENSILED)[a,b]

Forages		Additives					
Alfalfa	Wheat straw	None	Molasses[c,d]	Inoculant[e,f]	Molasses + Inoculant[g]	Average[h]	SE
%[b]		%					
100	0	8.34	15.49	7.36	21.31	13.12	.59
75	25	6.45	11.13	6.13	21.09	11.20	.59
50	50	4.95	9.90	4.63	10.91	7.59	.59
25	75	3.81	9.76	4.15	7.31	6.25	.59
0	100[i]	3.51	5.70	3.61	13.08	6.47	.59
0	100 (urea treated)[i]	3.31	6.75	4.54	7.87	5.61[j]	
Average		5.06	9.79	5.91	13.59	8.37	

[a]Each value represents the mean of six samples.
[b]DM basis.
[c]Forages x molasses interaction ($P < .01$).
[d]Effect of molasses ($P < .01$).
[e]Forages x inoculant interaction ($P < .01$).
[f]Effect of inoculant ($P < .05$).
[g]Molasses x inoculant interaction ($P < .01$).
[h]Linear effect of proportion of forages ($P < .01$).
[i]Water was added to achieve 60% DM.
[j]Effect of urea ($P < .05$).

TABLE 6. WATER SOLUBLE CARBOHYDRATE CONTENT OF DIFFERENT PROPORTIONS OF ALFALFA AND WHEAT STRAW ENSILED WITH AND WITHOUT DIFFERENT ADDITIVES[a,b]

Forages		Additives					
Alfalfa	Wheat straw	None	Molasses[c,d]	Inoculant[f]	Molasses + Inoculant	Average[e]	SE
- - - %[b] - - -		- - - % - - -					
100	0	2.54	4.36	2.73	4.75	3.60	.50
75	25	2.45	3.80	3.08	4.70	3.51	.50
50	50	2.55	4.12	4.56	5.21	4.11	.50
25	75	2.74	3.90	3.26	4.63	3.63	.50
0	100[g]	3.07	3.56	3.40	3.72	3.43	.50
0	100 (urea treated)[g]	4.90	4.23	5.84	5.98	5.24[h]	.50
Average		3.04	3.99	3.81	4.83	3.92	

[a]Each value represents the mean of six samples.
[b]DM basis.
[c]Forages x molasses interaction ($P < .05$).
[d]Effect of molasses ($P < .01$).
[e]Effect of proportion of forages ($P < .01$).
[f]Effect of inoculant ($P < .01$).
[g]Water was added to achieve 60% DM.
[h]Effect of urea ($P < .01$).

TABLE 7. TOTAL VOLATILE FATTY ACID CONTENT OF DIFFERENT PROPORTIONS OF ALFALFA AND WHEAT STRAW ENSILED WITH AND WITHOUT DIFFERENT ADDITIVES[a,b]

Forages		Additives					
Alfalfa	Wheat straw	None	Molasses[c,d]	Inoculant[e]	Molasses + Inoculant	Average[f]	SE
- - - - %[b] - - - -		- - - - - - % - - - - - -					
100	0	11.21	1.98	12.21	2.94	7.09	.56
75	25	10.71	1.76	10.27	2.62	6.34	.56
50	50	7.78	2.00	4.86	2.27	4.23	.56
25	75	.47	.48	3.29	.73	1.24	.56
0	100[g]	.13	.17	.35	.25	.23	.56
0	100 (urea treated)[g]	.30	6.25	.23	6.17	3.24[h]	.56
Average		5.01	2.11	5.20	2.50	3.73	

[a]Each value represents the mean of six samples.
[b]DM basis.
[c]Forages x molasses interaction ($P < .01$).
[d]Effect of molasses ($P < .01$).
[e]Forages x inoculant interaction ($P < .05$).
[f]Linear effect of proportion of forages ($P < .01$).
[g]Water was added to achieve 60% DM level.
[h]Effect of urea ($P < .01$).

Acetic acid was the major VFA for all silages (Table 8). As shown in table 8, acetic acid content decreased ($P < .01$) linearly with the increase in proportion of wheat straw. The effects of treatments on acetic acid were similar to the effects on total VFA. Acetic acid levels were decreased ($P < .01$) by addition of molasses, and inoculant had no marked effect. This is in agreement with Catchpoole and Henzell (1971) who found that tropical crops ensiled without wilting gave relatively high content of acetic acid, unless additional fermentable carbohydrates such as molasses was added. Urea treatment of wheat straw increased ($P < .01$) the acetic acid concentration, especially when molasses was added (Figure 2). Similar findings were reported by Oji et al. (1977) that NH_3 treatment of corn stover increased ($P < .05$) the acetic acid content.

Propionic acid concentrations were low for all silages (Table 9). The level decreased ($P < .01$) linearly with the increase in proportion of straw. Addition of molasses as an additive decreased ($P < .01$) the propionic acid concentration. Interactions were recorded for forages x molasses ($P < .01$) and forages x inoculant ($P < .01$).

No significant differences were found in isobutyric acid concentration (Table 10). There was a quadratic ($P < .05$) effect of forages on butyric acid concentration (Table 11) and a linear ($P < .01$) effect of forages on isovaleric concentration of the silages (Table 12).

Dry Matter Recovery. The DM recovery tended to increase linearly with the increase in wheat straw level in the mixtures but differences were small (Table 13). Average recovery exceeded 94%. Addition of

TABLE 8. ACETIC ACID CONTENT OF DIFFERENT PROPORTIONS OF ALFALFA AND WHEAT STRAW ENSILED WITH AND WITHOUT DIFFERENT ADDITIVES[a,b]

Forages		Additives					
Alfalfa	Wheat straw	None	Molasses[c,d]	Inoculant[e]	Molasses + Inoculant	Average[f]	SE
% [b]		%					
100	0	11.05	1.95	12.01	2.39	6.85	.57
75	25	10.58	1.46	10.16	1.78	6.00	.57
50	50	7.57	1.89	4.60	2.08	4.04	.57
25	75	.38	.46	3.14	.57	1.14	.57
0	100[g]	.09	.14	.35	.06	.16	.57
0	100 (urea treated)[g]	.22	6.22	.13	6.16	3.18[h]	.57
Average		4.98	2.02	5.06	2.17	3.56	

[a] Each value represents the mean of six samples.
[b] DM basis.
[c] Forages x molasses interaction ($P < .01$).
[d] Effect of molasses ($P < .01$).
[e] Forages x inoculant interaction ($P < .05$).
[f] Linear effect of proportion of forages ($P < .01$).
[g] Water was added to achieve 60% DM.
[h] Effect of urea ($P < .01$).

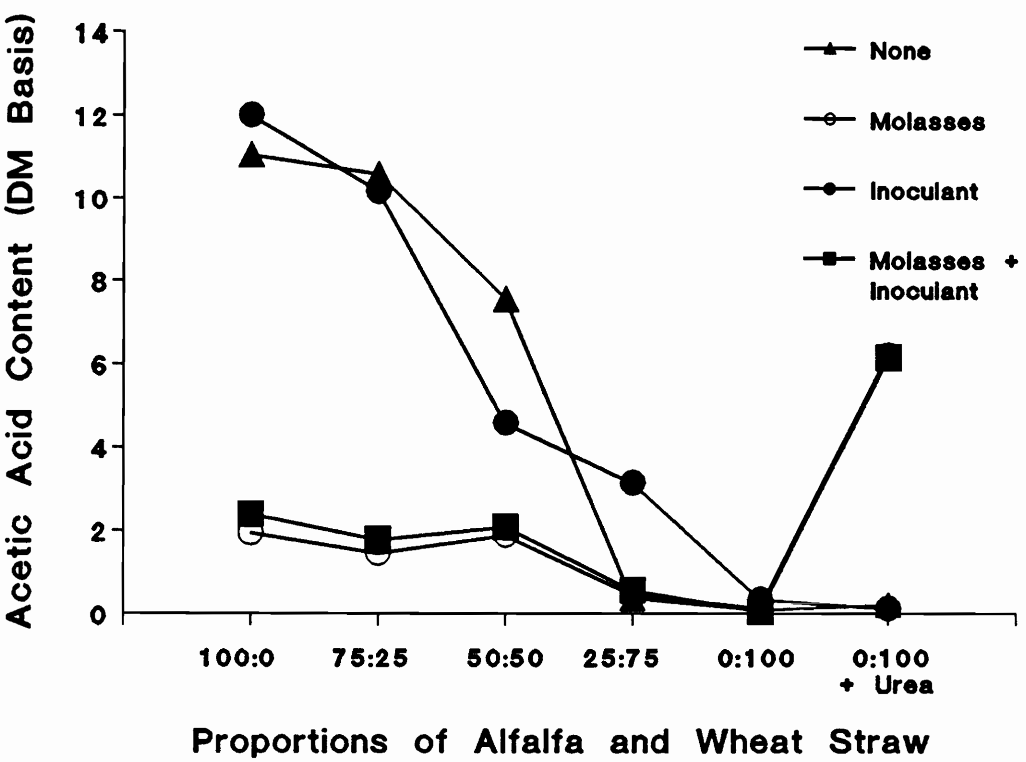

FIGURE 2. ACETIC ACID CONTENT OF DIFFERENT PROPORTIONS OF ALFALFA AND WHEAT STRAW ENSILED ALONE AND WITH DIFFERENT ADDITIVES

TABLE 9. PROPIONIC ACID CONTENT OF DIFFERENT PROPORTIONS OF ALFALFA AND WHEAT STRAW ENSILED WITH AND WITHOUT DIFFERENT ADDITIVES[ab]

Forages		Additives					
Alfalfa	Wheat straw	None	Molasses[cd]	Inoculant[e]	Molasses + Inoculant	Average[f]	SE
%		%					
100	0	.16	.03	.21	.02	.10	.03
75	25	.13	.10	.11	.04	.10	.03
50	50	.21	.05	.10	.00	.09	.03
25	75	.09	.02	.03	.01	.04	.03
0	100[g]	.04	.03	.01	.01	.02	.03
0	100 (urea treated)[g]	.01	.02	.02	.01	.01	.03
Average		.11	.04	.08	.01	.06	

[a]Each value represents the mean of six samples.
[b]DM basis.
[c]Forages x molasses interaction ($P < .01$).
[d]Effect of molasses ($P < .01$).
[e]Forages x inoculant interaction ($P < .01$).
[f]Linear effect of proportion of forages ($P < .01$).
[g]Water was added to achieve 60% DM.

TABLE 10. ISOBUTYRIC ACID CONTENT OF DIFFERENT PROPORTIONS OF ALFALFA AND WHEAT STRAW ENSILED WITH AND WITHOUT DIFFERENT ADDITIVES[ab]

Forages		Additives					
Alfalfa	Wheat straw	None	Molasses	Inoculant	Molasses + Inoculant	Average	SE
- - - %[b] - - -		- - - % - - -					
100	0	.00	.00	.00	.00	.00	.04
75	25	.00	.20	.00	.00	.05	.04
50	50	.00	.02	.04	.10	.04	.04
25	75	.00	.00	.05	.02	.02	.04
0	100[c]	.00	.00	.00	.18	.05	.04
0	100 (urea treated)[c]	.03	.00	.03	.00	.02	.04
Average		.00	.03	.01	.00	.03	

[a]Each value represents the mean of six samples.
[b]DM basis.
[c]Water was added to achieve 60% DM.

TABLE 11. BUTYRIC ACID CONTENT OF DIFFERENT PROPORTIONS OF ALFALFA AND WHEAT STRAW ENSILED WITH AND WITHOUT DIFFERENT ADDITIVES[a,b]

Forages		Additives					
Alfalfa	Wheat straw	None	Molasses	Inoculant	Molasses + Inoculant	Average[c]	SE
- - - %[b] - - -		- - - % - - -					
100	0	.00	.00	.00	.00	.00	.02
75	25	.00	.00	.00	.02	.00	.02
50	50	.00	.02	.05	.09	.04	.02
25	75	.00	.00	.04	.07	.03	.02
0	100[d]	.00	.00	.00	.00	.00	.02
0	100 (urea treated)[d]	.00	.00	.00	.00	.00	.02
Average		.00	.00	.05	.03	.01	

[a]Each value represents the mean of six samples.
[b]DM basis.
[c]Quadratic effect of proportion of forages ($P < .05$).
[d]Water was added to achieve 60% DM.

TABLE 12. ISOVALERIC ACID CONTENT OF DIFFERENT PROPORTIONS OF ALFALFA AND WHEAT STRAW ENSILED WITH AND WITHOUT DIFFERENT ADDITIVES[ab]

Forages[c]		Additives					
Alfalfa	Wheat straw	None	Molasses	Inoculant	Molasses + Inoculant	Average[c]	SE
- - - %[b] - - -		- - - % - - -					
100	0	.00	.00	.00	.54	.13	.09
75	25	.00	.00	.00	.78	.19	.09
50	50	.00	.01	.06	.00	.02	.09
25	75	.00	.00	.03	.06	.02	.09
0	100[d]	.00	.00	.00	.00	.00	.09
0	100 (urea treated)[d]	.03	.01	.04	.00	.02	.09
Average		.00	.00	.02	.23	.06	

[a]Each value represents the mean of six samples.
[b]DM basis.
[c]Linear effect of proportion of forages ($P < .01$).
[d]Water was added to achieve 60% DM.

TABLE 13. DRY MATTER RECOVERY OF DIFFERENT PROPORTIONS OF ALFALFA AND WHEAT STRAW ENSILED WITH AND WITHOUT DIFFERENT ADDITIVES[ab]

Forages		Additives					
Alfalfa	Wheat straw	None	Molasses[cd]	Inoculant[ef]	Molasses + Inoculant	Average	SE
- - - - - - - - %[b] - - - - - - - -		- - - - - - - - - - - % - - - - - - - - - - - -					
100	0	92.57	96.69	89.28	96.31	93.71	.97
75	25	93.36	96.72	90.88	94.61	93.89	.97
50	50	93.77	96.97	91.04	95.33	94.28	.97
25	75	94.68	98.17	91.42	94.49	94.69	.97
0	100[g]	94.97	93.72	94.71	95.16	94.64	.97
0	100 (urea treated)[g]	93.19	91.57	91.95	96.08	93.20[h]	.97
Average		93.76	95.64	91.55	95.33	94.07	

[a]Each value represents the mean of six samples.
[b]DM basis.
[c]Forages x molasses interaction ($P < .01$).
[d]Effect of molasses ($P < .01$).
[e]Forages x inoculant interaction ($P < .01$).
[f]Effect of inoculant ($P < .01$).
[g]Water was added to achieve 60% DM.
[h]Effect of urea ($P < .05$).

molasses increased (P < .01) the DM recovery. There was an interaction (P < .01) between forages and molasses. Microbial inoculant decreased (P < .01) the DM recovery in the silages, especially when no molasses was used. The results were not in agreement with Ely et al. (1981) who reported greater DM recovery in alfalfa and wheat straw silage mixtures inoculated with *Lactobacillus plantarum*. Waldo and Goering (1976) reported DM recoveries for control and lactobacillus culture treated alfalfa silages were 85.8 and 85.6%, respectively, for alfalfa, 97.4 and 97.1% for orchardgrass and 98.2 and 99.5% for corn. The DM recoveries of different proportions of alfalfa and wheat straw were slightly higher in our study than in that of Waldo and Goering (1976) who reported DM recoveries of 85.8 and 85.6% for untreated and Lactobacillus culture-treated alfalfa silage. In our study urea treatment decreased (P < .05) the DM recovery (94.6 vs 93.2%).

Chemical Composition

Dry Matter. The DM content of pre-ensiled mixtures is shown in Table 14 and for ensiled mixtures in Table 15. Overall, there were no significant (P < .05) differences between the DM content of pre-ensiled and ensiled mixtures. The DM content increased (P < .01) linearly with the level of wheat straw in the pre- and post-ensiled mixtures. This reflects the lower DM content in alfalfa than wheat straw. Addition of dry molasses increased (P < .01) the DM content in the silages, a reflection of higher DM for molasses than the mixtures. The forage x molasses interaction was significant (P < .01). Addition of inoculant had no effect.

TABLE 14. DRY MATTER CONTENT OF DIFFERENT PROPORTIONS OF ALFALFA AND WHEAT STRAW WITH AND WITHOUT DIFFERENT ADDITIVES (PRE-ENSILED)[a]

Forages		Additives					
Alfalfa	Wheat straw	None	Molasses[bc]	Inoculant[d]	Molasses + Inoculant[e]	Average[f]	SE
- - - %[g] - - -		- - - % - - -					
100	0	20.68	24.39	21.18	24.81	22.76	.43
75	25	25.08	29.05	25.95	28.29	27.09	.43
50	50	32.10	35.82	33.19	36.03	34.29	.43
25	75	49.69	48.67	50.64	52.61	50.41	.43
0	100[h]	53.97	57.46	53.96	55.39	55.19	.43
0	100 (urea treated)[h]	53.55	57.18	54.47	54.89	55.02	.43
Average		39.18	42.09	39.90	42.00	40.79	

[a]Each value represents the mean of six samples.
[b]Forages x molasses interaction ($P < .01$).
[c]Effect of molasses ($P < .01$).
[d]Forages x inoculant interaction ($P < .01$).
[e]Molasses x inoculant interaction ($P < .05$).
[f]Linear effect of proportion of forages ($P < .01$).
[g]DM basis.
[h]Water was added to achieve 60% DM.

TABLE 15. DRY MATTER CONTENT OF DIFFERENT PROPORTIONS OF ALFALFA AND WHEAT STRAW ENSILED WITH AND WITHOUT DIFFERENT ADDITIVES[a]

Forages		Additives					
Alfalfa	Wheat straw	None	Molasses[bc]	Inoculant	Molasses + Inoculant	Average[d]	SE
- - - - %[e] - - - -		- - - - % - - - -					
100	0	19.54	24.51	19.30	24.56	21.98	.51
75	25	23.77	29.08	24.03	27.28	26.04	.51
50	50	31.88	35.17	30.77	35.41	33.31	.51
25	75	47.44	50.04	47.68	50.57	48.33	.51
0	100[f]	54.08	55.64	52.65	54.43	54.20	.51
0	100 (urea treated)[f]	51.21	54.36	52.30	53.41	52.82[g]	.51
Average		37.99	41.47	37.79	40.94	39.45	

[a]Each value represents the mean of six samples.
[b]Forages x molasses interaction ($P < .01$).
[c]Effect of molasses ($P < .01$).
[d]Linear effect of proportion of forages ($P < .01$).
[e]DM basis.
[f]Water was added to achieve 60% DM.
[g]Effect of urea ($P < .01$).

Crude Protein. The CP content increased linearly ($P < .01$) with the increase in proportion of alfalfa in pre-ensiled (Table 16) and ensiled mixtures (Table 17). There were no significant differences between CP content of pre-ensiled and ensiled mixtures. Addition of molasses to silages decreased ($P < .05$) the CP content in the silages, reflecting the lower CP of molasses than the mixtures. Addition of inoculant did not affect CP of pre-ensiled mixtures, but increased ($P < .05$) the CP of ensiled mixtures. Urea treatment of wheat straw increased ($P < .01$) the CP content (14.35 vs 2.87%, DM basis). Increased N content by urea treatment was reported for rice straw (Ibrahim et al., 1986; Jayasuriya and Pearce, 1983) and urea-treated wheat straw (Dias-Da-Silva and Sundstol, 1986). Solaiman et al. (1979) treated wheat straw with 3.3% NH_4OH and reported an increased N content. Herera-Saldana et al. (1982) treated wheat straw with 5% NH_3 and reported that ammoniation increased the CP content from 3.6 to 8.1%. Increased N content in ammoniated wheat straw was also reported by Birkelo et al. (1986) and Zorilla-Rios et al. (1985). Lawlor and O'Shea (1979) reported that 3.3% anhydrous NH_3 treatment of barley increased CP from 3.1 to 7.6%. Cloete and Kritzinger (1984b) reported that urea supplementation and urea treatment increased the crude protein content of wheat straw from 3.1 to 8.9 and 9.7%, respectively.

Ash. The ash content of pre-ensiled (Table 18) and ensiled (Table 19) mixtures were similar. Ash content increased linearly ($P < .01$) with the increase in alfalfa level. This reflected high ash content in alfalfa. Microbial inoculant increased ($P < .01$) the ash content in

TABLE 16. CRUDE PROTEIN CONTENT OF DIFFERENT PROPORTIONS OF ALFALFA AND WHEAT STRAW WITH AND WITHOUT DIFFERENT ADDITIVES (PRE-ENSILED)[ab]

Forages		Additives					
Alfalfa	Wheat straw	None	Molasses[cd]	Inoculant	Molasses + Inoculant[e]	Average[f]	SE
- - - %[b] - - -		- - - - % - - - -					
100	0	21.96	19.40	21.62	19.54	20.63	.27
75	25	17.00	15.69	16.45	15.77	16.23	.27
50	50	12.55	11.89	12.58	12.25	12.31	.27
25	75	7.70	8.15	7.48	7.70	7.76	.27
0	100[g]	2.68	3.40	3.01	3.85	3.24	.27
0	100 (urea treated)[g]	17.50	16.32	16.14	17.34	16.82[h]	.27
Average		13.23	12.47	12.88	12.74	12.83	

[a]Each value represents the mean of six samples.
[b]DM basis.
[c]Forages x molasses interaction ($P < .01$).
[d]Effect of molasses ($P < .01$).
[e]Molasses x inoculant interaction ($P < .01$).
[f]Linear effect of proportion of forages ($P < .01$).
[g]Water was added to achieve 60% DM.
[h]Effect of urea ($P < .01$).

TABLE 17. CRUDE PROTEIN CONTENT OF DIFFERENT PROPORTIONS OF ALFALFA AND WHEAT STRAW ENSILED WITH AND WITHOUT DIFFERENT ADDITIVES[a,b]

Forages		Additives					
Alfalfa	Wheat straw	None	Molasses[c,d]	Inoculant[e]	Molasses + Inoculant	Average[f]	SE
- - - - %[b] - - - -		- - - - - - % - - - - - -					
100	0	22.66	19.96	24.22	19.83	21.67	.35
75	25	18.60	15.68	17.86	17.23	17.34	.35
50	50	12.52	12.09	13.89	12.48	12.74	.35
25	75	7.93	7.83	8.21	8.16	8.03	.35
0	100[g]	2.87	3.98	3.07	3.87	3.45	.35
0	100 (urea treated)[g]	14.35	17.14	13.37	17.46	15.58[h]	.35
Average		13.15	12.78	13.44	13.17	13.13	

[a]Each value represents the mean of six samples.
[b]DM basis.
[c]Forages x molasses interaction ($P < .01$).
[d]Effect of molasses ($P < .05$).
[e]Effect of inoculant ($P < .05$).
[f]Linear effect of proportion of forages ($P < .01$).
[g]Water was added to achieve 60% DM.
[h]Effect of urea ($P < .01$).

TABLE 18. ASH CONTENT OF DIFFERENT PROPORTIONS OF ALFALFA AND WHEAT STRAW WITH AND WITHOUT DIFFERENT ADDITIVES (PRE-ENSILED)[ab]

Forages		Additives					
Alfalfa	Wheat straw	None	Molasses[cd]	Inoculant	Molasses + Inoculant[e]	Average[f]	SE
- - - - %[b] - - - -		- - - - - - % - - - - - -					
100	0	10.93	10.38	11.05	11.20	10.89	.16
75	25	9.92	9.07	9.07	10.02	9.52	.16
50	50	8.03	7.58	7.58	8.05	7.81	.16
25	75	5.45	5.90	5.34	5.80	5.62	.16
0	100[g]	3.51	4.00	3.56	4.11	3.79	.16
0	100 (urea treated)[g]	3.28	3.62	3.32	3.87	3.52[h]	.16
Average		6.85	6.76	6.65	7.17	6.86	

[a]Each value represents the mean of six samples.
[b]DM basis.
[c]Forages x molasses interaction ($P < .01$).
[d]Effect of molasses ($P < .01$).
[e]Molasses x inoculant interaction ($P < .01$).
[f]Linear effect of proportion of forages ($P < .01$).
[g]Water was added to acahieve 60% DM.
[h]Effect of urea ($P < .05$).

TABLE 19. ASH CONTENT OF DIFFERENT PROPORTIONS OF ALFALFA AND WHEAT STRAW ENSILED WITH AND WITHOUT DIFFERENT ADDITIVES[a,b]

Forages		Additives					
Alfalfa	Wheat straw	None	Molasses[c,d]	Inoculant[e,f]	Molasses + Inoculant	Average[g]	SE
- - - - %[b] - - - -		- - - - - - % - - - - - -					
100	0	11.91	10.37	11.76	10.96	11.25	.22
75	25	9.59	8.62	10.33	9.97	9.63	.22
50	50	7.44	7.48	8.04	7.46	7.61	.22
25	75	5.22	5.39	5.29	5.52	5.35	.22
0	100[h]	3.69	3.70	3.41	3.79	3.65	.22
0	100 (urea treated)[h]	3.29	3.68	3.51	3.94	3.61	.22
Average		6.86	6.54	7.06	6.94	6.85	

[a]Each value represents the mean of six samples.
[b]DM basis.
[c]Forages x molasses interaction ($P < .01$).
[d]Effect of molasses ($P < .05$).
[e]Forages x inoculant interaction ($P < .05$).
[f]Effect of inoculant ($P < .01$).
[g]Linear effect of proportion of forages ($P < .01$).
[h]Water was added to achieve 60% DM.

ensiled mixtures and there was interaction between forages and inoculant ($P < .05$).

Neutral Detergent Fiber. The NDF content of pre-ensiled mixtures (Table 20) and silages (Table 21) increased ($P < .01$) linearly with the increase in wheat straw level, due to higher NDF in wheat straw than alfalfa (Table 1). Urea treatment decreased ($P < .01$) the NDF content in pre-ensiled mixtures and tended to decrease the NDF content of ensiled mixtures. Addition of molasses decreased ($P < .01$) the NDF content, resulting from a dilution effect. Decreased NDF content by ammoniation has been reported for wheat straw (Solaiman et al., 1979) and barley straw (Naseer, 1990).

Acid Detergent Fiber. The ADF content for pre-ensiled mixtures is shown in Table 22 and for ensiled mixtures in Table 23. The ADF content increased ($P < .01$) linearly with the increased wheat straw in the mixtures, reflecting the higher ADF in wheat straw than alfalfa. Urea treatment increased ($P < .01$) the ADF content in the ensiled straw. Molasses treatment decreased ($P < .01$) the ADF content and there was a forages x molasses interaction ($P < .01$). Increased ADF content by urea treatment does not agree with results of Zorilla-Rios et al. (1985) who reported slightly decreased (38.6 vs 37.7%) ADF content for untreated and NH_3-treated wheat straw. However, our finding agrees with Solaiman et al. (1979) and Cloete and Kritzenger (1984b). Cloete and Kritzinger (1984b) reported slightly increased ADF by urea-ammoniation. Solaiman et al. (1979) related the increase of ADF in ammoniated roughages to a

TABLE 20. NEUTRAL DETERGENT FIBER OF DIFFERENT PROPORTIONS OF ALFALFA AND WHEAT STRAW WITH AND WITHOUT DIFFERENT ADDITIVES (PRE-ENSILED)[a][b]

Forages		Additives					
Alfalfa	Wheat straw	None	Molasses[c]	Inoculant[de]	Molasses + Inoculant	Average[f]	SE
- - - %[b] - - -		- - - - - % - - - - -					
100	0	42.95	40.10	41.66	39.20	40.98	.98
75	25	49.88	49.87	52.55	46.09	49.60	.98
50	50	60.68	55.90	58.51	52.20	56.82	.98
25	75	69.77	65.13	69.36	65.86	67.53	.98
0	100[g]	81.50	76.15	75.77	72.51	76.48	.98
0	100 (urea treated)[g]	79.44	72.43	75.69	70.62	74.62[h]	.98
Average		63.92	59.93	62.26	57.74	61.00	

[a]Each value represents the mean of six samples.
[b]DM basis.
[c]Effect of molasses ($P < .01$).
[d]Forages x inoculant interaction ($P < .05$).
[e]Effect of inoculant ($P < .01$).
[f]Linear effect of proportion of forages ($P < .01$).
[g]Water was added to achieve 60% DM.
[h]Effect of urea ($P < .01$).

TABLE 21. NEUTRAL DETERGENT FIBER OF DIFFERENT PROPORTIONS OF ALFALFA AND WHEAT STRAW ENSILED WITH AND WITHOUT DIFFERENT ADDITIVES[ab]

Forages		Additives					
Alfalfa	Wheat straw	None	Molasses[c]	Inoculant	Molasses + Inoculant	Average[d]	SE
- - - %[b] - - -		- - - % - - -					
100	0	44.35	42.08	45.64	41.76	43.46	1.00
75	25	53.54	49.74	53.90	48.86	51.51	1.00
50	50	62.68	58.57	66.62	57.69	61.39	1.00
25	75	70.23	67.90	72.46	67.46	69.52	1.00
0	100[e]	79.88	76.54	78.97	76.89	78.07	1.00
0	100 (urea treated)[e]	79.25	76.27	78.59	76.46	77.64	1.00
Average		64.99	61.85	66.03	61.52	63.60	

[a]Each value represents the mean of six samples.
[b]DM basis.
[c]Effect of molasses ($P < .01$).
[d]Linear effect of proportion of forages ($P < .01$).
[e]Water was added to achieve 60% DM.

TABLE 22. ACID DETERGENT FIBER OF DIFFERENT PROPORTIONS OF ALFALFA AND WHEAT STRAW WITH AND WITHOUT DIFFERENT ADDITIVES (PRE-ENSILED)[a,b]

Forages		Additives					
Alfalfa	Wheat straw	None	Molasses[c]	Inoculant[d]	Molasses + Inoculant	Average[e]	SE
- - - - - - - - %[b] - - - - - - -		- - - - - - - - - - % - - - - - - - - - - - -					
100	0	34.37	31.02	33.13	32.12	32.66	.63
75	25	36.36	34.91	36.75	34.75	35.69	.63
50	50	40.65	38.11	40.48	38.31	39.39	.63
25	75	43.91	41.94	43.64	43.73	43.30	.63
0	100[f]	48.12	46.73	50.08	46.70	47.91	.63
0	100 (urea treated)[f]	46.74	44.73	48.29	45.96	46.43[g]	.63
Average		41.69	39.57	42.06	40.26	40.90	

[a]Each value represents the mean of six samples.
[b]DM basis.
[c]Effect of molasses ($P < .01$).
[d]Effect of inoculant ($P < .05$).
[e]Linear effect of proportion of forages ($P < .01$).
[f]Water was added to achieve 60% DM.
[g]Effect of urea ($P < .01$).

TABLE 23. ACID DETERGENT FIBER CONTENT OF DIFFERENT PROPORTIONS OF ALFALFA AND WHEAT STRAW ENSILED WITH AND WITHOUT DIFFERENT ADDITIVES[ab]

Forages		Additives					
Alfalfa	Wheat straw	None	Molasses[cd]	Inoculant	Molasses + Inoculant	Average[e]	SE
- - - - %[b] - - - -		- - - - - - % - - - - - -					
100	0	41.55	36.04	41.08	36.33	38.75	.80
75	25	44.43	39.87	41.66	38.70	41.16	.80
50	50	46.59	43.57	46.75	42.50	44.85	.80
25	75	46.24	47.47	48.92	45.08	46.93	.80
0	100[f]	52.00	49.90	50.53	49.27	50.43	.80
0	100 (urea treated)[f]	52.96	50.99	53.07	51.35	52.09[g]	.80
Average		47.29	44.64	47.00	43.87	45.70	

[a]Each value represents the mean of six samples.
[b]DM basis.
[c]Forages x molasses interaction ($P < .01$).
[d]Effect of molasses ($P < .01$).
[e]Linear effect of proportion of forages ($P < .01$).
[f]Water was added to achieve 60% DM.
[g]Effect of urea ($P < .01$).

dilution effect caused by solubilization of hemicellulose from ammoniated roughage.

Lignin. The lignin content of pre-ensiled mixtures is given in Table 24 and silages in Table 25. The lignin content did not show consistent trends in pre-ensiled mixtures, but in ensiled mistures the level decreased linearly ($P < .01$) with increase in wheat straw. Addition of molasses decreased ($P < .01$) the lignin content in pre-ensiled and ensiled mixtures, undoubtedly a dilution effect.

Cellulose. The cellulose content in the mixtures increased ($P < .01$) linearly with the increase in the level of wheat straw in the forage in pre-ensiled (Table 26) and ensiled mixtures (Table 27). Addition of molasses decreased ($P < .01$) the cellulose content in both cases.

Hemicellulose. The hemicellulose content for pre-ensiled mixtures (Table 28) and ensiled mixtures (Table 29) increased linearly ($P < .01$) with the increase in wheat straw in the mixtures. Microbial inoculant and molasses decreased ($P < .05$) the hemicellulose content in pre-ensiled and ensiled mixtures, probably due to dilution. Urea treatment of wheat straw decreased ($P < .01$) the hemicellulose content of ensiled straw, as compared to untreated wheat straw. This is in agreement with Cloete and Kritzinger (1984b) who reported that hemicellulose content tended to decrease slightly due to ammoniation. Similar reductions in hemicellulose content of ammoniated low quality roughages have been reported (Ibrahim and Pearce, 1983). Naseer (1990) reported that hemicellulose and NDF were slightly decreased ($P < .05$) in ammoniated

TABLE 24. LIGNIN CONTENT OF DIFFERENT PROPORTIONS OF ALFALFA AND WHEAT STRAW WITH AND WITHOUT DIFFERENT ADDITIVES (PRE-ENSILED)[a,b]

Forages		Additives					
Alfalfa	Wheat straw	None	Molasses[c]	Inoculant[d]	Molasses + Inoculant[e]	Average[f]	SE
% [b]		%					
100	0	10.22	8.97	9.80	8.93	9.48	.30
75	25	10.00	8.95	9.55	9.90	9.60	.30
50	50	9.79	8.77	9.93	9.70	9.55	.30
25	75	9.84	8.81	9.35	9.67	9.42	.30
0	100[g]	10.30	9.11	10.54	9.98	9.98	.30
0	100 (urea treated)[g]	9.09	8.40	9.00	9.23	8.93	.30
Average		9.87	8.83	9.69	9.57	9.43	

[a]Each value represents the mean of six samples.
[b]DM basis.
[c]Effect of molasses ($P < .01$).
[d]Effect of inoculant ($P < .05$).
[e]Molasses x inoculant ($P < .05$).
[f]Effect of proportion of forages ($P < .01$).
[g]Water was added to achieve 60% DM.
[h]Effect of urea ($P < .01$).

TABLE 25. LIGNIN CONTENT OF DIFFERENT PROPORTIONS OF ALFALFA AND WHEAT STRAW ENSILED WITH AND WITHOUT DIFFERENT ADDITIVES[a,b]

Forages		Additives					
Alfalfa	Wheat straw	None	Molasses[c]	Inoculant	Molasses + Inoculant	Average[d]	SE
- - - - %[b] - - - -		- - - - - % - - - - -					
100	0	13.41	11.27	13.21	11.33	12.31	.57
75	25	12.86	11.70	12.18	11.13	11.97	.57
50	50	12.62	11.59	13.05	11.23	12.12	.57
25	75	10.93	11.51	12.06	10.73	11.31	.57
0	100[e]	12.62	11.07	11.47	10.28	11.36	.57
0	100 (urea treated)[e]	11.46	11.41	11.59	11.28	11.43	.57
Average		12.32	11.42	12.26	11.00	11.75	

[a]Each value represents the mean of six samples.
[b]DM basis.
[c]Effect of molasses ($P < .01$).
[d]Linear effect of proportion of forages ($P < .01$).
[e]Water was added to achieve 60% DM.

TABLE 26. CELLULOSE CONTENT OF DIFFERENT PROPORTIONS OF ALFALFA AND WHEAT STRAW WITH AND WITHOUT DIFFERENT ADDITIVES (PRE-ENSILED)[a,b]

Forages		Additives					
Alfalfa	Wheat straw	None	Molasses[c]	Inoculant	Molasses + Inoculant	Average[d]	SE
- - - - %[b] - - - -		- - - - -	- - - - - %	- - - - -	- - - - -		
100	0	21.64	20.89	21.87	21.04	21.36	1.33
75	25	25.08	24.84	25.98	22.95	24.71	1.33
50	50	29.71	24.89	29.50	26.76	27.71	1.33
25	75	32.82	32.05	33.05	31.90	32.45	1.33
0	100[e]	37.27	36.59	38.09	41.23	38.30	1.33
0	100 (urea treated)[e]	36.67	35.35	37.40	34.96	36.09[f]	1.33
Average		30.53	29.10	30.98	29.81	30.10	

[a]Each value represents the mean of six samples.
[b]DM basis.
[c]Effect of molasses ($P < .05$).
[d]Linear effect of proportion of forages ($P < .01$).
[e]Water was added to achieve 60% DM.
[f]Effect of urea ($P < .05$).

TABLE 27. CELLULOSE CONTENT OF DIFFERENT PROPORTIONS OF ALFALFA AND WHEAT STRAW ENSILED WITH AND WITHOUT DIFFERENT ADDITIVES[ab]

Forages		Additives					
Alfalfa	Wheat straw	None	Molasses[c]	Inoculant	Molasses + Inoculant	Average[d]	SE
- - - %[b] - - -		- - - - - % - - - - -					
100	0	26.51	23.94	26.46	23.82	25.18	.63
75	25	30.23	27.32	28.42	28.41	28.60	.63
50	50	32.70	31.57	33.17	30.13	31.89	.63
25	75	34.37	34.71	35.87	33.25	34.55	.63
0	100[e]	38.84	37.68	37.91	37.71	38.04	.63
0	100 (urea treated)[e]	40.63	38.72	40.21	38.90	39.61[f]	.63
Average		33.88	32.32	33.67	32.04	32.98	

[a]Each value represents the mean of six samples.
[b]DM basis.
[c]Effect of molasses ($P < .01$).
[d]Linear effect of proportion of forages ($P < .01$).
[e]Water was added to achieve 60% DM.
[f]Effect of urea ($P < .01$).

TABLE 28. HEMICELLULOSE CONTENT OF DIFFERENT PROPORTIONS OF ALFALFA AND WHEAT STRAW WITH AND WITHOUT DIFFERENT ADDITIVES (PRE-ENSILED)[ab]

Forages		Additives					
Alfalfa	Wheat straw	None	Molasses[cd]	Inoculant[ef]	Molasses + Inoculant	Average[g]	SE
- - - %[b] - - -		- - - % - - -					
100	0	8.58	9.08	9.53	7.08	8.32	.78
75	25	13.52	14.96	15.81	11.34	13.91	.78
50	50	20.03	17.80	18.04	13.89	17.44	.78
25	75[h]	25.87	23.18	25.72	22.14	24.23	.78
0	100[h]	33.38	29.41	25.68	25.81	28.57	.78
0	100 (urea treated)[h]	32.70	27.70	27.40	24.67	28.11	.78
Average		22.35	20.35	20.20	17.49	20.10	

[a]Each value represents the mean of six samples.
[b]DM basis.
[c]Forages x molasses interaction ($P < .05$).
[d]Effect of molasses ($P < .01$).
[e]Forage x inoculant interaction ($P < .01$).
[f]Effect of inoculant ($P < .01$).
[g]Linear effect of proportion of forages ($P < .01$).
[h]Water was added to achieve 60% DM.

TABLE 29. HEMICELLULOSE CONTENT OF DIFFERENT PROPORTIONS OF ALFALFA AND WHEAT STRAW ENSILED WITH AND WITHOUT DIFFERENT ADDITIVES[ab]

Forages		Additives					
Alfalfa	Wheat straw	None	Molasses[cd]	Inoculant[e]	Molasses + Inoculant	Average[f]	SE
- - - - - - - - %[b]	- - - - - - -	- - - - - - - - - - - %	- - - - - - - - - - - -				
100	0	2.80	6.03	4.56	5.43	4.70	.88
75	25	9.11	9.88	12.24	10.16	10.35	.88
50	50	16.08	15.00	19.86	15.19	16.53	.88
25	75	23.99	20.43	23.54	22.39	22.59	.88
0	100[g]	27.88	26.64	28.43	27.62	27.64	.88
0	100 (urea treated)[g]	26.29	25.29	25.53	25.10	25.55[h]	.88
Average		17.69	17.21	19.03	17.65	17.89	

[a]Each value represents the mean of six samples.
[b]DM basis.
[c]Forages x molasses interaction ($P < .01$).
[d]Effect of molasses ($P < .05$).
[e]Effect of inoculant ($P < .05$).
[f]Linear effect of proportion of forages ($P < .01$).
[g]Water was added to achieve 60% DM.
[h]Effect of urea ($P < .01$).

barley straw compared to untreated straw. The reduction of hemicellulose may be related to a slight increase in ADF together with decreased NDF content (Solaiman et al., 1979). Chemical treatment may solubilize some of the hemicelluloses without changing the cellulose.

In Vitro Dry Mattter Digestibility. In vitro dry matter digestibility (IVDMD) decreased linearly ($P < .01$) with the increase in the level of wheat straw in ensiled mixtures (Table 30). Lal and Mudgal (1967) reported 10 to 12% increases in CF digestibility from adding paddy straw to green berseem and ensiling. Chauhan et al. (1987) reported increased crude fiber digestibility for berseem-wheat straw silage, and suggested an associative effect of the two products. Addition of molasses increased ($P < .01$) IVDMD. Hatch and Beeson (1972) reported that addition of 5, 10 and 15% sugar cane molasses to a steer finishing ration tended to increase the DM digestibility. White et al. (1973) reported that addition of molasses (0 to 20%) increased both DM and crude fiber digestibilities. Martin et al. (1981) reported that addition of molasses to forage-based diets increased DM digestibility.

In our study urea treatment of wheat straw increased the IVDMD by 11 percentage units, compared to untreated wheat straw. These results agree with the findings of Hadjipanayiotou (1982) with barley straw, and Jayasuriya and Perera (1982), Ibrahim et al. (1986) and Wanapat (1986) with rice straw. Wanapat (1986) reported that treatment of rice straw with 5% urea increased CP and DM digestibility by 5 to 7 and 10 to 12 percentage units, respectively. Doulberg et al. (1981) reported increased IVDMD by treating wheat straw with urea. Mbatya (1983)

TABLE 30. IN VITRO DRY MATTER DIGESTIBILITY OF DIFFERENT PROPORTIONS OF ALFALFA AND WHEAT STRAW ENSILED WITH AND WITHOUT DIFFERENT ADDITIVES[ab]

Forages		Additives					
Alfalfa	Wheat straw	None	Molasses[cd]	Inoculant	Molasses + Inoculant	Average[e]	SE
- - - - %[b] - - - -		- - - - - % - - - - -					
100	0	48.36	56.61	48.66	55.00	52.16	1.03
75	25	42.81	51.61	42.46	50.82	46.93	1.03
50	50	37.26	44.83	37.46	45.66	41.30	1.03
25	75	34.11	36.45	32.77	39.03	35.59	1.03
0	100[f]	30.35	32.45	29.45	34.24	31.46	1.03
0	100 (urea treated)[f]	43.01	39.37	43.74	41.97	42.02[g]	1.03
Average		39.32	43.58	39.09	44.45	41.58	

[a]Each value represents the mean of six samples.
[b]DM basis.
[c]Forages x molasses interaction ($P < .01$).
[d]Effect of molasses ($P < .01$).
[e]Linear effect of proportion of forages ($P < .01$).
[f]Water was added to achieve 60% DM.
[g]Effect of urea ($P < .01$).

reported that ensiling barley straw treated with urea increased DM digestibility. In the present study IVDMD of urea-treated straw was similar to the IVDMD of ensiled alfalfa and wheat straw (75:25, DM basis). The IVDMD of ensiled alfalfa and wheat straw 50:50 and 75:25 with molasses and molasses + inoculant were similar or numerically higher than the IVDMD of urea-treated wheat straw.

There were no differences ($P < .05$) between IVDMD of untreated and inoculant-treated silages. Rust et al. (1989) reported that microbial inoculation of corn silage did not affect its nutritional value. Ohyama et al. (1973) reported that inoculation with *L. plantarum* did not affect silage quality. Our results were not in agreement with Waldo and Goering (1976) who reported that average digestibilities of DM for untreated and inoculant-treated silages were 48.2 and 59.2% for alfalfa.

It was concluded that combined ensiling of alfalfa and wheat straw does have potential for improving the fermentation characteristics of alfalfa silage. In vitro dry matter digestibility increased ($P < .01$) linearly with level of alfalfa and was enhanced by molasses ($P < .01$). Ensiling urea-treated wheat straw increased ($P < .01$) the CP content, decreased the hemicellulose content and improved the IVDMD by 11 percentage units. The IVDMD of alfalfa and wheat straw ensiled in 75:25 proportion without additives was numerically equal to that of urea-treated wheat straw.

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CHAPTER IV.

ENSILING CHARACTERISTICS, CHEMICAL COMPOSITION AND MINERAL CONTENT OF DIFFERENT PROPORTIONS OF ALFALFA AND WHEAT STRAW, ALFALFA WITH MOLASSES AND UREA-TREATED WHEAT STRAW SILAGES

ABSTRACT

Leguminous forages are high in moisture, CP and mineral content. Higher moisture content, protein and minerals raise buffering capacity of legumes, thereby their ability to resist pH change. The present study was designed to investigate the ensiling characteristics, chemical composition and mineral content of different proportions of alfalfa and wheat straw, alfalfa with 5% molasses and 5% urea-treated wheat straw, using large silos. Alfalfa was harvested at 1/10 bloom (third cut) with a direct cut forage chopper. Wheat straw was chopped to about 1.5 cm length with a tub grinder. Alfalfa and chopped wheat straw were mixed in the following proportions (DM basis): 0:100, 25:75, 50:50, 75:25, 100:0, 100:0 + molasses, and 0:100 (urea-treated). Sufficient water was added to attain a DM content of 60% in wheat straw (0:100). Wheat straw was treated with 50 g of urea dissolved in .40 liter of water per kilogram of wheat straw, DM basis. After mixing in a horizontal mixer, the mixtures were firmly packed by trampling into 210-liter metal drums double-lined with .08 mm polyethylene bags. The bags were sealed after expulsion of air, and materials were allowed to ensile for 3 mo. Addition of wheat straw to alfalfa at different levels increased ($P < .01$) DM content and lactic acid ($P < .01$), and decreased ($P < .01$) pH and total VFA content. The CP, Ca, P, Mg and K contents decreased ($P <$

.01) with the increases in wheat straw level in ensiled mixtures, thereby lowering the buffering capacity. Urea ammoniation of wheat straw increased ($P < .01$) pH, decreased ($P < .05$) lactic acid and increased ($P < .05$) total VFA, compared to untreated wheat straw. Crude protein content increased ($P < .01$), and NDF and hemicellulose decreased ($P < .05$) with urea treatment of wheat straw. Composition of ensiled alfalfa:wheat straw proportions 50:50 and 75:25 was comparable with that of urea-treated wheat straw. Addition of molasses to alfalfa increased ($P < .01$) water soluble carbohydrates (WSC), lactic acid and Na content, and decreased ($P < .01$) pH and Ca content, compared to alfalfa ensiled alone. It is concluded that addition of wheat straw to alfalfa helps in improvement of fermentation by increasing DM content and reducing the buffering capacity.
(Key Words: Leguminous Forages, Wheat Straw, Ensiling Characteristics, Chemical Composition, Mineral Content, Urea-treated Wheat Straw.)

INTRODUCTION

Alfalfa (*Medicago sativa L.*) is a basic forage for maximizing milk and beef production (Conard and Klopfenstein, 1988). Alfalfa is high in CP, relatively low in fiber and is an excellent source of Ca, Mg, P, carotene and vitamin D (Van Keuren and Matches, 1988). Alfalfa, like other leguminous forages, is difficult to ensile (McDonald and Whittenbury, 1973), because of high moisture, low level of WSC, high CP and high buffering capacity. The DM content in fresh leguminous forage is not sufficient to avoid seepage and effluent losses (Miller and

Clifton, 1965). The DM can be added either by wilting or by addition of cereal crop residues.

Wheat straw, like other crop residues, is low in protein, high in lignocellulosic fraction, low in P and marginal in Ca (Anderson, 1978). Cereal crop residues are readily available in developing countries and can be used for making silage with green forages (Lal and Mudgal, 1967). Combining crop residue and green legume forage for ensiling has shown potential in opimizing nutritional value and utilization (Singh et al., 1984; Chauhan et al., 1987).

The Ca/P ratio in alfalfa (6:1 to 13:1) is higher than the recommended ratio for livestock feeds, thus alfalfa has a potential to produce Ca/P imbalance (Howarth, 1988). Grass-legume silages are more dificult to ensile (Lassiter and Edward, 1982), not only because of higher moisture levels, but also because they are higher in protein and minerals. These raise the buffering capacity of the plants thereby their ability to resist pH change, which need to be overcome to make satisfactory silage (Lassiter and Edward, 1982; Noller and Thomas, 1985). In the first study (Chapter III), in which different proportions of alfalfa and wheat straw with and without different additives were ensiled, combining alfalfa and wheat straw in different proportions showed potential.

The present study was designed to investigate the ensiling characteristics and chemical composition of different proportions of alfalfa and wheat straw, alfalfa with 5% dry molasses and 5% urea-treated wheat straw using larger silos.

EXPERIMENTAL PROCEDURE

Alfalfa was harvested at 1/10 bloom (third cut) with a direct cut forage chopper. Wheat straw was chopped to 1.5 cm length with a tub grinder. Chopped alfalfa and wheat straw were mixed in following proportions (DM basis): 0:100, 25:75, 50:50, 75:25, 100:0, 100:0 + molasses, and 0:100 (urea-treated). Dry molasses was added to alfalfa (100:0) at 5% level. Sufficient water was added to achieve a DM content of 60% in wheat straw ensiled alone. Wheat straw was treated with 50 g urea dissolved in .4 liter of water per kilogram wheat straw. After thorough mixing in a horizontal mixture for 30 min, the mixtures were firmly packed by trampling into 210-liter metal drums double-lined with .08 mm polyethylene bags. The bags were individually sealed and the materials were allowed to ensile for 3 mo. Representative initial samples of ingredients and mixtures were taken during the filling of each silo, composited, subsampled and frozen for later analysis. Upon opening the silos, the top 5 cm were removed and samples were taken from several areas of each silo.

Chemical Analysis. Water extracts of initial and ensiled mixtures were prepared by homogenizing 25 g samples with 225 ml distilled water in .5 liter jars in a blender at full speed for 2 min. The homogenates were filtered through four layers of cheesecloth and the extract was used for determining pH (electrometrically), lactic acid (Barker and Summerson, 1941, as modified by Pennington and Sutherland, 1956), WSC (Dubois et al., 1956, as adapted to corn plants by Johnson et al., 1966) and VFA by gas-liquid chromatography (Varian 6000 gas chromatograph, column packed with 10% SP-1200/1% H_3PO_4 on 80/100 chromasorb WAW). Nitrogen content of the ingredients, and initial and ensiled mixtures were determined by Kjeldahl procedure (AOAC, 1984). Dry matter was determined by drying duplicate samples of about 200 g in a forced draft oven at a maximum of 60° for 48 h. The samples were allowed to air equilibrate and dry weights were recorded. All initial and ensiled samples were ground through a 1-mm sieve and were analyzed for DM, ash (AOAC, 1984), NDF (Van Soest and Wine, 1967), ADF (Van Soest, 1963; Goering and Van Soest, 1970), lignin, cellulose and hemicellulose (Van Soest and Wine, 1968).

Mineral Determination. All initial and ensiled samples were ground through 1 mm stainless steel Wiley mill. Samples were wet ashed in nitric and perchloric acids (Hern, 1979). Samples were analyzed for Ca, Mg, K and Na by atomic absorption spectrophotometry using a Perkin-Elmer Zeeman 500 PC. Samples were diluted with lanthanum oxide (La_2O_3) solution to prevent interference from P in determination of Ca and Mg. For Na and K, samples were diluted with deionized water. Phosphorus was determined by the colorimetric procedure of Fisk and Subbarow (1925).

Statistical Analysis. Data were statistically analyzed using the General Linear Model (GLM) Procedure of the Satistical Analysis System (SAS, 1985) for a completely randomized design. The model included the effects of treatments (different proportions of alfalfa and wheat straw, and addition of molasses to alfalfa and urea treatment of wheat straw). The linear, quadratic and cubic contrasts were used to test the effect of different proportions of alfalfa and wheat straw. Individual contrasts were used to test the effects of urea treatment and molasses addition.

RESULTS AND DISCUSSION

<u>Physical Characteristics</u>. The silages had pleasant aromas, except that the urea-treated silage had an ammoniacal smell. No fungal or mold growth was recorded after removal of the top 5-cm layer from all silages. Intensive ammonia smell in urea-ammoniated straw agrees with Dias-Da-Silva and Sundstol (1986) and with our first study using the small silos (Chapter III).

<u>Composition of Forages</u>. Alfalfa was lower ($P < .01$) in DM, higher in CP and ash content, and lower in NDF, ADF, cellulose and hemicellulose content, compared to wheat straw (Table 31). These findings were in agreement with Miller and Clifton (1965), Anderson (1978), Noller and Thomas (1985) and Males (1987).

The pH of initial mixtures and ensiled mixtures are shown in table 32. Addition of molasses to alfalfa decreased ($P < .01$) and urea treatment of wheat straw increased ($P < .01$) pH. There were linear and quadratic effects of alfalfa and wheat straw proportions. Mckersie (1985) reported that a positive relationship exists between the initial pH of the forage at ensiling and proteolysis.

The WSC content of mixtures increased ($P < .01$) linearly with level of alfalfa (Table 32). Urea treatment of the wheat straw decreased ($P < .01$) and addition of molasses to alfalfa increased ($P < .01$) the initial WSC content. This was in agreement with Morrison

TABLE 31. CHEMICAL COMPOSITION OF FORAGES, LARGE SILO STUDY[a,b]

Component	Alfalfa	Wheat Straw
	- - - - - - - - % - - - - - - - -	
Dry matter[c]	19.77	89.44
Crude protein[c]	21.50	3.18
Ash[c]	9.10	3.34
Neutral detergent fiber[c]	43.40	81.62
Acid detergent fiber[c]	33.15	52.71
Lignin	12.36	13.32
Cellulose[c]	20.36	37.66
Hemicellulose[c]	10.24	28.91

[a]Each value represents the mean of six samples.
[b]DM basis, except DM.
[c]Forages differed ($P < .01$).

TABLE 32. ENSILING CHARACTERISTICS OF ALFALFA AND WHEAT STRAW ENSILED ALONE, IN DIFFERENT PROPORTIONS, AND WITH ADDITIVES, LARGE SILO STUDY[ab]

Item	Proportions of alfalfa and wheat straw and treatments							
	- - - - - - - - - %[b] - - - - - - - - -							
	0:100[c]	25:75	50:50	75:25	100:0	100:0 + molasses	0:100 urea[c] treatment	SE
pH (pre-ensiled)[defg]	6.26	5.21	5.05	5.05	5.12	4.86	8.70	.04
pH (ensiled)[defg]	4.63	4.37	4.58	4.72	4.93	4.40	8.69	.08
Water soluble carbohydrates[dfhi], % (pre-ensiled)	5.70	3.77	5.57	6.60	7.69	10.75	4.82	.23
Water soluble carbohydrates, % (ensiled)	4.34	3.45	4.02	3.94	3.36	4.56	5.06	.68
Lactic acid[fij], %	2.18	3.67	4.16	2.08	2.87	5.03	.60	.54

[a]Each value represents the mean of six samples.
[b]DM basis, except pH.
[c]Water was added to achieve 60% DM.
[d]Linear effect of alfalfa and wheat straw proportions ($P < .01$)
[e]Quadratic effect of alfalfa and wheat straw proportions ($P < .01$).
[f]Effect of molasses ($P < .01$).
[g]Effect of urea ($P < .01$).
[h]Cubic effect of alfalfa and wheat straw proportions ($P < .05$).
[i]Effect of urea ($P < .05$).
[j]Cubic effect of alfalfa and wheat straw proportions ($P < .01$).

(1959) that molasses increases the sugar content so that enough acid is formed for fermentation to preserve the silage properly.

The pH of ensiled mixtures increased ($P < .01$) linearly with level of alfalfa in the mixtures (Table 32), however, there was also quadratic ($P < .01$) effect. Urea treatment of wheat straw increased ($P < .01$) the pH value (4.63 vs 8.69), compared to untreated wheat straw. This is in agreement with results reported by Hinds et al. (1985), who reported higher pH with NPN (molasses-urea-mineral mixture)-treated sorghum silage, compared to control (no additive) sorghum silage. Addition of molasses to alfalfa decreased ($P < .01$) the pH (4.93 vs 4.40), compared to alfalfa alone. Lanigan (1961) reported that ensiling of alfalfa with large amounts of molasses decreased the pH. Similar results were reported by Singh et al. (1984) from addition of 5 to 19% molasses in combination with berseem and wheat straw (80:20, fresh basis). Increased pH with the increase in legume content observed in this study was in agreement with Chauhan et al. (1987) who reported pH values 4.60 and 4.80 in berseem wheat straw proportions 5:1 and 7:1 (fresh basis), respectively. McKersie (1985) studied the relative extent of proteolysis in three forage legumes and reported that optimum pH for proteolysis was 6.00 for alfalfa but 6.5 for red clover (*Trifolium pratense*) and birdsfoot trefoil (*Lotus corniculatus*). Muck et al. (1988) reported optimum pH around 6, with proteolytic activity declining linearly from 6.0 to 4.0.

There was a cubic effect ($P < .05$) of alfalfa and wheat straw proportions on lactic acid concentration (Table 32). Addition of molasses to alfalfa increased ($P < .01$) the lactic acid content. McDonald and Purves (1956) reported that addition of molasses stimulated lactic acid fermentation in field silage (mixture of grasses, predominantly perennial ryegrass, and clover). Lanigan (1961) reported that ensiling alfalfa in laboratory silos with molasses resulted in increased lactic acid content. Singh et al. (1984) reported that addition of 5% molasses to berseem:wheat straw (80:20, fresh basis) mixture increased the lactic acid content. In this study urea treatment decreased ($P < .05$) lactic acid content, compared to untreated wheat straw. This is in agreement with Oji et al. (1977b) that negligible amounts of lactic acid were contained in NH_3-treated corn stover.

Highest WSC value was recorded in urea-treated wheat straw silage. This may have been related to lower lactic acid type fermentation. Overall, the WSC in pre-ensiled mixtures was higher than ensiled mixtures; however, they did not show a specific pattern. The decrease in WSC values for proportions 75:25, 100:0, 100:0 + dry molasses was of the same magnitude as that of lactic acid production. There were no differences ($P > .05$) in WSC content of the silages.

<u>Volatile Fatty Acid</u>. Total VFA content increased linearly ($P < .01$) with the level of alfalfa in ensiled mixtures (Table 33). Kamra et al. (1983) reported that production of VFA decreased ($P < .05$) with the increase in DM of maize and wheat straw mixtures, regardless of wilting or mixing with wheat straw. Singh and Rekib (1986) reported a negative correlation between the DM content of the forage and total VFA content.

TABLE 33. VOLATILE FATTY ACID CONTENT OF ALFALFA AND WHEAT STRAW ENSILED ALONE, IN DIFFERENT PROPORTIONS, AND WITH ADDITIVES, LARGE SILO STUDY[a,b]

	Proportions of alfalfa and wheat straw and treatments (%[b])							
Item	0:100[c]	25:75	50:50	75:25	100:0	100:0 + molasses	0:100 urea[c] treatment	SE
	%							
Total volatile fatty acids[d,e]	.32	2.66	5.26	7.68	8.09	8.68	1.91	.46
Acetic acid[d,f,g]	.25	2.55	4.83	6.82	6.00	7.36	1.85	.40
Propionic acid[d,h,i]	.00	.04	.03	.76	.65	1.20	.00	.08
Isobutyric acid	.05	.05	.13	.04	.10	.04	.01	.02
Butyric acid[d,i,j]	.00	.00	.01	.03	1.25	.06	.00	.16
Isovaleric acid[k]	.01	.01	.03	.03	.06	.02	.04	.02
Valeric acid[f]	.00	.00	.00	.01	.03	.02	.00	.01

[a]Each value represents the mean of six samples.
[b]DM basis.
[c]Water was added to achieve 60% DM.
[d]Linear effect of alfalfa and wheat straw proportions ($P < .01$).
[e]Effect of urea ($P < .05$).
[f]Effect of molasses ($P < .05$).
[g]Effect of urea ($P < .01$).
[h]Cubic effect of alfalfa and wheat straw proportions ($P < .01$).
[i]Effect of molasses ($P < .01$).
[j]Quadratic effect of proportion ($P < .01$).
[k]Linear effect of alfalfa and wheat straw proportions ($P < .05$).

Acetic acid was the major VFA in ensiled mixtures (Table 33). The highest acetate value was recorded with 75:25 proportions (linear effect, $P < .01$). Addition of molasses increased ($P < .05$) the acetic and propionic and decreased butyric acid content of alfalfa. Urea treatment of the wheat straw increased ($P < .01$) the acetic acid, compared to untreated wheat straw, which is the opposite effect than on lactic acid. This is in agreement with Oji et al. (1977b) who reported increased ($P < .05$) acetic acid content in ammonia-treated corn stover, compared to untreated corn stover.

Chemical Composition. The DM content increased linearly ($P < .01$) with the increase in level of wheat straw in initial mixtures (Table 34). Initial DM content of forage has a significant role in ensiling process (Catchpoole and Henzell, 1971). The pH at which clostridial activity ceases depends upon the DM content of the herbage (Wieringa, 1957). The DM content affects the amount of substrate required by affecting the pH at which the bacterial activity ceases (Muck, 1988). The substrate required for complete fermentation is negatively correlated with the DM content of the crop (Muck, 1988). McKersie (1985) reported that proteolysis decreases as the DM content in the forage increases. The DM content of ensiled mixtures decreased ($P < .01$) linearly with the level of alfalfa (Table 35). Singh and Pandita (1985) reported that DM content of berseem increased through wilting or by addition of wheat or paddy straw. The CP content increased linearly ($P < .01$) with level of alfalfa in initial (Table 34) and ensiled mixtures (Table 35). Addition of molasses decreased ($P < .01$) the CP

TABLE 34. CHEMICAL COMPOSITION OF PRE-ENSILED ALFALFA AND WHEAT STRAW ALONE, IN DIFFERENT PROPORTIONS, AND WITH ADDITIVES, LARGE SILO STUDY[ab]

Item	Proportions of alfalfa and wheat straw and treatments (%[b])							
	0:100[c]	25:75	50:50	75:25	100:0	100:0 + molasses	0:100 urea[c] treatment	SE
	%							
Dry matter[d]	58.13	47.93	32.62	25.85	21.31	22.30	58.97	.50
Crude protein[def]	3.62	7.81	12.45	16.86	21.52	19.73	16.04	.41
Neutral detergent fiber[dgh]	80.37	70.11	60.29	54.35	47.20	45.02	78.45	.73
Acid detergent fiber[dfg]	51.07	47.09	41.77	39.16	37.08	36.94	53.81	.45
Lignin[fi]	10.99	12.82	12.18	11.72	12.38	11.78	12.50	.26
Cellulose[d]	39.00	33.31	28.61	26.75	24.40	23.82	39.97	.39
Hemicellulose[dfh]	29.30	23.01	18.51	15.18	10.12	8.08	24.65	.58
Ash[dh]	3.40	4.86	6.24	7.80	8.31	8.70	3.37	.10

[a]Each value represents the mean of six samples.
[b]DM basis, except DM.
[c]Water was added to achieve 60% DM.
[d]Linear effect of alfalfa and wheat straw proportions ($P < .01$).
[e]Effect of molasses ($P < .01$).
[f]Effect of urea ($P < .01$).
[g]Quadratic effect of alfalfa and wheat straw proportions ($P < .01$).
[h]Effect of molasses ($P < .05$).
[i]Cubic effect of alfalfa and wheat straw proportions ($P < .01$).

TABLE 35. CHEMICAL COMPOSITION OF ALFALFA AND WHEAT STRAW ENSILED ALONE, IN DIFFERENT PROPORTIONS, AND WITH ADDITIVES, LARGE SILO STUDY[ab]

Item	Proportions of alfalfa and wheat straw and treatments (%[b])							
	0:100[c]	25:75	50:50	75:25	100:0	100:0 + molasses	0:100 urea[c] treatment	SE
	%							
Dry matter[d]	57.08	44.94	31.33	26.47	20.66	21.24	57.68	.85
Crude protein[de]	4.32	8.50	13.43	17.53	23.16	22.33	13.56	.41
Neutral detergent fiber[df]	81.16	69.21	62.52	57.34	48.38	49.07	77.09	1.19
Acid detergent fiber[d]	51.23	47.56	45.10	44.31	42.33	42.07	51.58	.67
Lignin[g]	10.45	10.90	10.98	11.65	11.75	11.64	9.91	.45
Cellulose[d]	39.22	35.88	33.71	32.12	30.05	29.55	40.31	.41
Hemicellulose[de]	29.93	21.65	17.42	13.03	6.05	7.00	25.51	.80
Ash[d]	3.13	4.88	6.38	7.67	8.76	9.11	3.15	.16

[a]Each value represents the mean of six samples.
[b]DM basis, except DM.
[c]Water was added to achieve 60% DM.
[d]Linear effect of alfalfa and wheat straw proportions ($P < .01$).
[e]Effect of urea ($P < .01$).
[f]Effect of urea ($P < .05$).
[g]Linear effect of alfalfa and wheat straw proportions ($P < .05$).

content in pre-ensiled alfalfa, however, the decrease was not significant in ensiled alfalfa. Urea treatment of wheat straw increased ($P < .01$) the CP content, compared to untreated wheat straw (Tables 34 and 35). Solaiman et al. (1979) and Dias-Da-Silva and Sundstol (1986) reported increased N content with NH_4OH treatment of wheat straw. Herrera-Saldana et al. (1983) reported increased ($P < .05$) CP content from 3.6 to 9.8 and 11.0%, DM basis, with NH_3 amd NH_4OH treatment of wheat straw. Cloete and Kritzinger (1984b) reported that urea supplementation and urea ammoniation increased the CP content of wheat straw from 3.1 to 8.9 and 9.7%, respectively. Schneider and Flachowsky (1990) reported that increased N content of wheat straw from ammoniation depends upon NH_3 level, moisture or temperature. A maximum N value of 2.9% was reached with 4.5% NH_3, 45% moisture and 20° C.

Generally, NDF decreased linearly with increase in alfalfa in initial mixtures (Table 34). There was a quadratic effect also of alfalfa:wheat straw proportions. The NDF content in ensiled mixtures decreased linearly ($P < .01$) with the increase in the level of alfalfa (Table 35). Urea treatment decreased ($P < .05$) the NDF content of the ensiled wheat straw. The results were in agreement with Solaiman et al. (1979) that NH_4OH treatment of wheat straw decreased NDF.

The ADF content decreased ($P < .01$) linearly with the increase in alfalfa level in initial mixtures (Table 34). There was a quadratic effect ($P < .01$) also. The ADF content in ensiled mixtures also decreased linearly ($P < .01$) with the increase in alfalfa level in the mixtures. Urea treatment of wheat straw increased ($P < .01$) the ADF content of pre-ensiled mixtures and tended to increase ADF content of ensiled mixtures. Solaiman et al. (1979) related increased ADF from ammoniation due to dilution effect caused by solubilization of hemicellulose from ammoniated roughages.

There was a cubic effect ($P < .01$) of alfalfa and wheat straw proportions on lignin content of initial mixtures and a linear effect ($P < .05$) with the level of alfalfa in the ensiled mixtures. Generally, a decrease in lignin was seen in pre-ensiled and ensiled mixtures, as proportion of straw increased. Harkin (1973) reported higher lignin content in alfalfa. In the present study addition of molasses to alfalfa and urea treatment of wheat straw tended to decrease the lignin content in the silage.

The cellulose and hemicellulose content in pre-ensiled and ensiled mixtures decreased ($P < .01$) linearly with the increase in alfalfa level (Tables 34 and 35). Urea-ammoniation of wheat straw decreased ($P < .01$) the hemicellulose content in initial and ensiled mixture. This is in agreement with results of Solaiman et al. (1979), Ibrahim and Pearce (1983), and Cloete et al. (1984b). The reduction of hemicellulose content appears to be related to the reduced NDF. Addition of molasses decreased ($P < .05$) the hemicellulose content in initial mixtures.

Macrominerals in Alalfa and Wheat Straw. Macromineral contents of alfalfa and wheat straw are shown in Table 36. Potassium was the major macromineral in alfalfa (2%, DM basis). Results are in agreement with those of Van Keuren and Matches (1988) that alfalfa is a good source of Ca, Mg and P. Baker and Reid (1977) reported that Mg is higher in

TABLE 36. MINERAL CONTENT OF ALFALFA AND WHEAT STRAW, LARGE SILO STUDY[a,b]

Item	Alfalfa	Wheat straw
	- - - - - - - - - - % - - - - - - - - -	
Calcium[c]	.95	.16
Phosphorus[c]	.29	.06
Magnesium[c]	.19	.09
Potassium[c]	2.01	.52
Sodium[c]	.01	.00

[a]Each value represents the mean for six samples.
[b]DM basis.
[c]Forages differed ($P < .01$).

legumes than grasses. The Ca:P ratio in wheat straw was 2.7:1. Low Mg content in wheat straw is in agreement with results of Grings and Males (1987).

Calcium. The Ca content in initial and ensiled mixtures increased linearly ($P < .01$) with the level of alfalfa in the mixtures (Table 37 and Table 38). The Ca content in ensiled mixtures was higher ($P < .01$) than initial mixtures. Adding molasses decreased ($P < .01$) Ca content due to lower Ca in molasses than alfalfa. The calcium requirement of sheep ranges from .20 to .82% of the diet DM (NRC, 1985); for beef cattle from .18 to 1.04% (NRC, 1984). For dairy cattle, the requirement ranges from .43 to 2.0% of the diet DM (NRC, 1989). The value of feed as Ca source depends upon its content and biological availability (Hansard et al., 1957; Peeler et al., 1972). Ward et al. (1979) reported Ca in alfalfa is only 50 to 57% as available to cattle as that inorganic Ca. Fredeen (1989) reported that Ca absorption from alfalfa hay in goats exceeded 50% of the intake.

Phosphorus. The P content of initial (Table 37) and ensiled mixtures (Table 38) increased linearly ($P < .01$) with the level of alfalfa in the mixtures. Higher ($P < .01$) phosphorus concentration was observed in ensiled mixtures than pre-ensiled mixtures. The phosphorus requirements range from .16 to .38% of the diet DM for sheep (NRC, 1985); .18 to .75% for beef cattle (NRC, 1984); and .28 to .48% for lactating cows (NRC, 1989). Lofgreen and Kleiber (1953, 1954) found that true digestibility of P in alfalfa hay by wether lambs was above 90%.

TABLE 37. MINERAL CONTENT OF PRE-ENSILED ALFALFA AND WHEAT STRAW ALONE, IN DIFFERENT PROPORTIONS, AND WITH ADDITIVES, LARGE SILO STUDY[ab]

Item	Proportions of alfalfa and wheat straw and treatments							
	- - - - - - - %[b] - - - - - - -							
	0:100[c]	25:75	50:50	75:25	100:0	100:0 + molasses	0:100 urea[c] treatment	SE
	- - - - - - - % - - - - - - -							
Calcium[de]	.173	.343	.495	.730	.892	.782	.212	.024
Phosphorus[df]	.055	.101	.160	.224	.263	.227	.055	.010
Magnesium[dg]	.105	.108	.138	.190	.200	.182	.108	.007
Potassium[df]	.557	.853	1.377	1.863	1.885	1.560	.667	.114
Sodium[de]	.001	.004	.005	.007	.010	.012	.002	.000

[a]Each value represents the mean of six samples.
[b]DM basis.
[c]Water was added to achieve 60% DM.
[d]Linear effect of alfalfa and wheat straw proportions ($P < .01$).
[e]Effect of molasses ($P < .01$).
[f]Effect of molasses ($P < .05$).
[g]Cubic effect of alfalfa and wheat straw proportions ($P < .01$).

TABLE 38. MINERAL CONTENT OF ALFALFA AND WHEAT STRAW ENSILED ALONE, IN DIFFERENT PROPORTIONS, AND WITH ADDITIVES, LARGE SILO STUDY[a,b]

Item	Proportions of alfalfa and wheat straw and treatments - - - %[b] - - - 0:100[c]	25:75	50:50	75:25	100:0	100:0 + molasses	0:100 urea[c] treatment	SE
	- - - - - - -	- - - - -	- - - - %	- - - - -	- - - - -	- - - - -	- - - - -	
Calcium[de]	.252	.455	.753	.983	1.300	1.200	.293	.010
Phosphorus[d]	.072	.129	.224	.265	.342	.328	.059	.009
Magnesium[df]	.123	.140	.190	.215	.223	.240	.167	.007
Potassium[dg]	.493	.925	1.457	1.647	1.943	1.985	.505	.053
Sodium[de]	.002	.005	.007	.008	.011	.016	.002	.000

[a]Each value represents the mean of six samples.
[b]DM basis.
[c]Water was added to achieve 60% DM.
[d]Linear effect of alfalfa and wheat straw proportions ($P < .01$).
[e]Effect of molasses ($P < .01$).
[f]Effect of urea ($P < .01$).
[g]Quadratic effect of alfalfa and wheat straw proportions ($P < .01$).

Magnesium. The Mg content of initial mixtures increased with the level of alfalfa in the mixture (Table 37), however, the response was linear and cubic ($P < .01$). The Mg content in ensiled mixtures increased linearly ($P < .01$) with increases in alfalfa level (Table 38). Baker and Reid (1977) and Gross and Jung (1978) reported that legumes are higher in Mg content than in grasses. Gring and Males (1987) reported that Mg content of wheat straw is very low. Requirement of Mg ranges from .12 to .18% for sheep (NRC, 1985), .05 to .25% for beef cattle (NRC, 1984) and .20 to .25% of the diet DM for dairy cattle (NRC, 1989).

Potassium. The potassium (K) content in the initial mixtures increased linearly ($P < .01$) with the alfalfa level (Table 37). In ensiled mixtures, K content increased with the increase in alfalfa level, but linear and quadratic ($P < .01$) responses were seen (Table 38).

The dietary requirements of sheep for K ranges between .50 to .80% of the diet DM (NRC, 1985). The K requirement for beef cattle ranges between .5 to .7% of the diet DM (NRC, 1984) and for dairy cows .90 to 1.0 of the diet DM (NRC, 1989).

Sodium. Sodium content of initial mixtures (Table 37) and ensiled mixtures (Table 38) increased linearly ($P < .01$) with the level of alfalfa, however, values were very low. Addition of molasses increased ($P < .01$) the sodium content in the mixtures. Ensminger et al. (1990) reported that beet and sugar cane molasses are good sources of sodium. Sodium requirements range from .09 to .18% for sheep (NRC, 1985), .06 to

.1% for beef cattle (NRC, 1984) and .10 to .18% for dairy cattle (NRC, 1989), DM basis.

In conclusion, by ensiling alfalfa and wheat straw in different proportions a silage with adequate DM, CP, Ca, P, Mg, K contents could be produced to meet maintenance requirements for sheep, beef cattle and dairy cattle and would support growth in young growing animals, with supplementation of salt.

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CHAPTER V.

DIGESTIBILITY AND PALATABILITY BY SHEEP OF ALFALFA AND WHEAT STRAW ENSILED ALONE, IN DIFFERENT PROPORTIONS, AND WITH ADDITIVES

ABSTRACT

Two metabolism trials, each with 21 crossbred (1/2 Dorset, 1/4 Rambouillet and 1/4 Finn) wethers, and one palatability trial with 42 crossbred wethers, were conducted to investigate the effect of ensiling different proportions of alfalfa and wheat straw, alfalfa with 5% dry molasses (wet basis), and urea-treated (5% DM basis) wheat straw, on in vivo digestibility and voluntary intake. The diets were ensiled alfalfa and wheat straw in proportions of 0:100, 25:75, 50:50, 75:25, 100:0, 100:0 + dry molasses, and 0:100 (urea-treated). The ensiled wheat straw was supplemented with soybean meal because insufficient consumption was achieved when straw was fed alone. A linear increase ($P < .01$) in apparent digestibilities of DM, OM, and CP was recorded with increases in alfalfa. Addition of molasses increased ($P < .05$) DM digestibility (54.72 vs 60.36%) and OM digestibility (57.55 vs 62.69%). Apparent digestibility of CP of urea-treated wheat straw was lower ($P < .05$) than ensiled wheat straw supplemented with soybean meal. Linear increases ($P < .01$) in N-intake, fecal N, urinary N, total N excretion, apparent N absorption and N-retention were observed with increased level of alfalfa. Ruminal pH did not differ significantly among sheep fed the experimental diets. Ruminal NH_3-N and blood urea increased ($P < .01$) with level of alfalfa. Urea treatment of straw increased ($P < .01$) the ruminal NH_3-N and blood urea, compared to untreated straw. Total

ruminal VFA concentration increased (P < .01) linearly with level of alfalfa. Acetic and isobutyric acid concentrations increased linearly (P < .01), whereas propionic acid concentration decreased linearly (P < .01) with level of alfalfa. There was a quadratic (P < .01) effect of alfalfa and wheat straw proportions on butyric acid concentration. Feeding urea-treated straw increased (P < .01) concentrations (mol/100 mol) of acetic acid and decreased (P < .01) propionic acid, compared to untreated straw. Feeding alfalfa ensiled with molasses increased (P < .05) propionic acid and decreased (P < .05) butyric acid concentration, compared to feeding alfalfa ensiled alone. Daily DM intake increased linearly (P < .01) with level of alfalfa. It is concluded that combined ensiling of alfalfa and wheat straw does have potential in improving the nutritive value and utilization of low quality roughages. Addition of molasses to alfalfa improved the nutritional value of alfalfa silage.
(Key Words: Digestibility, Palatability, Sheep, Ensiled, Alfalfa, Wheat Straw.)

INTRODUCTION

Forage preservation techniques, such as ensiling and hay making, are used to ensure year-round supply of nutritious feed for livestock. Cereal crop residues are the only available forage during periods of green forage shortage in many developing countries. Ensminger et al. (1990) stated that more than 2.2 billion tons of crop residues are produced annually in the world. Wanapat (1986) and Males (1987) reported that cereal crop residues are low in nutritive value, because they are low in CP and high in lignocellulosic fractions. Klopfenstein

(1978) and Males (1987) reported that voluntary intake and digestibility of cereal crops are low.

Leguminous green forages, such as alfalfa, are high in CP, relatively low in fiber and are excellent sources of Ca, Mg, P (Van Keuren and Matches, 1988). Woolford (1978), however, reported that ensiling of direct cut herbage can lead to considerable effluent production, which may result in significant nutrient losses. Lal and Mudgal (1967) reported that cereal crop residues are easily available in developing countries and combined ensiling of cereal straws with legumes helps to improve palatability and digestibility of the straw.

One major problem in utilization of ensiled plant materials as feed for ruminant animals is reduced voluntary DM intake, compared to forages conserved with other techniques (Gordon et al., 1960). Thomas et al. (1969) reported that cattle and sheep consumed more DM as hay than as silage, but performance was not greater with hay. They further observed that DM from silage contained more digestible energy. Wilkins et al. (1971) reported that voluntary intake was positively correlated to the content of DM, N and lactic acid, over different ensiled forages. Jayasuriya and Perera (1982) reported that use of urea as NH_3 source in treating rice straw improved voluntary intake and fiber and DM digestibilities, as compared to untreated rice straw. Hadjipanayiotou (1982) reported that voluntary intake, crude fiber and DM digestibilities of urea-treated barley straw were higher than for untreated straw.

Two metabolism trials, each with 21 wethers, and one palatability trial were conducted to determine the digestibility, nutrient utilization and palatability of ensiled alfalfa and wheat straw in different proportions, alfalfa with 5% dry molasses and urea-treated wheat straw.

EXPERIMENTAL PROCEDURE

Metabolism Trials. Two metabolism trials were conducted, each with 21 crossbred (1/2 Dorset, 1/4 Rambouillet and 1/4 Finn) wethers, assigned to six blocks of seven animals each based on initial live-weight. The sheep within each block were randomly allotted to the experimental diets. The diets were alfalfa and wheat straw in proportions (DM basis) of 0:100, 25:75, 50:50, 75:25, 100:0, 100:0 + dry molasses and 0:100 (urea-treated) ensiled in 210-liter metal drums as described in Chapter IV. The wheat straw ensiled alone (0:100 + H_2O) was supplemented with 108 g soybean meal (44% CP), because sufficient consumption was not achieved when the straw was fed alone.

Wethers were placed in false bottom metabolism crates similar to those described by Briggs and Gallup (1949), permitting separate collection of urine and feces. Wethers were individually fed 800 g of DM plus 18, 16, 14, 12, 10, 12 and 20 g dicalcium phosphate, 5, 5, 2, 0, 0, 0 and 5 g limestone, respectively, for the diets in the order given above and 4 g NaCl in two equal feedings at 0630 and 1830 daily. Water was provided ad libitum, except during the 2 h feeding periods. The trials started with a 3-d adaptation period to the stalls, during which sheep were fed a diet composed of 50% orchardgrass hay (*Dactylis glomerata*), 40% ground corn, 3.5% soybean meal (44%), 6.0% molasses and .5% trace mineralized salt. This was followed by a 10-d transition period to experimental diets. A preliminary period of 10 d, during which the animals were fed a constant amount of feed, was followed by a 10 d collection of feces and urine.

Daily feed samples and refusals were collected 2 d before the start until 2 d prior to the end of the collection period and were frozen immediately. At the end of the trial these samples were thawed, composited by animals, subsampled, and frozen for later analysis.

During the collection period total feces were collected and dried daily in a forced air oven at a maximum of 60° C for a minimum of 24 h. For each animal the dried feces were composited in double-lined polyethylene bags in plastic containers with loose-fitting lids to equilibrate with atmospheric moisture. At the end of collection the total fecal collections were weighed, mixed by animal and subsampled. Separate samples were taken for N determination and DM determinations. After DM determination the fecal samples were ground in a Wiley mill through a 1-mm screen and stored in sample jars for further analysis.

Urine was collected in 4 liter plastic bottles containing 15 ml of 1:1 (V/V) H_2O and H_2SO_4 and 500 ml of H_2O. The urine bottles were changed daily at the time of collection. Urine was diluted to a constant weight (4000 g) daily and a 2% aliquot (by volume) was taken each day and placed in a capped plastic jar and refrigerated. At the end of the trial, urine samples were subsampled and refrigerated for subsequent N analysis.

On the last day of collection, ruminal fluid samples were taken 2 h post-feeding. The samples were strained through four layers of cheesecloth and were used for determination of pH (electrometrically), VFA by gas liquid chromatography (Varian 6000 gas chromatograph column packed with 10% SP-1200/1% H_3PO_4 on 80/100 chromasorb WAW) and ruminal NH_3 (Beecher and Whitten, 1970). Blood samples were taken 6 hr post-feeding by jugular puncture and were analyzed for blood urea N (Coulombe and Favreau, 1963).

Samples of feed, feed refusals and feces were analyzed for DM, ash (AOAC, 1984), NDF (Van Soest (1967), ADF (Van Soest, 1963; Goering and Van Soest, 1970), lignin and cellulose (Van Soest and Wine, 1968). Nitrogen was determined on wet feed, refusals, dry feces and urine samples (AOAC, 1984).

Palatability Trial. A palatability trial was conducted with 42 crossbred wethers (1/2 Dorset, 1/4 Finn and 1/4 Rambouillet) assigned to six blocks of seven animals based on initial liveweight basis. The sheep within each block were randomly allotted to experimental diets, which were the same as were fed in the metabolism trials. The wethers were kept in individual 1.1 x 1.6 m pens in an open shed. Water was provided ad libitum, and fresh feed was provided every 12 h. The trial consisted of a 3-d adaptation period to the stalls, 8-d transition period, 10-d preliminary period, followed by a 7-d measurement period. During the measurement period feed samples were obtained twice daily and feed refusals were obtained once daily, weighed and dried at 60° C in a forced draft oven for 48 h.

The sheep were weighed before and at the end of the palatability trial. The average of initial and final weights were used to determine the metabolic body size kg ($BW^{.75}$) on which DM intake was calculated.

Statistical Procedures. The data for metabolism and palatability trials were tested by analysis of variance by using the General Linear Model (GLM) procedure of the Statistical Analysis System (SAS, 1985). The experimental design was a randomized complete block. The model included the effects of treatment, trial and block. The linear, quadratic and cubic orthogonal contrasts were used to test the effect of different proportions of alfalfa and wheat straw. The effects of molasses addition and urea treatment were tested by single contrasts.

RESULTS AND DISCUSSION

Chemical Composition. The chemical composition of the silages is given in Table 39. Chemical composition of the experimental diets is the same as that of the silage except for the ensiled straw. The diet that included this silage contained 59.38% DM, 12.95% CP, 69.64% NDF, 45.36% ADF, 9.64% lignin, 34.83% cellulose, 24.29% hemicellulose and 3.66% ash, DM basis, except DM. The DM and cell wall components decreased linearly ($P < .01$) and CP content increased linearly ($P < .01$) with the proportion of alfalfa in the mixtures.

Apparent Digestibility. Apparent digestibility of DM, OM, CP, ADF, lignin and hemicellulose increased ($P < .01$) linearly with the increase in alfalfa proportion in the silages (Table 40). There was little effect of proportion of the forages on digestibility of NDF and cellulose until level of alfalfa was 100%. The response was represented by a quadratic ($P < .01$) effect. Lal and Mudgal (1967) reported 10 to 12% increase in crude fiber digestibility by ensiling paddy straw with green berseem, compared to ensiled paddy straw alone. Chauhan et al.

TABLE 39. CHEMICAL COMPOSITION OF SILAGES USED IN EXPERIMENTAL DIETS[ab]

Item	Proportions of alfalfa and wheat straw and additives						
	%[b]						
	0:100[c]	25:75	50:50	75:25	100:0	100:0 + molasses	0:100 urea[c] treatment
	%						
Dry matter[def]	55.11	45.70	31.21	23.76	18.78	19.60	57.63
Crude protein[dfg]	4.34	9.50	13.03	18.88	24.10	22.57	14.46
Neutral detergent fiber[dfg]	81.36	71.92	65.38	57.94	50.29	48.23	79.44
Acid detergent fiber[dgh]	52.98	49.16	47.28	44.75	44.67	41.99	52.48
Lignin[dgj]	11.45	11.50	11.48	12.07	13.55	12.39	10.77
Cellulose[dgh]	40.51	36.58	34.88	31.87	30.78	29.13	40.69
Hemicellulose[d]	23.87	22.76	18.01	13.19	5.62	6.23	27.04
Ash[deh]	3.02	4.50	5.87	7.83	8.34	8.83	2.91

[a]Each value represents the mean of six samples.
[b]DM basis except DM.
[c]Water was added to achieve 60% DM.
[d]Linear effect of alfalfa level ($P < .01$).
[e]Cubic effect of alfalfa level ($P < .01$).
[f]Effect of urea ($P < .01$).
[g]Effect of molasses ($P < .01$).
[h]Quadratic effect of alfalfa level ($P < .01$).

TABLE 40. APPARENT DIGESTIBILITY OF DIETS FED TO SHEEP[ab]

Item	Proportions of alfalfa and wheat straw and additives (%[b])							
	0:100[c]	25:75	50:50	75:25	100:0	100:0 + molasses	0:100 urea treatment	SE
	%							
Dry matter[de]	45.06	43.00	46.23	46.79	54.72	60.36	44.15	1.59
Organic matter[de]	48.12	45.30	48.52	47.97	57.55	62.69	47.23	1.47
Crude protein[df]	66.31	54.24	62.72	68.96	76.82	77.81	62.00	1.16
Neutral detergent fiber[gh]	44.62	40.68	43.09	43.03	48.50	50.85	54.56	1.58
Acid detergent fiber[dh]	43.09	44.10	45.03	44.58	52.02	55.03	51.93	1.37
Lignin[df]	10.54	21.24	21.61	24.74	34.33	36.32	16.18	1.88
Cellulose[gh]	53.85	51.90	53.60	51.34	60.58	64.43	63.23	1.53
Hemicellulose[dfi]	47.50	32.25	40.85	37.93	20.22	22.74	59.65	3.44

[a]Each value represents the mean of six samples.
[b]DM basis.
[c]Diet was supplemented with 108 g of soybean meal$\cdot$animal$^{-1}\cdot$d^{-1}.
[d]Linear effect of alfalfa level ($P < .01$).
[e]Effect of molasses ($P < .05$).
[f]Effect of urea ($P < .05$).
[g]Quadratic effect of alfalfa level ($P < .01$).
[h]Effect of urea ($P < .01$).
[i]Cubic effect of alfalfa level ($P < .01$).

(1987) reported that crude fiber digestibility of berseem and wheat straw mixtures 7:1 and 5:1 (fresh basis) was similar to that of control (concentrate) diet. They observed that the increase in CF digestibility of berseem and wheat straw silage may be due to the associative effect of two products.

The DM and OM digestibilities for urea-treated and untreated wheat straw supplemented with soybean meal were similar. The apparent digestibility of CP for urea-treated straw was lower ($P < .05$) than untreated wheat straw supplemented with soybean meal. Urea treatment of wheat straw increased ($P < .01$) the apparent digestibilities of NDF ($P < .01$), ADF ($P < .01$), cellulose ($P < .01$), lignin ($P < .05$) and hemicellulose ($P < .05$), compared to untreated wheat straw supplemented with soybean meal. Herrera-Saldana (1982) reported that digestibility coefficients of DM and OM did not differ among steer diets consisting of ammoniated wheat straw, untreated wheat straw and untreated wheat straw plus feather meal. Oji et al. (1977) reported decreased ($P < .05$) apparent digestibility of N with 5% NH_3 treatment of corn stover, compared to untreated corn stover.

Increased apparent digestibilities of NDF, ADF, lignin, cellulose and hemicellulose are in agreement with Oji et al. (1977), Herrera-Saldana et al. (1983), Hadjipanayiotou (1982) and Dias-Da-Silva and Sundstol (1986). Oji et al. (1977) reported that 3 and 5% NH_3 treatment of corn stover increased the apparent digestibility of ADF and cellulose. Herrera-Saldana (1982) reported increased ADF digestibility with steers fed ammoniated wheat straw, compared to untreated wheat straw. Dias-Da-Silva and Sundstol (1986) reported that urea treatment of wheat straw enhanced the apparent digestibility of cell wall constituents. Hadjipanayiotou (1982) reported that apparent digestibility of crude fiber increased when urea-treated barley straw was fed to wethers, compared to untreated straw. Cloete and Kretzinger (1984b) reported that urea treatment of wheat straw improved the apparent digestibility of CWC, ADF and hemicellulose compared to untreated straw.

Oji et al. (1977) reported that 3 and 5% NH_3 treatment of corn stover increased the DM and OM digestibilities compared to untreated corn stover. Horton and Steacy (1979) reported that 3.5% (w/w) anhydrous NH_3 treatment of barley, oat and wheat straw increased ($P < .01$) apparent digestibility of DM, OM and CP, compared to untreated straws. Hadjipanayiotou (1982) reported increased DM digestibility.

The possible reason for similar DM and OM digestibility for urea-treated and untreated wheat straw in the present study was increased digestibility resulting from supplementing soybean meal to low-protein ensiled wheat straw. The apparent DM digestibility of urea-treated wheat straw was 44.15%, which was 14 percentage units higher than IVDMD of untreated wheat straw (30.35% IVDMD) reported in Chapter III.

Addition of dry molasses to alfalfa before ensiling increased ($P < .05$) the apparent digestibilities of DM and OM. The apparent digestibilities of CP and cell wall fractions tended to be higher. Increased apparent digestibility of DM by addition of dry molasses at 5% level to alfalfa forage before ensiling was in agreement with results reported by Hatch and Beeson (1972) that addition of 5, 10 and 15% sugar cane molasses to steer finishing ration tended to increase the DM digestibility. Martin et al. (1981) reported that addition of molasses to a forage-based diet increased the DM digestibility in sheep.

Nitrogen Utilization. Nitrogen intake increased ($P < .01$) linearly with the increase in alfalfa in the silages (Table 41), a reflection of the higher N in alfalfa. Addition of dry molasses to alfalfa decreased ($P < .01$) the N intake. Fecal N, urinary N and total N excretion increased ($P < .01$) linearly with the increase of alfalfa level in the silages. Addition of molasses to alfalfa decreased the fecal N excretion ($P < .05$). Fecal N excretion, urinary and total N excretion for wethers fed urea-treated wheat straw tended to be higher than wethers fed ensiled untreated wheat straw supplemented with soybean meal.

Apparent N absorption, expressed as g/d or percent of intake increased ($P < .01$) linearly with the level of alfalfa in silages (Table 41). Addition of molasses to alfalfa decreased ($P < .01$) the apparent absorption of N (g/d) compared to alfalfa ensiled alone, due at least partly to differences in N intake. Urea treatment of wheat straw decreased ($P < .05$) the apparent N absorption expressed as percent of intake. Nitrogen retention, expressed as g/d, increased ($P < .01$) linearly with increases in proportion of alfalfa in the silages. Nitrogen retention, expressed as percent of the intake, showed a quadratic ($P < .01$) response and N retention, expressed as percent of absorbed, showed a quadratic ($P < .05$) effect of alfalfa and wheat straw proportions. Urea treatment of wheat straw decreased ($P < .05$) N

TABLE 41. NITROGEN UTILIZATION BY SHEEP FED EXPERIMENTAL DIETS[a,b]

	Proportions of alfalfa and wheat straw and additives							
	%[b]							
Item	0:100[c]	25:75	50:50	75:25	100:0	100:0 + molasses	0:100 urea treatment	SE
Intake, g/d[de]	10.83	7.77	11.20	15.68	18.87	16.87	10.80	.31
Excretion, g/d								
Fecal[df]	3.65	3.56	4.18	4.88	4.34	3.75	4.15	.18
Urinary[d]	6.02	3.69	6.44	8.92	10.91	10.90	6.80	.43
Total[d]	9.67	7.25	10.64	13.80	15.24	14.65	10.95	.45
Apparent absorption								
g/d[de]	7.18	4.21	7.02	10.80	14.53	13.12	6.65	.32
% of intake[dg]	66.32	54.25	62.70	68.96	76.82	77.83	61.83	1.17
Retention								
g/d[dfg]	1.17	.51	.58	1.88	3.64	2.22	- .15	.39
% intake[hi]	10.77	6.42	5.18	11.96	19.15	13.12	-1.26	2.67
% absorbed[ij]	16.25	11.87	8.12	16.28	24.95	16.87	-2.50	4.24

[a]Each value represents the mean of six samples.
[b]DM basis.
[c]Diet (silage) was supplemented with 108 g of soybean meal$\cdot$animal$^{-1}\cdot$d^{-1}.
[d]Linear effect ($P < .01$) of alfalfa level.
[e]Effect of molasses ($P < .01$).
[f]Effect of molasses ($P < .05$).
[g]Effect of urea ($P < .05$).
[h]Quadratic effect ($P < .01$) of alfalfa level.
[i]Effect of urea ($P < .01$).
[j]Quadratic effect ($P < .05$) of alfalfa level.

retention as compared to ensiled untreated wheat straw supplemented with soybean meal. Addition of molasses also decreased ($P < .05$) N retention, apparently due to decreased N intake.

Ruminal and Blood Parameters. Ruminal pH did not differ greatly among sheep fed the different proportions of alfalfa and wheat straw, but there was a cubic ($P < .05$) response (Table 42). Highest levels were recorded for the diets with 25 and 100% alfalfa. Adding molasses did not affect ruminal pH. Martin and Wing (1966) reported that ruminal pH did not appear to be affected by feeding low levels of molasses to dairy steers. Hatch and Beeson (1972) found no differences in ruminal pH by adding up to 15% molasses to a high concentrate finishing steer diet. Hadjipanayiotou (1982) reported no difference in ruminal pH with wether sheep fed urea-treated and untreated barley straw. Zorrilla-Rios et al. (1985) reported no difference in ruminal pH with steers fed ammoniated and unammoniated wheat straw.

Animals fed urea-treated wheat straw had higher ($P < .01$) ruminal NH_3-N. This is in agreement with Hadjipanyiotou (1982), who reported that feeding urea-treated straw resulted in increased ruminal NH_3 concentration. Herrera-Saldana et al. (1982) reported that ruminal NH_3-N in sheep fed untreated wheat straw diet was lower ($P < .05$) than in sheep fed NH_3-treated wheat straw. Roffler and Satter (1975) reported that ruminal NH_3 concentration was positively related to CP concentration of the diet. Bartley et al. (1976) reported a rise in ruminal NH_3-N as CP in the diet increased. Roffler et al. (1976) reported that feeding large quantities of urea increases ruminal NH_3 and leads to

TABLE 42. RUMINAL pH, AMMONIA-N AND BLOOD UREA-N OF SHEEP FED ALFALFA AND WHEAT STRAW SILAGES[a]

Item	Proportions of alfalfa and wheat straw and additives (%[b])							
	0:100[c]	25:75	50:75	75:25	100:0	100:0 + molasses	0:100 urea treatment	SE
Rumen pH[d]	6.94	7.08	6.96	6.83	7.10	7.06	7.07	0.10
Rumen NH_3-N[ef], mg/100 ml	24.91	9.00	16.99	32.16	29.09	34.26	42.68	3.07
Blood urea-N[fg], mg/100 ml	13.33	11.76	15.07	15.38	17.15	19.21	19.54	1.58

[a]Each value represents the means of six samples.
[b]DM basis.
[c]Diet (silage) was supplemented with 108 g soybean meal$\cdot$animal$^{-1}\cdot$d^{-1}.
[d]Cubic effect ($P < .05$) of alfalfa level.
[e]Cubic effect ($P < .01$) of alfalfa level.
[f]Effect of urea ($P < .01$).
[g]Linear effect ($P < .05$) of alfalfa level.

enhanced absorption of NH_3. There was a cubic effect ($P < .01$) of proportions of alfalfa on ruminal NH_3.

Blood urea-N increased ($P < .05$) linearly with level of alfalfa (Table 42). Blood urea-N (BUN) concentration increased ($P < .01$) when urea-treated wheat straw was fed, as compared to untreated wheat straw supplemented with soybean meal. Preston et al. (1965) reported that BUN was related to level of CP in the diet. Martin et al. (1981) reported that BUN level increased with greater N supplemental NPN levels. Herrera-Saldana (1982) reported that plasma urea N was lower ($P < .05$) in steers fed an untreated wheat straw diet, compared to ammoniated wheat straw.

Total ruminal VFA concentration, expressed in μmol/ml increased ($P < .01$) linearly with proportion of alfalfa in the silages (Table 43). Addition of 5% dry molasses to alfalfa before ensiling tended to increase total ruminal VFA concentration. Martin and Wing (1966) reported that total ruminal VFA concentration did not appear to be affected by feeding low levels of molasses. Hatch and Beeson (1972) reported that addition of up to 15% molasses to a high concentrate finishing diet increased the total VFA content of the ruminal fluid.

There were linear ($P < .01$) and cubic ($P < .01$) responses of alfalfa and wheat straw proportion on ruminal acetic and propionic acid concentrations, expressed as mol/100 mol (Table 43). Generally, acetic acid concentration increased, whereas propionic concentration decreased with level of alfalfa in the diets. Isobutyric acid increased ($P < .01$) linearly with the level of alfalfa. There was quadratic ($P < .01$)

TABLE 43. RUMINAL VOLATILE FATTY ACIDS IN SHEEP FED ALFALFA AND WHEAT STRAW SILAGES[ab]

Item	Proportions of alfalfa and wheat straw and additives, %[b]							SE
	0:100[c]	25:75	50:50	75:25	100:0	100:0 + molasses	0:100 urea treatment	
Total VFA, µmol/ml[d]	55.20	63.01	66.22	79.78	71.32	83.34	51.85	7.44
Moles/100 moles								
Acetic acid[efg]	65.46	68.74	72.00	80.45	72.26	71.17	77.58	1.19
Propionic acid[efgh]	19.95	20.89	16.89	9.33	11.92	14.78	14.97	.76
Isobutyric acid[eg]	1.68	1.41	1.56	1.90	2.25	2.19	.79	.15
Butyric acid[ghi]	9.01	5.50	5.54	4.19	8.00	5.53	4.70	.73
Isovaleric acid[dgi]	2.64	1.69	2.24	2.51	2.74	4.08	1.11	.38
Valeric acid	1.25	2.20	1.77	1.61	1.82	2.23	.79	.36

[a]Each value represents the mean of six samples.
[b]DM basis.
[c]Diet (silage) was supplemented with 108 g soybean meal·animal^{-1}·d^{-1}.
[d]Linear effect ($P < .05$)of alfalfa level.
[e]Linear effect ($P < .01$) of alfalfa level.
[f]Cubic effect ($P < .01$) of alfalfa level.
[g]Effect of urea ($P < .01$).
[h]Effect of molasses ($P < .05$).
[i]Quadratic effect ($P < .01$) of alfalfa level.

effect of alfalfa and wheat straw proportions on butyric acid concentration. There were linear ($P < .05$) and quadratic ($P < .01$) responses of alfalfa and wheat straw proportions on isovaleric acid concentration. Valeric acid values did not show any specific trend.

Feeding urea-treated straw increased ($P < .01$) the concentration (mol/100 mol) of ruminal acetic acid and decreased ($P < .01$) propionic, butyric and isobutyric, and isovaleric acid compared to untreated straw. The decrease in valeric acid concentration with urea-treated straw was not significant. Ensiling alfalfa with molasses increased ($P < .05$) propionic acid and decreased ($P < .05$) butyric acid concentration, compared to alfalfa ensiled alone. Leng et al. (1973) reported that high level of isovaleric acid may indicate ruminal proteolytic activity.

<u>Palatability</u>. DM intake, expresed as g/kg of metabolic size ($BW^{.75}$) and digestible DM intake/d increased linearly with proportion of alfalfa in the silages (Table 44). Addition of molasses to alfalfa decreased DM intake. The DM intake of urea-treated straw tended to be lower than ensiled wheat straw supplemented with soybean meal. Because in the present study sufficient DM intake could not be achieved when ensiled wheat straw was fed alone, ensiled wheat straw was supplemented with soybean meal, hence, a direct comparison between untreated and urea-treated straw could not be made. Rounds et al. (1976) reported that intake by lambs of a diet containing 85% NH_4OH-treated corn cobs was less than diets containing NaOH or NaOH + $Ca(OH)_2$-treated cobs, and suggested that NH_3 odor may have contributed to the reduced intake. Solaiman et al. (1979) suggested that if the NH_3 odor of ammoniated

TABLE 44. DAILY DRY MATTER INTAKE BY SHEEP FED ALFALFA AND WHEAT STRAW SILAGES[ab]

Item	Proportions of alfalfa and wheat straw and additives, %[b]							
	0:100[c]	25:75	50:50	75:25	100:0	100:0 + molasses	0:100 urea treatment	SE
Dry matter intake, g/d[de]	566.03	559.39	765.08	945.93	1175.68	1025.38	452.64	48.11
Dry matter intake, $g \cdot BW^{.75^{-1}} \cdot d^{-1}$[d]	40.44	39.51	52.83	64.11	77.53	69.46	32.52	3.06
Digestible dry matter intake, g/d[d]	255.29	239.93	353.14	441.85	648.24	618.98	201.65	31.41

[a]Each value represents the mean of six samples.
[b]DM basis.
[c]Diet (silage) was supplemented with 108 g of soybean meal$\cdot$animal$^{-1}\cdot$d^{-1}.
[d]Linear effect ($P < .01$) of alfalfa level.
[e]Effect of molasses ($P < .05$).

materials inhibits intake, aeration prior to feeding can solve the problem. Orskov et al. (1983) reported lower DM intake of NH_3-treated barley straw by Friesian heifers, compared to untreated barley straw.

Lawlor and O'Shea (1979) reported improved intake of anhydrous NH_3-treated barley straw compared to untreated straw. Hadjipanayiotou (1982) reported voluntary intake of urea-treated barley straw was higher than untreated straw when straws were fed alone. Mbatya (1983) reported that ensiling of urea-treated barley straw increased the intake, compared to freshly prepared urea-treated straw.

It is concluded that combined ensiling of crop residues and leguminous green forage has potential in improving the nutritional value and utilization of cereal crop residue. Addition of molasses to alfalfa before ensiling was effective in improving the nutritive value of alfalfa silage.

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CHAPTER VI.

GENERAL DISCUSSION

Forage conservation techniques such as ensiling and hay making are used to ensure year-round supply of nutritive feed for livestock. Rapid increase in human population has forced farmers to grow more cereal grain crops, hence, the culturable land available for forage crop is decreasing. Cereal crop residue in most cases is the only available forage during periods of green forage shortage in many developing countries. Klopfenstein (1978) stated that for each kilogram of grain produced, an equal quantity of residue is obtained. Ensminger et al. (1990) reported that 2.2 billion tons of cereal crop residue are produced annually in the world. Anderson (1978) and Males (1987) reported that cereal crop residues are low in CP and high in ligno-cellulosic compounds. Klopfenstein (1978) and Males (1987) reported that voluntary intake and digestibility of these forages is low.

Various chemical treatments, such as NaOH, anhydrous or aqueous NH_3 and $Ca(OH)_2$, have been introduced to improve the nutritive value of these poor-quality roughages. These treatments have not gained popularity with the farmers in developing countries because of expense or unavailability. The traditional and cultural practices in agriculture and livestock farming resist all unfamiliar and complex methods of improving the nuritional value of low-quality roughages. Ammonia treatment of crop residues via hydrolysis of urea after ensiling is comparatively new. Farmers in developing countries, such as Pakistan, are familiar with urea, and it is readily available in most developing countries. In developed countries, where grains and green forage are readily available, cereal crop residues are a neglected feed resource, and their disposal is a major problem. There is a need to find new methods to improve the nutritional value and utilization of this major feed resource for livestock. Lal and Mudgal (1967) reported that cereal straws are easily available in developing countries and combined ensiling of cereal straws with legumes helps to improve the palatability and digestibility of the straw. Ensiling of cereal crop residues with green forages, especially leguminous forages, offers some possibilities to improve the nutritive value and utilization of cereal crop residues and enhance ensiling of the high-moisture legume forage.

Leguminous green forages, such as alfalfa (*Medicago sativa L.*), are high quality forages and valuable for milk and meat production. VanKeuren and Matches (1988) reported that leguminous forages, such as alfalfa, are high in CP, low in fiber components and are excellent sources of Ca, Mg and P. McDonald and Whittenbury (1973) reported that leguminous green forages are difficult to ensile because of high moisture content, low level of water-soluble carbohydrates and high buffering capacity. They are also high in protein and minerals, which raise their ability to resist pH changes (Lassiter and Edwards, 1982).

Dry matter content in direct cut green forages may not be sufficient for adequate preservation. Woolford (1978) reported that ensiling of direct cut herbage can lead to considerable effluent production. In this study no putrifaction was observed for either, small or large silos. Muck (1988) reported that the amount of substrate required for adequate fermentation is negatively correlated with the DM content of the crop. The DM content affects the amount of substrate required by affecting the pH at which bacterial activity ceases. McKersie (1985) reported that proteolysis decreased as the DM content in the forage increased. Ensiling of leguminous forage, such as alfalfa, with crop residue is not used widely in the U.S., but may be helpful in ensiling. In the present study, lactic acid values increased with the increase in wheat straw in the ensiled mixtures. In both our small silo and large silo studies the DM content increased ($P < .01$) linearly with increasing levels of wheat straw. Total VFA concentration decreased ($P < .01$) with the level of wheat straw or increase in the DM content in the silages. The DM content of ensiled mixtures tended to be low, compared to initial mixtures, possibly due to the respiration of the plant cells and the action of microbes on ensiled material.

The microbial inoculant did not significantly affect pH. Average lactic acid content in the silages was lower when inoculant was used in the absence of molasses, but was higher in the presence of molasses (molasses x inoculant interaction $P < .01$). It seems apparent that lack of adequate substrate could be one of the reasons of ineffectiveness of microbial inoculant. The IVDMD of alfalfa and wheat straw ensiled in 75:25 proportion without additives was similar to urea-treated wheat straw.

In the study with large silos (210-liter metal barrels double-lined with polyethylene bags), addition of wheat straw to alfalfa at different levels increased ($P < .01$) the DM content, lowered ($P < .01$) the pH values and increased ($P < .01$) the lactic acid concentration in alfalfa and wheat straw proportions of 25:75 and 50:50, compared to alfalfa ensiled alone and wheat straw ensiled alone. Additionally, the CP, Ca, P, Mg and K contents decreased ($P < .01$) with the increase in wheat straw level in ensiled mixtures, hence indirectly helping in lowering the buffering capacity.

Urea ammoniation of wheat straw increased pH, decreased ($P < .01$) lactic acid and increased ($P < .01$) total VFA (acetic acid was major VFA) as compared to untreated wheat straw in both small and large silos studies. This indicates acetic acid type fermentation with urea treatment rather than lactic acid type fermentation. Urea treatment of wheat straw increased ($P < .01$) the CP, compared to the untreated wheat straw. Higher ($P < .01$) rumen NH_3-N in sheep fed urea-treated straw could be related to higher N level. Roffler and Satter (1973) reported that ruminal ammonia concentration was positively related to CP content in the diet. Depressed N-retention could be related to the increased ($P < .01$) ruminal NH_3-N, and subsequent increased absorption of NH_3. Roffler et al. (1976) reported that feeding of large quantities of urea increased ruminal NH_3 and enhanced absorption of NH_3. Absorption of NH_3 improves apparent N digestibility but depresses N retention. In this study fecal and urinary N tended to be higher for sheep fed NH_3-treated straw, compared to intake in sheep fed untreated straw plus soybean meal.

The DM intake increased linearly ($P < .01$) with the level of alfalfa in our study. It could be attributed to increased CP content with the level of alfalfa in silages. It was concluded that by ensiling alfalfa and wheat straw in proportions 50:50 and 75:25, a silage with adequate DM, CP, cell wall component, Ca, P and Mg content can be achieved which can meet maintenance requirements for sheep, maintenance requirement for dry pregnant beef cows and dairy cattle requirements, and can support some growth in young growing lambs and calves with supplementation of sodium and some phosphorus.

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VITA

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He received Master of Science (M.Sc.) in Animal Nutrition from College of Veterinary Sciences, Lahore, University of Agriculture, Faisalabad, Pakistan, in 1985. Besides technical training, he also received planning, administrative management and human relationship trainings. In fall 1987, he joined the Animal Science Department of VPI&SU as graduate student. He is a member of American Society of Animal Science. He has attended two annual meetings - in July 1988 at Rutgers, New Jersey, and in July 1990 in Ames, Iowa. He attended

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