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IMPACT OF VARYING MOISTURE LEVELS, DIFFERENT ADDITIVES AND FERMENTATION PERIODS ON NUTRITIVE VALUE OF LEGUMINOUS AND NON-LEGUMINOUS FODDER SILAGES IN LACTATING NILI-RAVI BUFFALOES

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INTRODUCTION

Efficient ruminant productivity is only possible if a steady supply of quality forage in sufficient amounts is made available to them. In Pakistan, there are two important fodder scarcity periods, one is during winter months (November to January) and other is during summer months (May to July) and in rest of the year fodder availability is fairly regular and abundant. This abundant fodder if not properly managed is the wastage of fodder resource. This situation calls for the exploration of different means to improve quality and quantity of roughages without sacrificing the area under cash crops. Manipulating this surplus fodder can bridge the gap between supply and demand. Silage making is one of the important techniques in this regard (Tauqir et al., 2007).

The main goal of silage making is to preserve as much of the nutritional value of the original crop as possible. Preservation is achieved by acidity and by maintaining an oxygen-free (anaerobic) environment. Acids are produced by bacteria that convert fermentable carbohydrates into organic acids, predominantly lactic and acetic acids. As fermentation progresses, more acids are produced, pH drops, and eventually the acidity level is adequate to inhibit or kill most bacteria and other microorganisms. At this pH if protected from exposure to air and water seepage, silage can be preserved for a long period. Concentrations of fermentable carbohydrates in the forage, its buffering capacity, dry matter (DM) content and the number and type of bacteria present on the forage are the main factors that could affect the rate of pH decline and final pH of the silage (Bolsen *et al.*, 1996; Higginbotham, *et al.*, 1998). Grasses have relatively low buffering capacity and low concentrations of fermentable carbohydrates, therefore, pH decline is not rapid and final pH is usually high. Leguminous fodders on the other hand, have a high buffering capacity (due to high protein and mineral content), and relatively high concentrations of fermentable carbohydrates, therefore, pH drop in leguminous crop silages was also slow and loss of nutrients could be high (Bolsen *et al.*, 1996). Leguminous crops that are extensively wilted prior to ensiling to lower the moisture content undergo very limited fermentation and final pH values are usually between 4.5 and 5, which are higher than that of non-leguminous silages. Therefore, for a rapid and extensive fermentation to occur, the forage must have high concentration of fermentable carbohydrates, low buffering capacity, relatively low dry matter content (20-40%), and adequate lactic acid bacteria present prior to ensiling. Any fodder, which has sufficient amount of fermentable carbohydrates, can be ensiled, but the most popular fodder is maize (Woolford, 1984). However, jambo and mott grasses, lucerne and berseem (legumes fodders) can be used for silage making provided that a source of fermentable carbohydrates is added before ensilation (Tauqir N. A. 2007). The choice of crops for ensilage depends primarily on the local environment. Generally high yielding multicut fodders can be a good choice for silage making.

Various silage additives like molasses, starch, nitrogen (N), bacterial inoculants and different types of absorbents are available and are used for different reasons. Additives are used to improve nutrient composition of silage to reduce storage losses by promoting rapid fermentation, to reduce fermentation losses by limiting the extent of fermentation and to improve bunk life of the silage (increase aerobic stability). Various additives like molasses (Bolsen, *et al.*, 1996) and crushed grains (De Visser, et al., 1998) are added in non-leguminous fodders as a source of soluble carbohydrates before ensilation to increase the lag phase in silage. While, leguminous fodders are already high in crude protein (CP) and moisture content. So, before ensiling the leguminous fodders, the moisture content is reduced either by field wilting or by the addition of some absorbent (Fransen and Strubi, 1998). Dry roughages high in DM and low in N like wheat straw can be used to improve the DM of berseem and lucerne before ensilation (Tauqir N. A. 2007). However, the scientific evidence regarding the nutritive value of silages of grasses and legumes as affected by the use of various additives, fermentation periods and moisture absorbents is limited and inconsistent. .Therefore, the objective of this review is to examine the effect of additives, fermentation periods and moisture levels on nutritive value of various silages in growing and lactating animals.

1. Ensilation process

Until recently agricultural practices have been dominated by the drive for maximum production using minimum resources. Different methods were adopted and reviewed in the literature for the preservation of surplus fodders alongwith the techniques to minimize the loss of nutrients during ensiling process. These methods include silage and hay making of surplus fodder depending upon the requirement of the animals and weather conditions of the region. Silage making of surplus fodders has proved to be the best method in this regard. A great deal of research has been undertaken in recent years on the factors influencing silage quality (Thomas and Thomas, 1985; Bolsen *et al.*, 1996). One consistent conclusion from this research was that the feeding value of grass was reduced by ensilage, partly through effects on voluntary intake and in part through adverse effects on the nutritive value per unit of dry matter (DM) as the grass was converted to silage (Thomas and Thomas, 1985).

As ensilage is a fermentation process, anaerobic conditions must be achieved rapidly and the undesirable activities of microorganisms' spoilage must be inhibited. Under such anaerobic conditions, lactic acid bacteria, which occur naturally on the crop rapidly, ferment water-soluble carbohydrate to produce mainly lactic and acetic acids. These fermentation acids lower the pH and preserve the silage by combinations of low pH and the anti-microbial nature of the undissociated acids (McDonald, 1981; Bolsen *et al.*, 1996).

2. Substrates for fermentation

The major substrates for bacterial fermentation are the water-soluble carbohydrates. The total content of water-soluble carbohydrates in grasses varied from 5 to 300 g/kg DM. Their quantity is increased with the growth of the crop. Non-leguminous crops have relatively low buffering capacity and low concentrations of fermentable carbohydrates; therefore, pH decline is not rapid. Leguminous crops, on the other hand, have a high buffering capacity (due to high protein and mineral content), high moisture content and relatively high concentrations of fermentable carbohydrates. Therefore, pH drop in leguminous crop silage is also slow and final pH is comparatively high (Bolsen, *et al.*, 1996). There is evidence to suggest that the sum of the total contents of organic acids and residual water-soluble carbohydrates in some silage is greater than that of the original water-soluble carbohydrate content of the corresponding herbage. The substrate might be available from alternative sources, most probably by the breakdown of polysaccharides in the grass during ensiling (Ruiz *et al.*, 1992).

3. Fermentation pathways

Fermentation pathways of bacteria can be subdivided into two main routes depending on the nature of the substrate they metabolize and end products produced. These pathways are categorized as under:

3.1 Clostridial fermentation

Clostridial silage is characterized by the presence of butyric acid (McDonald, 1981). The main source of clostridial species in the silo is the soil contaminant added during harvesting of the crop. High moisture content, high N content, high buffering capacity and a low content of water-soluble carbohydrates in the herbage are the conditions that enhance the probability of clostridia becoming dominant during ensilage and adversely affected the lactic acid producing bacteria (McDonald, 1981; Matsuoka, *et al.*, 1993).

Clostridia spp. can be subdivided into two routes depending on the nature of the substrate they metabolized. These include, saccharolytic clostridia i.e. *Clostridium butyricum* that ferment carbohydrate and organic acids to butyric acid. These organisms have limited proteolytic activity but they create favorable conditions for proteolytic clostridia by increasing the pH in the silo. Secondly, proteolytic clostridia i.e. *Clostridium sporogenes* having limited activity towards carbohydrates but can ferment proteins by de-aminating amino acids (Garcia *et al.*, 1989).

3.2 Lactic acid fermentation

Lactic acid bacteria are divided into two groups, depending on whether they ferment sugars homo-fermentatively or hetero-fermentatively. The homo-fermentatives form 2 moles of lactic acid per mole of glucose or fructose fermented. The hetero-fermentatives produce 1 mole of lactic acid, 1 mole of ethanol and 1 mole of carbon dioxide per mole of glucose fermented; from every 3 moles of fructose they produce 1 mole of lactic acid, 1 mole of acetic acid, 1 mole of carbon dioxide and 1 mole of mannitol (McDonald, 1981). It was reported that a homo-fermentative fermentation in the ensiling process is the more efficient process than a hetero-fermentative one, with reference to minimizing the loss of DM (McDonald, 1981; Seale, 1986).

The major organisms responsible for aerobic deteriorations included yeast, bacteria and moulds (Garcia et al., 1989). These are thought to be indigenous to the silage rather than being aerial borne organisms; consequently additives to the crop at ensiling may control these organisms. Propionic acid is considered to be the most potentially effective bacteriostat in silages, particularly with high DM content. High levels of propionic acid were needed to prevent the aerobic deterioration of silages (Thomas and Thomas, 1985).

4. Factors affecting chemical composition of silage

There are many factors, which affect the chemical composition of silage. The most important of them are plant species, plant physiological stage, forage DM and silage additives.

4.1 Plant specie

Various workers reported a great disparity in chemical composition of silages of different species of fodder. Khorasani *et al.* (1993) reported higher ADF and lignin and lower NDF contents of Alfalfa (*Medicago sativa*) silage than the cereal grain silages. Within cereal grain silages, oats (*Avena sativa*) contained the highest ADF and NDF, triticale was intermediate and barley contained the lowest fiber fractions. Neutral detergent fiber was the highest for barley silage, intermediate for pea silage and the lowest for alfalfa silage. The ADL followed a reverse sequence to that NDF. However, non-structural carbohydrate levels were 9 and 7% units higher in pea silage and barley silage, respectively, than in alfalfa silage. This was mainly due to higher starch content of both silages relative to alfalfa silage while differences of fiber composition between three types of silages can be attributed to differences in fiber characteristics between grasses and legumes (Mustafa *et al.*, 2000; Khorasani *et al.*, 1993).

4.2 Plant physiological stage

Silage from early maturity alfalfa contained more DM and less NDF, hemicellulose cellulose and ADL as compared to silage from late maturity alfalfa. Similarly, silage from early maturity orchard grass contained less DM, NDF, hemicellulose, cellulose and ADL but more energy and sugars as compared to silage from late maturity orchard grass (Thomson *et al.*, 1992). Silage from early-cut grass contained more N and sugar than did the silage from late-cut grass but was lower in NDF (De Visser *et al.*, 1998). Barley silage at boot stage had less DM, NDF, ADF, ADL and more CP as compared to soft dough stage silage. The reason for low CP content of soft dough stage was that with increasing maturity, cell content decreased and cell wall contents increased (Acosta *et al.*, 1991). Increased cell wall components and decreased cell contents of forages with increasing maturity were also reported by Givens *et al.* (1989).

Kim *et al.* (1989) reported increased NDF from 51.9 to 59% ADF from 30.6 to 39.7% and ADL from 7.2 to 14.6% with advancing age. Boddroff and Ocumpangh (1986) reported a similar trend in the growth of fibrous fractions of the Mott grass when harvested at varying growth stages. Neutral detergent fiber increased from 40 to 65%, ADF from 20 to 38% while CP contents decreased 13 to 10.5% in ryegrass (*Lolium Multiflorum*) as the growing season progressed (Cherney *et al.*, 1993).

4.3 Forage dry matter

Chemical composition of silage depends upon the crop ensiled, but the most important controllable factor determining silage quality is the moisture content. Dry matter content of the ensiled material affected lactic acid, TP and NPN concentrations more than any other factors. Low DM silages contained several-fold the amount of lactic acid as compared to those of high DM silages while, high DM silages had more TP than low DM silages. High DM inhibited microbial proliferation especially *clostridia* spp. which may explain why NPN was greater in low DM (46%) than in high DM (62%) silage. The fermentation rate declined as the DM content of wilted herbage increased (Polan *et al.*, 1998).

The DM was the most frequently quoted parameter affecting silage quality. It influenced the number of microflora directly, selecting those organisms best able to survive in wetter or dryer environments and indirectly, because dried fodder will contain a higher concentration of sugar and other soluble components. It also affected the amount of effluent produced. Furthermore, Fransen and Strubi (1998) reported that DM content at ensiling affected TP and NPN contents significantly, compared to any other factor. The 27% DM silage contained larger soluble N fraction, but a smaller fraction of potentially digestible N than 46 or 56% DM silages (Campbell and Smith, 1991).

Fransen and Strubi (1998) suggested that the moisture content of the fodder at the time of ensilation should be around 80 to 60%, which could be achieved either by wilting or by the addition of some absorbent. Silage DM could also be increased by wilting of the fodder and/or by the use of barley, beet pulp, newspapers or alfalfa cubes as absorbent.

4.4 Forage protein content

During ensiling process, there was an extensive proteolysis resulting in higher NPN concentration and lower TP contents of the silage (Ruiz *et al.,* 1992). However, Garcia *et al.* (1989) reported that during the ensiling process CP content of fodder had undergone extensive degradation and significant amount of ammonia (NH_3) was liberated. It was noted however, that even in well-preserved silages up to 60% of the proteins may be hydrolyzed (McDonald, 1981). Freshly harvested elephant grass contained 12.4% CP compared to only 10.7% in its silage. The reduction in CP concentration can be attributed to CP loss during the ensiling process (Ruiz *et al.,* 1992).

Proteolytic clostridia are assumed to be the major source of de-aminative activity and hence of NH_3-N production in silage. Ammonia N was also known to be produced by the action of plant enzymes and coliform (Seale, 1986). It, thus, seemed probable that the rapid achievement of a low pH would reduce both the extent of proteolysis and de-amination, resulting into silage with a lower NH_3-N content. The production of NH_3-N in silage is a two stage process; *viz.* the hydrolysis of herbage proteins to their constituent peptides and amino acids. The rapid stabilization of silage has been shown to reduce the extent of proteolysis in the silo by the inactivation of plant proteases (McDonald, 1981; McDonald *et al.*, 1991).

5. Silage additives

Judicious use of silage additives is a useful tool to improve silage quality and ultimately animal performance. Silage additives include various feedstuffs, urea, NH_3, molasses, inoculants and acids. Their main functions are to either increase nutritional value of the silage or improve fermentation so that storage losses are reduced. Responses to additives depend on which forage is being treated. Leguminous silages are generally more difficult to ensile and may respond to many silage additives (Weiss, 2001).

The role of additives for silage has been well established as additives assist in achieving a stable pH in the silo and improve nutritive value of ensiled material (McDonald *et al.*, 1991). Silage additives must increase DM (nutrient) recovery, improve animal performance (milk yield, quality and/or composition, weight gain and body condition) or decrease heating and molding during storage (Kung *et al.*, 2000; Kung, 1996). A draw back for some of the chemical additives was that they could be corrosive to the equipment used and can be dangerous to handle. The biological additives are non-corrosive and safe to handle, but they can be costly. Further more, their effectiveness can be less reliable, since it is based on the activity of living organisms (Bolsen *et al.,* 1995; Kung, 1996 and Weinberg and Muck, 1996).

Presently a wide range of nutritional and microbial additives is available to be added before ensilation. The role of silage additives to assist in achieving a low and stable pH within the silo as speedily as possible has been well recognized (McDonald, 1981 and Bolsen *et al.*, 1996). Additives have been classified into four categories, although recognizing that these categories were not clearly defined and there may be considerable overlap. These are (i) stimulants; which encourage a lactic acid fermentation, (ii) inhibitors; partially or completely restrict microbial growth, (iii) aerobic deterioration inhibitors; which prevent the deterioration of silage during feed out phase and (iv) nutrients; to enhance the nutritive value of crop after ensilage. Two additional categories of additives have been introduced, which include (i) effluent absorbents (Ferris and Mayne, 1994; Fransen and Struby, 1998) and (ii) enzyme additives (Kung 1992; Kung and Muck, 1997; Bolsen *et al.*, 1996).

McDonald (1981) has subdivided the fermentation stimulants into (i) cultures of bacteria, which dominate the silage fermentation, or (ii) soluble carbohydrate sources (sugars, molasses, cereals, whey and beet pulp etc.), which are added to the crop to increase the supply of readily available energy to the endogenous lactic acid bacteria. Certain additives comprised a combination of the two (Sharp *et al.*, 1994; Bolsen *et al.*, 1996; Ridla and Uchida, 1998ab). Such products are important when substrate (water-soluble carbohydrates) is limiting in the crop.

5.1 Carbohydrates

Carbohydrates have been added to forage at ensiling for many years. The principle products used are grains and molasses. The beneficial action of these added carbohydrates is two fold. Firstly, they supply a readily fermentable source of energy for the microbes to produce more acids and secondly, they increase the DM content, which not only reduces effluent but also concentrates the nutrients for fermentation. The major limitation for the use of these additives is the additional labor required to mix with fodder before ensilation but may be economical in the sense of reducing major losses (Bolsen *et al.*, 1996; Yokota *et al.*, 1992).

It has been repeatedly demonstrated that the addition of sugars at ensilage increased the initial number of lactic acid bacteria on the crop, especially those with a high potential for producing lactic acid (Sharp, 1999; Yunus *et al.*, 2001). Of the two sugars, glucose and fructose, which constitute sucrose, the former is preferable as a substrate for fermentation, since some of the fructose component of sucrose is converted to mannitol, which being a neutral product, has no effect on pH. Glucose, however, is likely to be converted to lactic acid and VFA, which could reduce the pH of the silage quickly (Yunus *et al.*, 2000).

Recently, cereals are used as additives when ensiling grasses as an alternative to feeding cereals as a supplement. It is generally assumed that the addition of cereal starch does not assist in silage fermentations, since starch is not an available substrate for lactic acid bacteria (McDonald and Whittenbury, 1977; McDonald, 1981). Nevertheless, Jones (1990) observed that the addition of ground oats or barley at a rate of 13 or 53kg/ tonne of herbage ensiled significantly improved the fermentation of late autumn silage. This was not however due to starch hydrolysis as 100% of the starch was recovered in the silage. A further benefit of adding substantial quantities of cereal prior to ensiling is that of effluent absorption (Jones, 1990; Fransen and Strubi, 1998). It was reported that cereals have the absorptive capacity like fibrous materials such as hay and straw. Moreover, using cereals as absorbents increased the nutritive value of silages while addition of fibrous materials is likely to depress quality (Jones, 1990).

The pH values of the silage were significantly lower when molasses was added (Man and Wiktorsson, 2001). Molasses addition has been predicted to benefit for un-wilted crops with low water-soluble carbohydrates and high buffering capacity by reducing final pH and the reduced clostridial spoilage (Leibensperger and Pitt, 1988; McDonald *et al.*, 1991; Scudamore and Livesey, 1998). Addition of molasses led to improve fermentation quality by decreasing pH value of silage, volatile basic N and butyric acid and by increasing lactic acid content (Yunus *et al.*, 2000). Molasses addition in clover before ensiling was found to produce more lactate and less acetate and NH_3-N than controls (McDonald *et al.*, 1991). Yokota *et al.* (1992) reported that 4% molasses as an additive in wilted napier grass (*Pennisetum purpureum*) silage decreased the pH value from 4.72 to 3.99 and lactate dominated in fermentation products. In contrast, Anderson and Jackson, 1970 reported that addition of molasses to wilted or unwilted grass crops increased the residual water-soluble carbohydrate content but did not always lower the final pH.

It was further reported that adding molasses to herbage increased the water-soluble carbohydrate contents and lowered the water activity of the silage juice (Muck, 1987). When water-soluble carbohydrate contents were not limiting, final pH increased slightly with increasing application rate due to the effect of molasses on initial water activity (Svensson and Tveit, 1964). Carpintero *et al.* (1969) reported a similar effect of molasses on final pH of unwilted legume silage. Proteolysis was unaffected by molasses even in the case where molasses reduced final pH (Leibensperger and Pitt, 1988).

Nisa et al. (2005) reported that ruminal DM and NDF degradabilities of Mott grass silage (MGS) were significantly ($p<0.05$) higher than that of Mott grass (MG). However, the rate of degradation of DM and NDF, lag time and extent of degradation were non-significant between MGS and MG. The higher ruminal degradation of DM and NDF of MGS than MG was probably a reflection of fermentation of MG during ensilation that improved its degradability by improving the availability of easily degradable structural polysaccharides to ruminal microbial population.

5.2 Urea

Certain crops are deficient in essential dietary components for ruminants. The nutritional quality of these crops can be improved by supplementation with specific additives at the time of ensiling. Additives that have been used in this respect are NH_3 and urea to increase CP content of the silage. Urea addition is a common and cheap method of increasing N supply to ruminants fed silage. Urea and NH_3 were also known to improve the aerobic stability of the silage as well (Glewen and Young, 1982; McDonald *et al.*, 1991; Yunus *et al.*, 2000). During the initial phase of ensiling at neutral pH, added urea in silage is easily decomposed to NH_3 by urease activity of plant and microbial enzymes (Stephanie and Simon, 1992).

Although urea addition raised total N content, it also decreased the fermentation quality of silage by increasing pH with the release of NH_3 (Yunus *et al.*, 2000; Khan et al., 2006). These workers also reported that the addition of different combinations of urea and molasses improved protein content and fermentation quality of the silage. Molasses addition reduced nutrient loss and ultimately increased DM percentage while N content decreased significantly (Yunus *et al.*, 2000). A significant interaction between urea and molasses levels for N implied that the increasing effect of N by urea addition disappeared as molasses level increased. At all urea levels, pH decreased significantly with increased molasses addition. Increase in lactic acid content has also been reported for chopped whole plant corn silage treated with NH_3 or urea as compared to untreated silage (Huber *et al.*, 1979).

Anhydrous NH_3 or water or molasses NH_3 mixtures have been used as silage additives. Ammonia additions resulted in addition of an economical source of N (Huber *et al.*, 1979), prolonged bunk life during feed out phase (Britt and Huber, 1975), reduced molding and heating during ensiling and decreased protein degradation in the silo (Johnson *et al.*, 1982). Kung *et al.* (2000) suggested that anhydrous NH_3 should be applied at approximately 6 to 7% of forage DM. This will increase CP content of the silage from about 8 to 12% on DM basis. Excess NH_3 may result in poor fermentation in the silage because of the prolonged buffering effect and therefore may lower the animal performance. Contrary to the above findings, Bolsen *et al.* (1992) reported that use of anhydrous NH_3 adversely affected DM recovery, particularly in high moisture sorghum silage.

5.3 Enzymes

Under adverse environmental conditions for ensilage the availability of readily fermentable substrate could be a more limiting factor in achieving a satisfactory fermentation than is the quantity of bacteria available. It has been recognized that enzymes may provide a potential means of releasing suitable energy substrates (Chen *et al.*, 1994; Fredeen and McQueen, 1993). Such enzymes include hemicellulases and cellulases, which break down structural carbohydrates. Enzyme additives had the potential not only to increase the availability of fermentable sugars during ensilage by hydrolysis of structural carbohydrates, but also to improve the degradability of the subsequent silage in the rumen (Chen *et al.*, 1994; Fredeen and McQueen, 1993). It was further reported that enzyme treated silage had an acid detergent fiber (ADF) content with a higher soluble fraction compared to the ADF content of a formic acid treated silage. Selmer *et al.* (1993) demonstrated that most of the additional substrate released by enzymes was produced by the breakdown of cellulose and not the hemicellulose. Other studies involving the use of laboratory silos have also shown some beneficial effect on the rate of silage fermentation when cell wall degrading enzymes were added (Spoelstra *et al.*, 1992).

The subsequent effects of enzyme treated silages upon animal performance were not consistent. Sheperd and Kung (1996) reported the yield of milk solids to be on an average only 2% greater with enzyme treated silage than untreated silage when these were fed to cows. Murphy *et al.* (1982) observed only marginal improvements in milk yield, although the enzyme performed better where difficult to preserve grass was ensiled. Commercial biological additives frequently contain a mixture of cell wall degrading enzymes and an inoculant of lactic acid bacteria. Nadeau, *et al.* (2000) showed that such a mixed preparation produced silage with a stimulated fermentation, compared to both untreated silage and formic acid treated silage. Cattle consumed significantly more of the enzyme inoculant treated silage and had a greater live weight gain than those fed the untreated silage. However, they gained less weight than those fed formic acid treated silage. The success of enzyme additives will ultimately depend upon the preparation of effective products using modern production techniques, capable of enhancing the ensilage process at economical levels of usage (Nadeau *et al.*, 2000).

Ammonia N increased during ensiling and was lower in treated than in untreated silage. The CP on day 0 was 19.7, 21.5, and 20.7% and on day 177 was 20.2, 19.7 and 20.0% for untreated silage, silage treated with additive "fresh plus^{TM}" (SFP) and silage treated with "alfazyme^{TM}" (ALF), respectively. The reduction in NH_3-N likely was a result of the restriction of proteolysis in the silage. The microbial inoculation also reduced NH_3-N content in silages (Rooke *et al.*, 1988, Gordon, 1989 and Kung *et al.*, 1990). The NDF was 35% at ensiling and did not differ between treated and untreated silage after 14 days of ensiling. However, differences were found in the NDF content after 51 day of ensiling.

5.4 Acids

The main fermentation inhibitors are acids applied directly at ensiling. Formic acid and sulfuric aid are the two most commonly used. The objective of using acids is to lower the pH of the crop immediately after harvesting. This was beneficial in minimizing the loss of nutrients (Gordon, 1989). During ensiling process, CP contents are extensively degraded and significant amounts of NPN are produced. It was noted however, that even in well-preserved silages up to 60% of the proteins were hydrolyzed. That's why the direct applications of acids had long been practiced during silage making to reduce the pH of the crop immediately after ensiling (McDonald, 1981).

McDonald (1981) used acids in combination with sugar as additive before ensiling fodder and reported that the addition of acid lowered the initial pH and addition of sugars reduced the risk of premature arresting of lactic acid fermentation due to depletion of water-soluble carbohydrates. Three additives i.e. (i) 4% formic acid (ii) 0.4% formic acid+ 3% formalin, respectively and (iii) 0.5% common salt of fodder were used. During ensiling the DM and OM contents were reduced in all silages and the additives affected the DM content in bajrae (*Echinochloa colona*) + cowpea (*Vigna slnensis*) silages only. Formic acid+formalin application before ensiling reduced the DM and OM losses and lowered the NH_3-N, pH as well as the buffering capacity and increased the lactic acid content. Whereas, CP and water-soluble carbohydrates contents decreased in all ensiled forages (Grewal *et al.*, 2000). Similar results were also observed by Nadeau *et al.* (1996) when orchard grass and alfalfa silages were treated with cellulase and formic acid.

The use of formic acid as a silage additive has been extensively reviewed (McDonald, 1981; Thomas and Thomas, 1985). It is an effective additive and is often used as a standard for the comparison of other additives. Formic acid was found to be effective silage additive that lowered pH of the silage and had a selective bactericidal activity (Thomas and Thomas, 1985). Although the antibacterial activity of formic acid, as with mineral acid owes something to the hydrogen ion concentration, the major part of its selective bactericidal activity lies in the nature of the undissociated acid. Formic acid did not, however, inhibit the growth of yeasts in silage (McDonald *et al.*, 1991).

Minerals acids have been used as silage additives for many years, i.e. hydrochloric acid in the AIV (A.I. Virtanen) process (Virtanen, 1938). There are several disadvantages in the use of sulfuric acid as a silage additive. Firstly the additive is extremely corrosive to farm machinery and equipment, secondly, the intakes by animal consuming the resultant silage were often depressed and thirdly, such silage has been shown to reduce the copper status of animals (Bolsen *et al.*, 1995).

5.5 Formaldehyde

Formaldehyde is effective as a silage additive by virtue of two independent mechanisms. Firstly, it restricted silage fermentation and secondly it bound to plant proteins and reduced the proteolysis both in the silo (Barry, 1975) and in the rumen (McDonald, 1981). High rates of addition of formaldehyde have been shown to have detrimental effects upon silage intake. On the other hand, low levels of formaldehyde tended to stimulate the growth of undesirable organisms such as clostridia and could result in the production of silage with high butyric acid contents (Barry, 1975).

The inclusion of formic acid with formaldehyde as an additive permits a reduction in the level of formaldehyde application, which is required to restrict the silage fermentation effectively. To a certain extent, this alleviated the problem of restricted intake associated with high levels of formaldehyde application (Barry, 1975). It was noted, however, that in practice, the use of formaldehyde in mixtures with formic acid had no advantage over formic acid alone with respect to its effects on silage fermentation and animal performance.

5.6 Lactic acid bacteria

In recent years, there has been a renewed interest in the inoculation of forage crops intended for silage with selected strains of lactic acid bacteria. The aim is to dominate the indigenous micro flora which were less efficient in fermenting sugars to lactic acid than the introduced bacteria (Higginbotham *et al.*, 1998; Yunus *et al.*, 2000) The need for a biological additive to replace the acid base additives has long been recognized (Bolsen *et al.*, 1996). Acid additives are both unpleasant and unsafe to handle and are corrosive to the ensilage equipment.

For many years it has been assumed that, anaerobic conditions created in the silo and an adequate supply of fermentable substrate is essential for natural lactic acid bacteria on the crop to be ensiled to ensure a normal fermentation. Under such ideal circumstances, the epiphytic lactic acid bacteria should have the capacity to become dominant and suppress undesirable microorganisms such as enterobacteria, clostridia, yeast and the resulting silage should have a pH low enough to be stable during anaerobic storage (Higginbotham *et al.*, 1998; Garcia *et al.*, 1989).

However, the concentration of lactobacillus on fresh grass has been shown to be relatively low (Bolsen *et al.*, 1996). High counts of lactic acid bacteria have been found only occasionally on the standing crop (Weinberg and Muck, 1996). In contrast, Fenton (1987) showed that by the time of harvest ensiled herbage reached the clamp count of lactic acid bacteria as high as 103 colony-forming units (CFU) per gram of grass ensiled. It was concluded that passage through the silage making equipment served to inoculate the grass with lactic acid bacteria. This phenomenon of equipment inoculation was, however, disputed in the ninth silage conference (Pahlow and Muller, 1990). Furthermore, Rooke (1990) concluded from a study of the numbers of lactic acid bacteria on herbage at the silage pit on commercial farms that the number of lactic acid bacteria on grass exceeded the previously estimated value. However, Rooke (1990) reported that the number of epiphytic bacteria present on herbage to be ensiled varied very markedly from year to year. Lindgren *et al.* (1985) observed that adverse conditions for ensiling could reduce the endogenous lactic acid bacteria and increase the likelihood of unsatisfactory clostridial fermentations.

A further point that needs consideration has been reported by Weinberg and Muck (1996) who demonstrated that in silages prepared without the use of an additive of homo fermentative lactic acid bacteria, the microbial population could become dominated by hetero fermentative lactic acid bacteria. Thus, because of the uncertainty of the numbers and strains of lactic acid bacteria present on harvested crops, there was a great potential for the use of a suitable inoculant containing homo fermentative lactic acid bacteria to dominate the indigenous micro flora and induce a more rapid lactic acid production and hence quick pH reduction in the silo.

With the improvement in production technology and the realization that the efficacy of inoculants could be predetermined by the conditions prevailing at ensilage, there followed growing evidence reporting the successful use of inoculants in laboratory scale silos (Sharp *et al.*, 1994). It was however, still equivocal whether or not these improvements in silage fermentation could be justifiably applied to farm scale silo. The differences in temperature and pressure between laboratory and farm scale silo have been demonstrated to affect silage composition (Garcia *et al.*, 1989). These beneficial effects upon fermentation are primarily reflected in a more rapid decline in pH of the inoculant treated silage to a significantly lower final pH (Rooke *et al.*, 1985; Anderson *et al.*, 1989 and Yunus *et al.*, 2000). This rapid decline in pH is associated with a speedy use of lactic acid content and a slower accumulation of acetic acid. Because lactic acid is the main product of fermentation therefore, a stable pH is achieved in a much shorter time period. This is at the expense of less water-soluble carbohydrates resulting in higher residual water-soluble carbohydrates in inoculant treated silages (Rooke *et al.*, 1985).

Inoculant treated silages have been repeatedly demonstrated to have a lower NH_3-N content than untreated silage (Gordon, 1989; Rooke *et al.*, 1988; Anderson *et al.*, 1989). This effect is not, however, consistent (Anderson *et al.*, 1989; Higginbotham *et al.*, 1998). The production of NH_3-N in silage is a two stage process; *viz.* the hydrolysis of herbage proteins to their constituent peptides and amino acids. The rapid stabilization of silage has been shown to reduce the extent of proteolysis in the silo by the inactivation of plant proteases (McDonald, 1981; McDonald *et al.*, 1991). However, it should be recognized that even in well-preserved silages, some 60% or more of the herbage proteins are hydrolyzed during the ensiling process (McDonald, 1981; McDonald *et al.*, 1991). Proteolytic clostridia are assumed to be the major source of de-aminative activity and hence of NH_3-N production in silage. Ammonia N was also known to produce by the action of plant enzymes and coliform (Seale, 1986). It thus seemed probable that the rapid achievement of a low pH would reduce both the extent of proteolysis and de-amination, resulting into silage with a lower NH_3-N content. Indeed, Sharp (1999) demonstrated that an inoculant of lactic acid bacteria reduced the extent of proteolysis in silage by a small amount but markedly reduced the extent of de-amination. Moreover, the inoculant treated silage was associated with a lower pH.

6. Silage characteristics

6.1 pH

Silage pH is an important indicator of quality (Bolsen *et al.*, 1996). Quality silage has a pH value of 4.2 or lower (Yunus *et al.*, 2000). Factors involved in the rate of pH decline and final pH of the silage include water-soluble carbohydrates concentration of the original forage, its buffering capacity (related to the amount of acid needed to change the pH), DM content and the type and amount of bacteria present on the forage (Bolsen, *et al.*, 1996; Higginbotham, *et al.*, 1998).

The pH of grass herbage when initially cut is usually between 6.0 and 7.0 and after effective silage fermentation it is reduced to 4.0 or below. It is the rapidity of this decline in pH, which is increasingly regarded as being crucial in minimizing the loss of nutrients during ensilage (Yahaya *et al.,* 2001). As described earlier, this fall in pH is facilitated by the production of lactic acid and other organic acids. Such a decline in pH is desirable because a rapid drop in the pH immediately after ensilage causes a reduction in the counts of coliform and clostridial bacteria (Seale, 1986; McDonald *et al.*, 1991; McDonald, 1981). Clostridia and coliform are undesirable because they have the capacity to ferment water-soluble carbohydrates and lactic acid to end products such as acetate, butyrate, propionate, ethanol and butanol (Thomas and Morrison, 1982). They can also metabolize amino acids to produce a variety of end products including volatile fatty acids (VFA), amines and NH_3 (McDonald, 1981).

Silage pH was the lowest when rolled barley or beet pulp was used as an absorbent and was the highest for wilted grass (Fransen and Strubi, 1998). It was further reported that wilting was an effective treatment in young napier grass to lower pH value compared with fresh young napier grass silage. They also found that the pH value of direct cut silage of napier grass was 5.09 while wilted silage had a pH of 4.72.

The pH was lower and concentrations of lactic acid, acetic acid and total organic acids were higher in corn silage whereas butyric acid concentrations were higher in Mott grass silage (Ruiz *et al.*, 1992). The pH of alfalfa silage was 5.9 while the pH of perennial ryegrass silage was 5.8, which showed that both silages were aerobically stable (Hoffman *et al.*, 1998). Pearl millet (*Echinochloa colona*) silage had higher pH as compared to sorghum and corn silages. The relatively high pH of pearl millet silage can probably be attributed to the low pre-ensiling water-soluble carbohydrate concentration in pearl millet (Ward *et al.*, 2001).

6.2 Lactic acid

Lactic acid content between 3 and 13% of DM and total N less than 11% indicated that the silage was of good quality and preserved well (Yunus *et al.*, 2000). Variations in the concentration of fermentation products of early and late cut grasses were reviewed by De Visser *et al.* (1998) who reported that the concentration of lactic acid were 14 and 35, acetic acid 5 and 13, butyric acid 0.5 and 0.5, ethanol 17 and 12, NH_3 2 and 3g/kg of DM, respectively for early and late cut grasses. They showed a higher concentration of fermentation products except ethanol in late cut grass silage. The higher concentrations of fermentation products in silage from late cut grass may be attributed to its high fiber (ADF and NDF) concentration. Pearl millet silage had less lactic acid than sorghum and corn silages. The low lactic acid of pearl millet silage was probably due to its low content of water-soluble carbohydrates as compared to sorghum and corn (Ward *et al.*, 2001).

According to Catchpoole and Henzell (1971), quality silage had a butyric acid concentration of less than 0.2% with lactic acid between 3 and 13% of DM. The silage from early cut grass contained more N and sugar than did the silage from late-cut grass but was lower in NDF because of respiration during the longer period of wilting. High sugar content led to the formation of more fermentation products (lactic and acetic acid) during the ensiling process (De Visser *et al.*, 1998).

The lactic acid content of the corn silage was not influenced significantly by the inoculants throughout the fermentation and storage period. Final lactic acid concentrations were within expected ranges for silages containing greater than 65% moisture (Higginbotham *et al.*, 1998). Gordon *et al.* (1961) reported that as moisture level increased in silage, lactic acid decreased which was due to a dilution effect. In contrast Soderholm *et al.* (1988) reported that lactic acid production in control hand harvested snapped ear corn during fermentation was not affected by moisture content. Final lactic acid concentrations in medium moisture snapped ear corn silage were similar to values reported for fermented ear corn of comparable moisture (Dutton and Otterby, 1971).

7. Effect of silage on feed intake

The depression in DMI of silage was studied by Wilkinson (1983), Thomas and Thomas (1985) and Ruiz *et al.* (1992) who reported a lower intake of silage due to the presence of fermentation products. They further explained that there had been a significant correlation of DMI with silage pH, with the concentrations of acids in the silage DM (negative correlation) and with indices of fermentation quality. The latter include the proportion NH_3-N in the total N (negative), the proportion of lactic acid in total acids (positive) (Rook and Thomas, 1982) and moisture content of the silage (NRC, 2001; Sarwar and Hasan, 2001). Contrary to the above results, Bilal *et al.* (2001), West *et al.* (1998) and Cushanhan and Gordon (1995) reported that DMI may not be affected by feeding of silage based diets when silage was fed as total mixed ration. Khorasani *et al.* (1993) found that substituting alfalfa silage for barley silage had no effect on DMI of cows fed 50:50, forage to concentrate diet.

It seemed that there was little relationship between the digestibility and intake of silages. Indeed, Wilkins *et al.* (1979) suggested that relatively little of the total variation in silage intake was associated with its digestibility and that intake was more closely related to the products of silage fermentation. Similarly Henderson *et al.* (1979) concluded from a survey of the intake potential of a range of well preserved silages offered to lambs; silages with the greatest positive effect upon intake were those with the highest contents of residual sugar and protein N and the lowest content of ethanol. Rooke (1990) concluded from an extensive statistical survey using principal component analysis and ridge regression analysis, that fermentation characteristics were the most important factors affecting silage intake. The relationship between butyric acid content and silage intake was found to be inverse. The content of butyric acid was shown to have a more powerful effect in determining silage intake than the content of other VFA or NH_3-N.

There was a decrease in intake of actual DM, DM as percentage of body weight and OM with dwarf elephant grass silage as compared to corn silage (Ruiz *et al.*, 1992). At least three factors may be responsible for a reduction in DMI by cows fed dwarf elephant grass silage; low fiber digestibility, higher organic acids and NH_3-N concentrations in dwarf elephant grass silage and increased water concentration of the diet. Intake of NDF as a percentage of body weight was the same in both groups of fed corn silage and dwarf elephant grass silage (Ruiz *et al.*, 1992). Bilal *et al.* (2001) reported that lactating buffaloes when fed a blend of 25% mott grass and 75% of its silage consumed higher ($p<0.05$) DM than those fed 100% mott grass, 100% mott grass silage and a blend of 25% mott grass and 75% of its silage. But the animals fed fodder or silage alone showed a non-significant difference in DMI. The higher DMI in buffaloes fed 25:75% of grass to silage may be attributed to some positive associative effect between fodder and silage.

Increased forage maturity has been correlated positively with rumen fill and negatively with DMI. Anderson (1982) showed that there was a non-significant effect of stage of maturity on silage intake by sheep. The DMI of maize silage was higher at the latter stage of maturity (De Boever *et al.*, 1993). Although the inclusion of fermented wheat and urea treated whole crop wheat increased DMI but milk yield was not significantly affected (Phipps *et al.*, 1995). Increased dietary NDF concentration linearly decreased DM and OM intake as a percentage of body weight and linearly increased NDF intake as a percentage of body weight (Ruiz *et al.*, 1995).

Feeding wilted silage increased OM intake, but it had no effect on the proportion of OM apparently digested in the rumen (Teller *et al.*, 1992). At equal digestibilities legumes are consumed in greater amounts than grasses and a smaller daily decline in intake occurred with increasing maturity of legumes than grasses (Waldo and Jorgensen, 1981). The intake of OM increased as the level of concentrate in the diet increased but was not affected by source of forage fiber (Stensig and Robinson 1997).

Sarwar et al. (2005) evaluated feeding value of Berseem and Lucerne silages as a replacement for conventional fodder (Berseem fodder) in lactating *Nili* Buffaloes. In their study, fifteen early lactating multiparous *Nili* buffaloes, five buffaloes in each group were allotted three experimental diets. Berseem and Lucerne fodders were ensiled at 30% DM (wheat straw was used to adjust the DM of fodders) with molasses (at the rate of 2% of fodder DM) in two bunker silos for 30 days. The diets contained 75% DM from Berseem fodder (BF) 75% DM from Berseem silage (BS) and 75% DM from Lucerne silage (LS). Each diet contained 25% concentrate DM. The intake of DM was significantly higher in buffaloes fed BF diet than those fed LS diets. Similarly, intake of NDF (NDFI) was higher in buffaloes fed BF diet followed by those fed L.S and BS diets. The difference was significant (p 0.05) across fodder and silage based diets but NDFI was non-significant across both silage-based diets. Lower DMI with silage-based diets was probably because of low silage pH, which might have depressed the feed intake. In another study feeding value of Jambo grass (Sorghum Bicolour X Sorghum Sudanefe) silage and Mott grass (*Pennisetum Purpureum*) silage as a replacement of conventional fodder (Jambo grass) was studied by Tauqir et al. (2007) in the diet of lactating Nil*i* buffaloes (*Bubalus bubalis*). The results revealed that Intake of DM was higher with the JG diet compared with JGS and MGS diets. However, DMI as % body weight did not differ significantly in buffaloes fed either fodder or silage based diets. Crude protein, digestible CP and NDF intakes were significantly higher on JG compared with silage-based diets. It was opined that the presence of fermentation end products and low silage pH are the factors that might have depressed intake of silage-based diet. Apparent total tract digestibilities of DM, CP and NDF were similar in buffaloes fed JG, JGS and MGS diets.

Dry matter intake was numerically lower by 0.8 kg/day when cows were fed the diet containing silage treated with cornzyme but feed efficiency was the same (Chen *et al.*, 1994; Sheperd and Kung, 1996).

These anomalies are not novel in the research for the factors determining the intake characteristics of silages especially where attempts are made to relate intake to specific constituents of the silages. It is clear however, that the use of inoculants of lactic acid bacteria and other additives could improve the voluntary intake of silages compared to untreated, especially where improvements in fermentation were noticed.

8. Effect of silage on ruminal characteristics

Low ruminal pH could affect attachment of microbes to fiber particles that seemed to be needed by many species of bacteria before most efficient digestion occurred (Hoover 1986). Similarly, Erdman (1988) reported that the ADF digestion decreased 3.6% units for every 0.1 unit pH decrease below 6.3 in the rumen. Shiver *et al.* (1986) using continuous cultures reported a marked reduction in attachment of microbes at pH 5.8 compared to pH 6.2 which corresponded to a significant decreasing NDF digestion.

The supplementation of rumen degradable starch can reduce the rumen pH because of higher volatile fatty acid (VFA) concentrations. The lower pH can reduce the activity of cellulolytic bacteria, resulting in a longer lag phase and a lower rate of degradation of NDF. For various silages, degradation rate and lag phases of DM, OM and CP were similar. The degradation characteristics of the NDF did not differ among silages (De Visser *et al.*, 1998).

The effect of starch was significant for silage from early cut grass, but not for silage from late cut grass. Starch supplementation significantly reduced the fractional turnover rate of NDF (Van Vuuren, *et al.*, 1999). The addition of flaked corn starch to the diet reduced the fractional passage rate of NDF but had no effect on the fractional passage rates of other nutrients. Starch had also a significant effect on the fractional degradation rate of NDF, calculated as the difference between the fractional turnover and passage rates (Shaver *et al.*, 1986).

Ruminal acetate increased linearly from 61.4 to 63.4 mol/ 100 mol of VFA with dwarf elephant grass silage based diet. This was expected because of the higher concentration of structural carbohydrates in the diet as dwarf elephant grass silage was substituted for corn silage. Contrary to the above findings, the concentration of ruminal butyrate declined with dwarf elephant grass silage based diet (Ruiz, *et al.,* 1992). There were no differences in molar percentages of valerate, isovalerate, or lactate because of dietary treatments. However, the ruminal acetate to propionate ratio appeared to increase non-significantly in cows consuming diets containing dwarf elephant grass silage. Overall, the concentration of total VFA appeared to decline linearly from 105.3 to 94.8 mol/ liter in cows fed diets based on corn silage as compared to dwarf elephant grass silage (Ruiz *et al.,* 1992).

Cheng *et al.* (1983) reported that the bacterial proliferation was evident during low pH conditions but none was tightly adherent to fiber particles as viewed from electron micrographs. The increased concentration of H^+ might displace divalent calcium or magnesium, which might be needed by some bacteria to attach to feed. Russel *et al.* (1990) reported reduced yields of cellulolytic bacteria in continuous culture when pH decreased below 6.0. They further noted that the reduction in the number of cellulolytic bacteria from 10^6-10^4/ml due to the destruction of membrane potential of cellulolytic bacteria causing lower viability at low pH.

Ruminal pH increased from 6.39 to 6.79 with the diets based on corn silage and dwarf elephant grass silage, respectively (Ruiz, *et al.,* 1992). The lowest observed pH was within the range needed for adequate fiber digestion in the rumen.

The contribution of lactate metabolism to the proportions of the individual VFA is an important process in the digestion of silage diets. Some silage has a lactic acid content which account for as much as 1% of the DM (Henderson, 1987; Rooke *et al.*, 1988). This would be particularly relevant in the case of inoculant treated silages with their high lactic acid content (Rooke *et al.*, 1985; Hopper *et al.*, 1988). When Rees (1997) infused lactic acid into the rumens of silage fed cows they observed decreases in the proportion of acetate and associated increases in the molar proportion of propionate and butyrate. Sharp, (1999) on the other hand claimed that acetate is a major end product of lactate fermentation and other substrates were responsible for the production of propionate.

Dry matter intake is one of the important factors that affect the rate and extent of feed digestion (Okine and Mathison, 1991). In a study with dairy cows fed at different levels of intake (1.0, 1.3, 1.5, and 1.7x maintenance) the rate and extent of ruminal NDF digestion decreased with increasing level of feed intake (Shaver *et al.,* 1986; Van Soest, 1965). The *in situ* rate of NDF digestion was higher and extent was lower in legumes compared with grasses.

Rate of digestion is an important characteristic of forage quality. Both rate and extent of cellulose and DM disappearance were higher for dwarf elephant grass silage than corn silage. The rate of DM disappearance was 24% higher and the extent of disappearance at 72 hour was 27% higher in dwarf elephant grass silage. The ruminal rate of cellulose disappearance was 37% faster and extent of disappearance was 14% higher for dwarf elephant grass silage than for corn silage (Ruiz *et al.,* 1992). The rate of cellulose digestion in corn silage based diets was increased; rates were highest when incubated in cows fed the dwarf elephant grass silage diets (Ruiz *et al.,* 1992). A slight linear increase in the extent of cellulose digestion in corn silage was observed with dwarf elephant grass silage based diets. This increased digestion followed the observed increase in ruminal pH (Ruiz *et al.,* 1992). The rate and extent of DM disappearance values were higher for leguminous and lower for non-leguminous fodders (Sarwar *et al.*, 1996). Rate and lag of NDF digestion between alfalfa silage and perennial ryegrass silage were not different (Hoffman *et al.*, 1998). Tropical corn silage had less lag time and slower NDF rate of digestion as compared to sorghum silage, but the extent of digestion of NDF for sorghum silage was greater than for corn silage (Nicholas *et al.*, 1998). The *in situ* extent of DM and cellulose digestion was higher for elephant grass than for corn silage (Ruiz *et al.,* 1992).

9. Effect of silage on nutrient digestibility

The digestion of silage based diets has been well documented (Rooke, *et al.*, 1985; Thomas and Thomas, 1985). The inefficient utilization of the N components of silages is a characteristic point, which separates the digestion of silage from that of the forage from which it was made. This inefficient utilization of N in silage is conventionally attributed to the rapid and extensive rumen degradation of silage NPN and soluble protein N, resulting in high rumen NH_3-N concentrations, inefficient microbial capture of this rumen degradable N, an associated losses of NH_3-N across the rumen wall with subsequent excretion in the urine (Sharp, 1994).

In sheep, digestibility of OM decreased when intake was increased from 1.0 to 2.0 and 2.6 to 3.1xmaintenance (Alwash and Thomas, 1971). The reduction in digestibility can be attributed to the increased rate of passage of the feed. Ruminal retention time declined with increasing feed intake. Digestibility depression at high intake was related to shortened ruminal residence time (Shaver *et al.*, 1986). Intake of DM was associated with rate and extent of fiber digestion in the rumen (Hoover, 1986). Firkins *et al.* (1986) reported decreased ruminal NDF digestion in steers when intake was increased from 60 to 90% of *ad-libitum* feeding. But total tract digestibility of nutrients usually remained unaltered when the intake level were below *ad-libitum* feeding (Slabbert *et al.*, 1992). *In-situ* DM and NDF fractional rates of digestion at low and high intake were inconsistent (Shaver *et al.*, 1986).

Corn starch supplementation increased the lag phase of DM and OM in early and late cut grass silage (De Visser, *et al.*, 1998). However, maturity did not influence NDF digestibility probably because lignification of NDF was similar for both silages from early and late-cut grasses. Rate of degradation was decreased for NDF on corn starch supplementation (De Visser, *et al.*, 1998). The addition of ruminally available cornstarch to diet based on grass silage did not influence the soluble, degradable or undegradable fractions of DM, OM, CP and NDF in either silages but significantly decreased the degradation rates of NDF in both silage based diets (Van Vuuren *et al.*, 1999).

The bulk of research with regard to the effect of inoculants of lactic acid bacteria on silage digestibility has been performed using maize or legume crops (Bolsen and Heidker, 1985 Bolsen *et al.*, 1996). Studies have conducted to show that the inoculant treated silage had undergone a more efficient fermentation and produced silage with a better chemical composition, thus improving digestibility and animal performance when compared with a control treatment.

Gordon (1989) fed inoculant treated and untreated silage of similar composition to sheep: the digestibilities of DM, OM, N and energy were significantly greater for the inoculant treated silage. This was in agreement with trends recorded previously using the same inoculant (Anderson *et al.*, 1989). In contrast to the above findings reported by Anderson *et al.* (1989) on the basis of judgment of quality through contents of butyric acid and NH_3-N, the inoculant treated silage appeared to be of lower quality than the untreated silage. However, there was non-significant difference in silage digestibility. Thus, it would seem that changes were not necessarily associated with any improvement in digestibility.

Yahaya, *et al.* (2001) while working on evaluation of structural carbohydrates losses and digestibility in alfalfa and orchard grass during ensiling reported that ensiling alfalfa and orchard grass for 0, 5, 21 and 56 days maintained a decreasing trend of DM digestibility in alfalfa (83.8, 82.5, 79.3 and 78.9%) and orchard grass (80.5, 77.0, 77.1 and 76.4%). While, the digestibility of cellulose and ether extract increased in silage of both species. The digestible energy values in silage were reduced from 2.6 to 2.3 and 2.9 to 2.7 Mcal/ kg DM, respectively in alfalfa and orchard grass during 5 to 56 days ensiling.

Digestibility of DM and fiber fractions usually decreased with advancing maturity in forages because of the increased amount of ADF present (Messman *et al.*, 1991). Sarwar *et al.* (1999) also reported similar observations with advancing plant maturity. The digestibility decreases with increased maturity of temperate as well as of tropical forages. Apparent digestibilities of DM, CP, NDF and ADF of silages were higher for two weeks than for a three week growth stage (Panditharatne *et al.*, 1987). Digestibility of CP at the soft dough stage was low and might be explained by the low CP intake and high indigestible DM (Acosta *et al.*, 1991).

When alfalfa, barley, oat and triticale silages were incubated in the rumen for 10, 16 and 24 hour, the oat silage diets had the highest residual DM at 10 hour, alfalfa and barley silage diets were intermediate and triticale silage diet had the lowest residual DM. Residual DM did not differ among diets at 16 and 24 hour of incubation in the rumen. At these time points alfalfa silage diet had the highest residual CP, the barley and oat silage diets were intermediate and the triticale silage diet had the lowest residual CP (Khorasani *et al.*, 1993). The difference in digestibilities of these various types of fodder may be because of species differences (Sarwar *et al.*, 1996).

Azim *et al.* (2000) prepared four different types of silages from (i) maize alone, (ii) maize + cowpea (85:15), (iii) maize + cowpea (70:30) and (iv) maize supplemented with 2.5% urea. After 60 days of ensiling, *in situ* DMD was maximum (61.8%) for maize+cowpea (70:30) silage followed by 59.3% for maize+cowpea (85:15%) silage, 57.5% for maize silage supplemented with 2.5% urea and 55.7% for maize silage alone. The digestibility of NDF and hemicellulose declined non-linearly with increasing maturity stage. *In situ* DMD of corn silage was lower than silage of corn and cowpeas. The reason for the higher DM digestibilities of corn plus cowpea silage was that legumes have higher digestibility than grasses (Azim *et al.*, 2000). Digestion rate of NDF, cellulose and hemicellulose was faster in vegetative stems than in productive stems. Hemicellulose was digested faster than cellulose (Sanderson *et al.*, 1989).

Sarwar et. al. (2005) studied influence of berseem and lucerne silages on feed intake, nutrient digestibility and milk yield in lactating Nili buffaloes. Fifteen early lactating multi-parous Nili buffaloes, five buffaloes in each group were allotted three experimental diets. Berseem and Lucerne fodders were ensiled at 30% DM (wheat straw was used to adjust the DM of fodders) with molasses (at the rate of 2% of fodder DM) in two bunker silos for 30 days. The diets contained 75% DM from BF 75% DM from BS and 75% DM from LS. Each diet contained 25% concentrate DM. Diets were mixed daily and fed twice a day at ad libitum intakes. The results reviewed that the apparent DM digestibility was significantly different ($p<0.05$) between fodder and silage-based diets but was non-significant between LS and BS diets. It was opined that higher DMD of fodder was probably because of higher concentration of soluble carbohydrates and lower lignin content in fodder than that of its silage (Khorasani et al. 1993). While, the lower DMD of silage-based diets might be because of low silage pH due to lactic acid content that might have depressed ruminal pH at least initially and thus cellulolytic activity.

10. Effect of silage on animal performance

In an experiment with lactating cows, Weinberg and Muck (1996) reported that the cows consumed significantly less inoculant treated silage than that of untreated silage and yet produced the same volume of milk and quantity of milk constituents. These findings implied a greater efficiency of utilization for the inoculant treated silage. However, Gordon (1989) concluded that the increased milk yield and milk protein output from cows fed an inoculant treated silage were a reflection of an increase in the intake of metabolizable energy (ME). It was further proposed that some further experimentation was required to elucidate that hypothesis. It should be noted, however, that different inoculants were used in the experiments of Weinberg and Muck (1996) and Gordon (1989). In a further similar experiment, Gordon (1989) compared responses in milk yield arising from feeding three different silage types; *viz* formic acid treated, untreated and inoculant treated. The use of the inoculant resulted in an increase in silage DMI of 12% over the untreated and the positive response in milk yield was 10%. There was no effect of formic acid on either silage DMI or milk yield. Higginbotham *et al.* (1998), however, did not show any beneficial responses to the use of the same inoculant as used by Gordon (1989) for dairy cows.

A small linear decrease in actual milk and 4% fat corrected milk (FCM) yields resulted from dwarf elephant grass silage based diets. Total decrease was only 1.5 and 1.4 kg/day for actual and 4% FCM yields, respectively. Milk fat and protein percentages were not affected by dwarf elephant grass silage based diet averaging 3.38 and 2.94%, respectively (Ruiz *et al.,* 1992). Average body weight changes were 0.55 and 0.14 kg/day due to corn silage and dwarf elephant grass silage diets, respectively. Apparent gross efficiency of milk production in terms of mega calories of 4% FCM per mega calories of NE_L intake favored corn silage based diet. However, when efficiency was corrected for body weight gain, reduction from 0.55 to 0.14 kg/day with corn silage to dwarf elephant grass silage based diet was observed. It was suggested that diets based on corn silage tended to be used most efficiently (Ruiz, *et al.,* 1992).

Sarwar *et. al.* (2005) fed lactating nili buffloes Berseem fodder, Berseem and Lucerne silage diets that contained 75% DM from BF 75% DM from BS and 75% DM from LS, respectively while rest 25% DM was concentrate portion. The results showed that DMI was significantly higher in buffaloes fed BF diet than those fed LS and BS diets. Four percent fat corrected milk yield was significantly different ($p<0.05$) between fodder and silage-based diets but was non-significant between LS and BS dies. Higher milk yield with fodder-based diet was probably because of more digestible nutrient intake compared with silage-based diets. Milk CP, TP, NPN and SNF did not show any treatment effects.

With reference to experiments with beef cattle, Anderson *et al.* (1989) used an inoculant of lactic acid bacteria for the ensilage of relatively poor quality herbage having DM content of 165g DM per kg fresh grass. The water-soluble carbohydrate content of this grass was 18.9g per kg fresh grass. There was no improvement in fermentation quality or digestibility of the resultant silage compared to the untreated silages. However, treatments with inoculants of lactic acid bacteria resulted in a significantly greater intake and live weight gain of growing beef cattle fed the silage. Anderson *et al.*, (1989) reported that inoculant treated silages showed an improvement in fermentation quality relative to the untreated silages in 3 out of 4 harvests. Only in one of these harvests the inoculant improved silage intake and animal performance. Similarly, Hopper, *et al.* (1988) reported that the use of an inoculant of lactic acid bacteria only resulted in a slight refinement in silage composition but had no effect on silage DMI, weight gain or feed conversion efficiency in cattle fed silage and concentrate as a mixed ration. It was noted, however, that the untreated silage was of usually high quality, with an NH_3-N content of only 39g per kg total N with no detectable butyric acid.

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