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EFFECT OF STAGE OF MATURITY ON NUTRITIONAL VALUE OF PEARL MILLET HARVESTED AS SILAGE OR HAY

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INTRODUCTION

Summer annuals could become important forage crops in the United States but they must be properly managed if they are to be utilized efficiently by ruminants.

In the past sudangrass and sorghum-sudangrass hybrids were the most common summer annuals used. But pearl millet also can be a high quality summer annual forage that does not accumulate prussic acid and usually is low in nitrate. Pearl millet is ideally suited for pasture grazing and it has a higher leaf to stem ratio than other summer annuals (Kilgore, 1975).

Animal production per land unit of forage depends on both quantity and quality of the forage produced and the animal's ability to utilize the forage efficiently. However, very limited information is available on quantity and quality characteristics of pearl millet grown in Kansas.

Objectives of this research were to measure the feeding value of pearl millet (Pennisetum Typhoides) harvested as silage and hay and to determine the effect of stage of growth on its nutritive value.

REVIEW OF LITERATURE

A. Morphological Development of Summer Annual Plants

The following outline describes the morphological development of summer annual forages as modified from Metcalfe (1973).

I. Early vegetative stage - leaves only, stems not elongated.

II. Stem elongation stage - should specify early or late jointing which depends on amount of leaves exposed. Less than 50% leaves exposed would be early-stem elongation; more than 50% leaves exposed, late elongation.

III. Boot stage - inflorescene enclosed in the flag leaf sheath and not visible.

IV. Heading stage - inflorescene emerging or emerged from the flag leaf sheath but no shedding of pollen.

V. Anthesis stage - flowering state and anthers actively shedding pollen.

VI. Milk stage - seeds immature and endosperm has a watery texture.

VII. Dough stage - well-developed seeds, and endosperm has a doughy texture.

VIII. Ripe seed stage - seeds mature and leaves green to yellow brown.

IX. Postripe seed stage - a few seeds shattered from the head and a few brown, dead leaves.

X. Stem-cured stage - most seeds cast from the head and all leaves brown.

B. <u>Stage of Maturity and its Relationship to Nutritive Value of Forages</u>

Intake and digestibility are factors that combine to determine the nutritive value of forages for ruminants. Crampton (1957) showed the feeding value of a forage depended more on the amount consumed than its chemical composition. This concept lead Crampton <u>et al</u>. (1960) to suggest a "nutritive value index" for forages based on their voluntary intake and digestibility by ruminants. Reid <u>et al</u>. (1959) pointed out that nutritive value of a forage depended on the rate at which it was consumed and its useful energy content per unit weight. Establishing useful energy values for forages would require digestion (or metabolism) trials.

Various studies involving a wide variety of hand-fed forages and roughages indicated that intake increased proportionately as digestibility of the forage increased (Blaxter <u>et al</u>. 1961; Campling, 1964; Lloyd <u>et al</u>. 1961; McCullough, 1963). The proportion and chemical composition of the morphological areas of a plant show significant variation due to stage of plant maturity at harvest, and research shows forage changes with advancing maturity, there by changing the digestibility and voluntary intake (Ademosum, 1968; Jung <u>et al</u>. 1964; Hosterman and Hall, 1938; McDonald, 1946). Owen and Webster (1963) showed that sorghum silage decreased in moisture and crude protein content but increased in crude fiber and nitrogen-free extract content as the sorghum plant matured. Sudangrass, sudangrass hybrids and pearl millet increase in nitrogen percentages when harvested four times annually compared to three times (Burger and Hittle, 1967; Broyles and Friboug, 1959). Although structural constituents (i.e., crude fiber, cellulose or lignin) increase as a forage plant matures, fiber in a mature plant is lower in cellulose and higher in lignin than fiber in the same plant at an immature stage of growth (Patton and Gieseker, 1942; Armstrong, Cook, and Brynmor, 1950).

Lignin is undigestible and reduces animal production from a forage (Bennett, 1940; Morosov, 1939; Crampton, 1938; Ellis, 1946; Gray, 1947; Ely, 1953). Lignin acts as a physical barrier between plant carbohydrates and rumen bacteria (Dehority et al., 1964; Johnson, 1969; Kamstra et al., 1958). Lignin tends to make cellulose less available to rumen microorganisms at a faster rate than it does hemicellulose (Waite and Gorrod, 1959; Sullivan, 1955). These workers reported a decline in rumen fermentation due to lignification, thereby lowering digestibility of a forage.

Certain chemical constituents of forages are used to determine forage nutritive values. Forage crude fiber and crude protein contents were used by Forbes (1950) and Phillips (1954) as criteria to evaluate forage digestibility. Dry matter, crude protein, and crude fiber contents have been used to estimate voluntary intake and digestibility of forages by several workers (McCullough, 1959; Morrison, 1950; Reid et al., 1959; Sullivan, 1962; Holton and Reid, 1959).

Forage Factor

There is a forage factor which is a relationship between stage of maturity and forage intake. McCullough (1959) reported that forage intake is influenced by forage quality and found a positive correlation of .512 between dry matter digestibility and dry matter intake.

Animal Factor

There is an animal factor that determines the production potential of an animal. Body size has a .98 correlation with forage intake (MacLusky, 1955; Legates *et al*., 1956). Dry matter consumption increases with increasing animal production (McCullough, 1956; Cox *et al*., 1956; Jarl, 1952; Wallace, 1956). Animal individuality adds factors which are difficult to measure and evaluate (MacLusky, 1955) and these are possibly influenced by environment.

Environmental Factors

Environmental factors of a ruminant can also influence forage intake (Ragsdale *et al*., 1958; Winchester and Morris, 1956; MacDonald and Bell, 1958). Wayman *et al*. (1962) reported a rise in ambient temperature lead to decreased hay intake. Conversely, other researchers report that a decrease in temperature lead to increased hay intake, also they demonstrated a thermostatic affective food and water intake, thus, environment can influence forage intake.

C. Effect of Chemical and Physical Properties Upon Rumen Parameters

The metabolism of carbohydrates and nitrogen in forages and an interaction with stage of growth influence the efficiency of forage utilization in the ruminant animal. Though the chemical composition of the ration is clearly an important factor affecting the proportions of the VFAs produced in the rumen, the rumen microflora population, which will be influenced by both the chemical and physical nature of the ration, must be of equal or greater importance.

Fermentation of dietary carbohydrates and hydrolysis of triglycerides to glycerol are the substrate for VFA production. (Annison and Lewis, 1959). Nitrogenous compounds, such as proteins and amino acids are substrate for VFA production as well as production of ammonia, amino acids, and bacterial and protozoal protein (Blackburn and Hobson, 1960).

Molar VFA concentrations will vary with type of ration fed, form of forage that was fed, animal from which sample was taken, and time of sampling. Physical condition of a ration alters the digestibility of ration constituents and probably the proportion of energy absorbed as VFAs (Shaw et al., 1960; Bath and Rook, 1963). Whether a ration contains silage, pellets, or hay it effects VFA concentrations (Wright et al., 1963). An immature, leafy forage has 50 to 67% acetic acid, 18 to 33% propionic acid, and 10 to 21% butyric acid proportions in the rumen during digestion. A mature, stemmy forage lowers the values for propionic and butyric acids. (Rook et al., 1961; Van Soest, 1973; Baker et al., 1959). Understanding the efficiency of rumen metabolism and its relationship to chemical and physical properties of forages is important when managing an economic forage system.

D. Factors Affecting the Utilization of Silage or Hay

Efficient utilization of a conserved forage depends on several factors; the two most important being the voluntary intake and digestibility of the forage by the animal. Both intake and digestibility can be influenced by the efficiency of the forage conservation practice. Nutrient losses during conservation also determine the quantity of nutrients contained in the conserved forage.

Losses Associated with Making Silage

According to Murdock and Holdsworth (1958), sources of nutrient losses in silage making include surface spoilage, plant respiration, anaerobic fermentation, and effluent.

During the ensiling process a forage under goes an anaerobic fermentation in which bacteria produce primarily lactic and acetic acids from carbohydrates contained in the forage. With a sufficient lowering of pH, the potential for growth of spoilage microorganisms is minimized. Numerous reviews have summarized management practices that are necessary to produce an efficient silage fermentation (Bolsen, 1977; Oltjen and Bolsen, 1978).

High nutrient losses during silage making can occur from "secondary fermentation" or deterioration by aerobic microorganisms. During this aerobic deterioration lactic acid, acetic acid, proteins, amino acids and sugars (Ohyama, 1975[a]) are respired by aerobic microorganisms resulting in the production of energy, carbon dioxide, and water. The assimilation of lactic and acetic leads to a rise in silage pH. The deamination of amino acids and increase in ammonia-nitrogen in the silage also contributes to the increase in pH. The formation of carbon dioxide and its subsequent release to the atmosphere accounts for the loss of dry matter (Woolford and Cook, 1977).

Aerobic spoilage of silage can result in very high nutrient losses, and as a silage is exposed to air for a greater time, there losses increase rapidly (Sears and Goodall, 1947; Culpin, 1960; Ohyama, 1975[a]).

Losses Associated with Making Hay

Nutrient losses in haymaking are primarily from plant respiration, mechanical damage, leaching by rain and adverse storage conditions. Losses during storage appear to be low (Watson et al., 1937; Murdoch et al., 1959), unless there is extensive heating in the hay mass (Monroe et al., 1946). Losses during storage are directly related to the moisture content of the hay when stored (Monroe et al., 1946; Dijkstra, 1947). From mechanical damage, large losses occur only when the dry matter content of the herbage drying in the field is high (Watson and Nash, 1960).

Conditioning machinery can be used to accelerate the rate of drying of hay (Shepperson, et al., 1962), thus reducing the length of time during which the hay is exposed in the field, but such treatment may result in an increase in nutrient loss, presumably due to mechanical damage (Murdoch, 1960; Shepperson et al., 1962).

Comparison of Silage and Hay

Conditions under which the preserved forages are made will have a marked effect on the nutritive value of the forage and animal production from it.

Evidence is conflicting as to the relative value of hay and silage made from forage at the same stage of maturity and it is often difficult to determine whether differences are due to conservation methods or to the relative efficiency with which the methods of conservation have been carried out. Data are available which indicate that an advantage in terms of digestibility can exist for either silage or hay (Trimberger, et al., 1955; Culpin, 1962; Gordon et al., 1963[a]), but in general, differences in digestibility are small (Carter, 1960). Ekern and Reid, (1963) have found a greater mean retention of energy with silage than with hay, although both were made from forage at the same stage of maturity and had almost identical gross energy values.

Comparison of Intake with Silage or Hay

One of the main factors determining the voluntary intake of a roughage is its dry matter content. Cattle given silages seldom consume as much dry matter as when they are offered hay (Sykes et al., 1955; Moore et al., 1960; Brown et al., 1963).

The reason for lower intake of silage compared to hay is unknown, but workers speculate that water contained in silage is probably not a direct limiting factor (Moore et al., 1960; Brown et al., 1963), although, within limits the drier the silage the more of it will be eaten (Dodsworth, 1954; Moore et al., 1960; Thomas et al., 1961). Histamine, tyramine and lactic acid have been linked to low silage intakes, but data are inconsistent (Thomas et al., 1961).

It has been suggested that rate of disappearance of digesta from the rumen may be slower for silages than hays.

There is considerable variation in results when attempts have been made to assess the increase in dry matter intake in terms of production. The digestibility of silage is generally equal to that of the hay prepared from similar forage (Harris and Raymond, 1963).

Increases in milk yield (Moore *et al*., 1960; Gordon *et al*., 1961; Brown *et al*., 1963) and in live weight gain (Dodsworth and Campbell, 1953; Murdoch *et al*., 1958; Moore *et al*., 1960) have been found consistent with increase in dry matter intake with hay but some results showed no increase in production (Brown, 1960; Slack *et al*., 1960[b]; Brown *et al*., 1963).

E. Comparative Utilization of Forage by Sheep and Cattle

The comparative digestion of feed by sheep and cattle has been studied by several workers.

In a statistical study of published data, Cipolloin *et al*. (1951) concluded that sheep digested concentrates more efficiently, but that cattle generally digested dry roughages better.

Breuer, (1966) found that when sorghum grain was fed to mature wethers both energy and protein digestibilities were approximately 10 percentage points higher than when fed to young bulls. The bulls and wethers were fed at comparable levels relative to body weight. Similar results were obtained by Keating *et al*. (1965).

Sheep digested energy in corn silage more efficiently than cattle as shown by Vander Noot *et al*. (1965). When fed according to metabolic weight, cattle digested corn silages better than sheep (Watson *et al*., 1948). Alexander *et al*. (1962) found little difference in mean dry matter digestibility of corn silages between cattle and sheep. This apparent disagreement may have been due to differences between the silages in grain-roughage ratio.

Cows, yearling cattle, and sheep digested dry matter, energy and protein equally well in four alfalfa hays (Buchman and Hemken, 1964). Similar results in digestion trials with alfalfa silages were obtained by Vander Noot *et al*. (1965).

Cattle tended to digest coastal bermuda grass hays slightly better than sheep (Alexander *et al*., 1962) and steers digested timothy hay (Watson *et al*., 1948), and prairie hay (Jordan and Staples, 1951) somewhat better than sheep.

An advantage in protein digestibility by sheep when fed hays low in protein has been reported by a few workers (Alexander et al., 1962; Forbes, 1950). The difference was generally not great and might well be explained by the higher metabolic fecal matter for cattle when fed low quality hays (Van Soest et al., 1966).

A review of the literature suggests that when intake is standardized on the basis of metabolic weight and physiological function, sheep digest the starch in at least some grains better than cattle and that cattle digest forages high in cell wall content better than sheep (Riewe and Lippke, 1969).

EXPERIMENTAL PROCEDURE AND RESULTS

Forages, Forage Conservation Methods and Sample Analyses

Whole-plant pearl millet forages used were vegetative stage silage, boot stage silage and hay, and late-dough stage silage and hay. Inclement weather prevented harvesting of vegetative hay.

The three stages of plant growth and 1978 harvest dates were: vegetative (83 cm plant height; July 26); boot (160 cm plant height; September 5) and late-dough (170 cm plant height; October 12). At each harvest, adjacent windrows were harvested for silage at 65 to 70% moisture or field-dried and harvested for hay at 20 to 25% moisture. Silages were ensiled in upright, concrete stave silos (3.1 x 15.3 M) and stored for several months before being transferred to polyethylene lined, 208 l metal drums prior to feeding. The rectangular hay bales (approximate wt., 34 to 36 kg) were chopped with a tub grinder fitted with a 5.08 cm recutter screen prior to feeding. Molasses was added to the hays after grinding and to silages when the rations were mixed.

All forage samples were dried at $55^{o}C$ and ground with a Wiley mill to pass through a 40 mesh screen. Proximate analyses and gross energy were determined by A.O.A.C. (1970) methods. Silage pH was determined by extracting 25 gms of fresh silage in 200 mls of distilled water (Barnett, 1954). Analyses of silages for volatile fatty acids (VFA), lactic acid and ammonia-nitrogen were by extraction of 25 gms of fresh silage in 200 mls of .2N H_2SO_4 and the supernate analyzed by gas chromatograph (Parks, 1970). Analyses for cell wall constituents (CWC), acid detergent fiber (ADF), lignin, cellulose, and acid detergent nitrogen (ADN) were by the technique of Goering and Van Soest (1970). *In vitro* dry matter digestibility (IVDMD) was determined using the Tilley and Terry (1963) two-stage technique. Mineral analyses were conducted using spectrophotometer, atomic absorption, and flame emission techniques (Fiske and Subbarow, 1925).

Experiment 1: Lamb Growth Trial

Sixty crossbred feeder lambs were used in a 42-day growth trial (December 8, 1978 to January 19, 1979). Rations contained 85.5% silage or hay, 4.5% cane molasses and 10.0% supplement on a dry matter basis. Composition of the supplements is shown in Table 1. Supplement A was fed with late-dough silage; supplement B, with boot and vegetative silages; supplement C, with boot hay; and supplement D, with late-dough hay.

The lambs, native to Kansas and averaging 32.3 kg, were randomly allotted by weight to the five forage rations. There were three pens of five lambs per ration. Rations were mixed and fed *ad-libitum* twice daily. Rations were formulated to 13% crude protein and were equal in minerals, vitamins and additives. Initial and final weights of the lambs were taken after 15 hr without feed or water. Samples of silage and hay were taken weekly during the trial and composited for analyses.

Analyses of the five forages for dry matter, IVDMD and proximate and Van Soest analyses are in Table 2; pH, volatile fatty acids, lactic acid, ammonia-nitrogen, and minerals are in Table 3.

Crude protein and IVDMD were highest and crude fiber, cellulose, and lignin were lowest for forages in the early stages of growth. Mineral analyses indicated the highest mineral content (particularly phosphorus and potassium) for vegetative and boot stage forages.

Performance of the lambs in the Growth Trial is shown in Table 4. Lambs fed pearl millet boot hay had the fastest ($P<.05$) rate of gain and highest ($P<.05$) feed intake. Rate of gain and feed intake for lambs fed vegetative or boot silages were greater

(P<.05) than that of lambs fed late-dough silage or hay. 42-day feedlot performance for all lambs was unusually low. This was due, in part, to the extreme cold temperatures and low intakes and digestibilities of the late-dough forages.

TABLE 1. COMPOSITION OF SUPPLEMENTS FED IN THE LAMB GROWTH TRIAL

Ingredients	Supplement A	Supplement B	Supplement C	Supplement D
	% on a dry matter basis			
Soybean meal	54.42	-----	5.28	66.13
Urea	7.67	-----	-----	18.78
Milo, rolled	-----	62.20	82.45	-----
Dicalcium phosphate	5.25	5.23	7.68	9.45
Salt	2.28	2.28	3.25	3.98
Trace minerals	.26	.26	.33	.40
Molasses, dry (cane)	29.43	29.34	-----	-----
Aurofac - 10[1]	.57	.57	.83	1.02
Vitamin A[2]	.06	.06	.09	.13
Vitamin D[3]	.02	.02	.02	.03
Vitamin E[4]	.04	.04	.07	.08

1 - Formulated to provide 20 mg of aureomycin/lamb/day.

2 - Formulated to provide 3,000 IU/lamb/day.

3 - Formulated to provide 300 IU/lamb/day.

4 - Formulated to provide 30 IU/lamb/day.

TABLE 2. DRY MATTER, IVDMD, AND PROXIMATE AND VAN SOEST ANALYSES FOR FORAGES IN THE LAMB GROWTH TRIAL

Item	Vegetative	Boot		Late-dough	
	silage	silage	hay	silage	hay
Dry matter, %	29.7	33.4	87.5	34.4	86.5
IVDMD, %	62.5	62.9	62.6	50.1	52.8
	% of the dry matter				
Crude protein	14.7	11.8	11.1	7.3	5.3
Crude fiber	31.0	30.0	27.4	35.2	35.0
Ether extract	3.3	3.0	2.0	2.3	1.7
N-free extract	35.6	43.6	49.0	46.1	49.4
Ash	15.4	11.6	10.5	9.1	8.6
CWC	59.3	64.4	60.6	70.4	67.6
ADF	39.8	39.5	37.2	42.4	41.5
ADN	.182	.137	.222	.168	.176
Cellulose	30.8	29.2	27.8	33.5	33.1
Lignin	5.7	5.2	4.2	7.9	6.4

TABLE 3. PH, VFA, LACTIC ACID, AMMONIA-NITROGEN, AND MINERAL ANALYSES FOR FORAGES IN THE LAMB GROWTH TRIAL

Item	Vegetative silage	Boot silage	Boot hay	Late-dough silage	Late-dough hay
Ph	4.25	4.06	-------	3.99	-------
Ammonia-nitrogen[1]	21.8	16.2	-------	13.6	-------
	% of the dry matter				
Acetic acid	.184	.112	-------	.189	-------
Propionic acid	.007	.009	-------	.006	-------
Butyric acid	.002	.002	-------	.008	-------
Lactic acid	3.36	4.84	-------	4.26	-------
Phosphorus	.6965	.8081	.6789	.4738	.3212
Calcium	1.5798	1.2536	1.1285	1.1072	.8287
Iron	.0454	.0558	1.0158	.0305	.0339
Magnesium	.0952	.0863	.0781	.0787	.0638
Sodium	.0807	.0542	.0802	.0408	.0339
Potassium	5.0000	5.9679	5.6332	4.8869	4.4482

[1]PPM

TABLE 4. PERFORMANCE OF THE LAMBS FED THE FIVE FORAGE RATIONS IN LAMB GROWTH TRIAL

Item	Vegetative silage	Boot silage	Boot hay	Late-dough silage	Late-dough hay
No. of lambs	12	12	12	12	12
Initial wt., kg	32.2	32.2	32.2	32.3	32.1
Final wt., kg	34.2	34.5	36.4	33.4	32.8
Avg total gain, kg	1.9	2.2	4.2	1.1	.7
Avg daily gain, kg	.05[b]	.06[b]	.10[a]	.03[c]	.02[c]
Avg daily feed, kg[1]					
Silage or hay	.91	.88	1.11	.75	.81
Molasses	.05	.05	.06	.04	.04
Supplement	.11	.11	.13	.09	.10
Total	1.07[b]	1.04[b]	1.30[a]	.88[c]	.95[c]
Feed/kg of gain, kg[1]	26.2[a,b]	21.1[a,b]	13.0[a]	32.8[b]	58.7[c]

[1] 100% dry matter basis.

[a,b,c] Means on the same line with different superscripts differ significantly (P<.05).

Experiment 2: Silage Aerobic Stability Trial

The objective of this trial was to determine the aerobic stability of the three pearl millet silages when they were exposed to air. Deterioration of silage exposed to air is characterized by heating and spoiling, which results from activity of fungi, molds, and bacteria.

About 26 kg of each pearl millet silage was collected in plastic bags and stored for 12 hr at room temperature. Six weighed samples of each silage were then placed firmly into expanded polystyrene containers lined with plastic. Sample weights were 1,500 g for vegetative; 1,300 g for boot; and 1,400 g for late-dough silages. A thermocouple wire was inserted in the center of the silage and cheesecloth was placed over all containers to prevent dust contamination. Containers were stored at 18^{o}C and temperature recorded twice daily. Two containers of each silage were weighed, thoroughly mixed, and sampled after 8, 10, and 12 days air exposure. Samples were analyzed as previously described (page 13).

Composition of the silages after 0, 8, 10, and 12 days air exposure is shown in Table 5.

For all three silages crude protein and acetic acid were highest at the initial day and lowest at 12 days exposure to air. Ammonia-nitrogen and pH increased as time exposure to air increased.

Dry matter losses for all silages were lowest after 8 days exposure and losses increased sharply at 10 and 12 days exposure (Figure 1). Temperature increased rapidly after day 8 of exposure for boot silage and day 10 for late-dough silage, but temperature of the vegetative silage increased only slightly by day 12 of exposure (Figure 2).

TABLE 5. COMPOSITION OF PEARL MILLET SILAGES AFTER 0, 8, 10, AND 12 DAYS EXPOSURE TO AIR IN THE SILAGE AEROBIC STABILITY TRIAL

Item	Dry matter %	pH	% of dry matter: Crude protein	% of dry matter: Acetic acid[1]	Ammonia-nitrogen[2]
Initial day					
Vegetative	31.3	4.26	16.85	.22	24.22
Boot	32.6	4.06	12.82	.10	13.38
Late-dough	34.3	4.07	7.74	.23	10.98
After 8-day air exposure					
Vegetative	32.7	4.35	15.12	.21	27.85
Boot	36.7	4.17	12.57	.09	15.17
Late-dough	36.9	4.07	7.55	.23	12.02
After 10-day air exposure					
Vegetative	34.9	4.36	14.99	.21	25.33
Boot	37.1	5.07	12.43	.06	15.85
Late-dough	38.4	4.13	7.51	.17	14.41
After 12-day air exposure					
Vegetative	35.2	4.45	14.78	.15	31.15
Boot	37.7	7.80	11.54	.03	35.66
Late-dough	39.0	7.10	7.09	.03	14.89

[1] % acid in silage

[2] PPM

Figure 1. The losses of dry matter after 8, 10, and 12 days exposure to air for pearl millet silages in the Silage Aerobic Stability Trial.

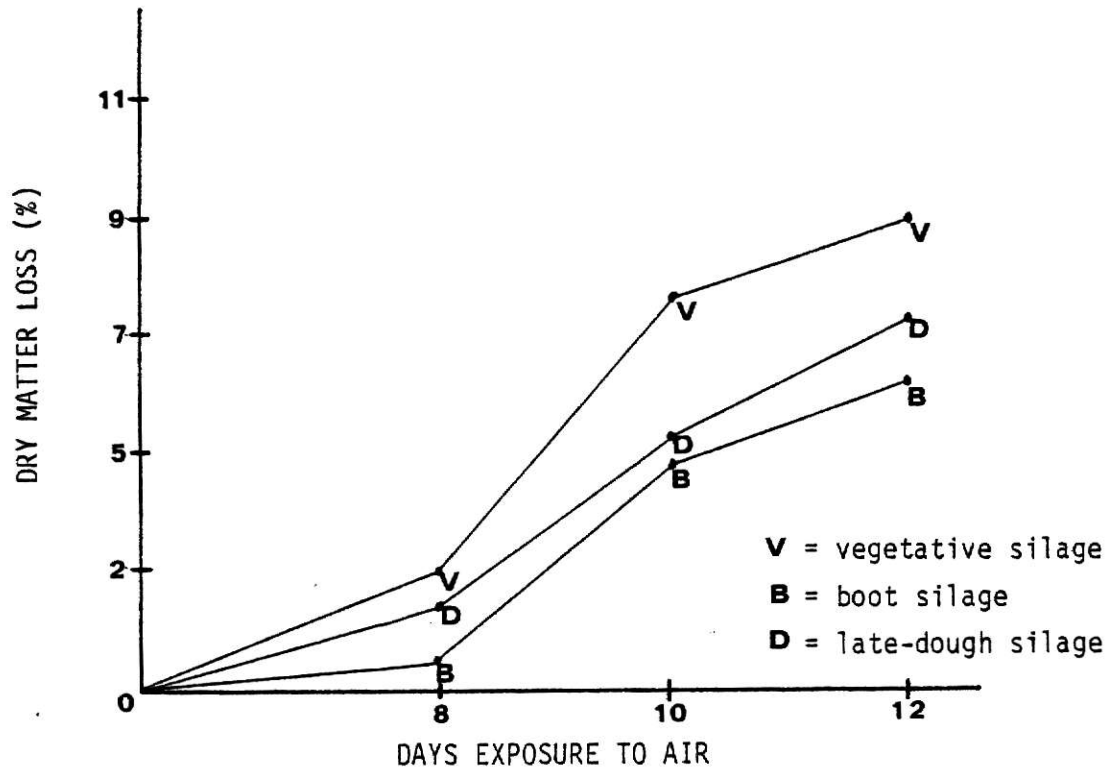
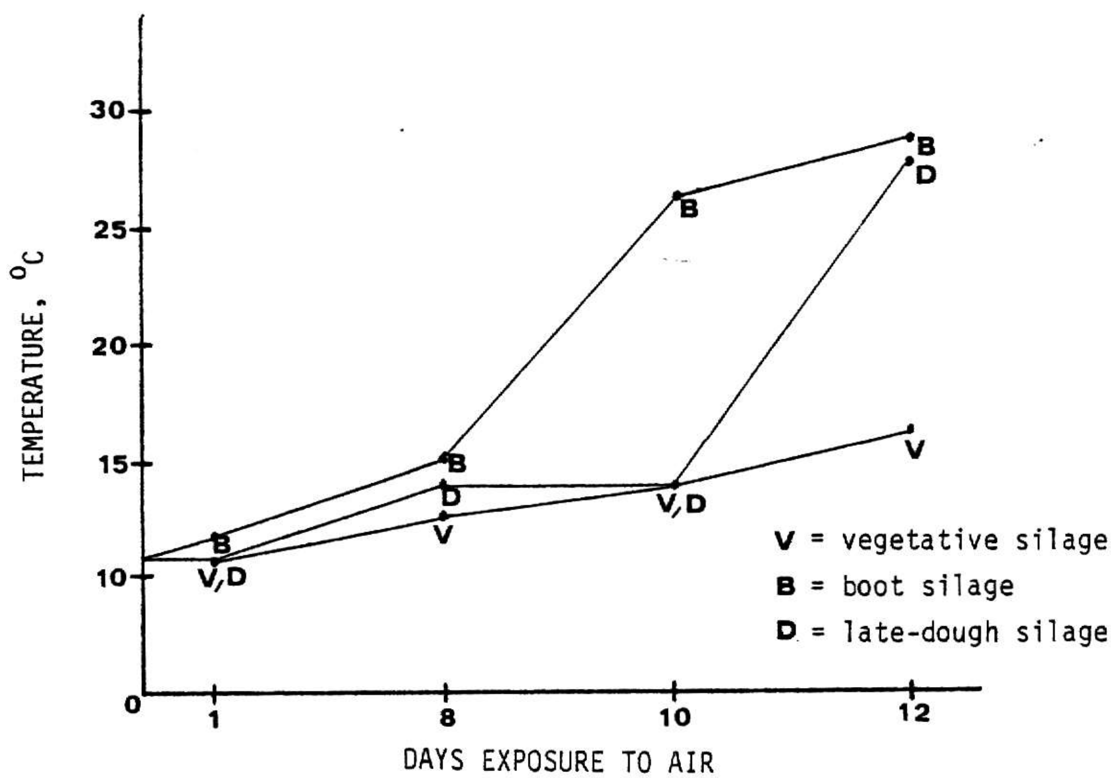


Figure 2. The changes in temperature during exposure to air for pearl millet silages in the Silage Aerobic Stability Trial.



Experiment 3: Lamb Digestion Trial 1

The purpose of this trial was to determine the effect of stage of growth of pearl millet harvested as silage or hay on forage voluntary intake, forage digestibility and nitrogen retention by lambs.

After completion of the Lamb Growth Trial, three lambs from each forage were placed in steel crates designed for total collection of feces and urine. The trial consisted of a 7-day pre-feeding, 5-day voluntary intake, 2-day forage intake adjustment, and 5-day total collection periods. Rations were 95.5% silage or hay and 4.5% cane molasses. Block salt was offered ad libitum and forages were fed twice daily.

Lambs were fitted with a canvas harness equipped with a fecal collection bag. Urine was collected daily in plastic buckets containing 50 ml of 50% HCl to maintain acidity. Urine volume was diluted with water to the next highest liter and 10% aliquot sample stored in glass bottles. Daily fecal collections were weighed and 20% aliquot sample frozen. Forage samples were taken daily during the 5-day voluntary intake and 5-day total collection periods. At the end of the trial, forage, feces and urine samples were composited for chemical analyses.

Forage and feces were dried and ground as previously described (page 13). Forage, feces, and urine samples were analyzed for nitrogen by the Kjeldahl method as outlined by A.O.A.C. (1965). Proximate analyses was determined for forages and feces by A.O.A.C. (1970) methods.

Forage voluntary intakes and digestion coefficients are shown in Table 6 and nitrogen retention by lambs is shown in Table 7.

Lambs fed boot hay consumed the most (P<.05) dry matter; lambs fed late-dough silage, the least (P<.05). Dry matter, crude fiber, crude protein, and organic matter digestion coefficients were higher (P<.05) for vegetative and boot silages or boot hay forages than for late-dough forages. Lambs fed boot forages consumed more (P<.05) dry matter than lambs fed vegetative or late-dough forages. Digestibilities of dry matter, crude fiber, crude protein and organic matter were lowest (P<.05) for late-dough forages. Hays had higher (P<.05) voluntary intakes, lower (P<.05) crude protein and higher (P<.05) nitrogen-free extract digestibilities than silages.

All forages resulted in negative nitrogen balances in lambs. Nitrogen retention as a percent of nitrogen consumed was significantly higher (P<.05) for vegetative and boot stage forages than for late-dough stage forages. Lambs fed hays had lower (P<.05) nitrogen retention than lambs fed silage.

TABLE 6. VOLUNTARY INTAKES AND DIGESTION COEFFICIENTS FOR FORAGES IN LAMB DIGESTION TRIAL 1

Item	Dry matter intake, g/day	Digestion coefficient (%)					
		Dry matter	Organic matter	Ether extract	Crude fiber	Nitrogen-free extract	Crude protein
Silages and hays[1]							
Vegetative silage	909.67[b,c]	60.98[a]	61.66[b]	49.19	66.09[a]	57.85[b,c]	63.41[a]
Boot silage	926.67[b]	60.71[a]	63.29[a,b]	58.91	65.92[a]	62.52[b]	60.47[a]
Boot hay	1301.67[a]	65.66[a]	68.23[a]	48.43	64.89[a]	70.97[a]	67.71[a]
Late-dough silage	827.67[c]	46.39[b]	47.49[c]	55.58	46.22[b]	49.89[d]	36.85[b]
Late-dough hay	948.67[b]	50.45[b]	51.52[c]	56.06	49.58[b]	56.12[c]	27.71[c]
Forage stage of growth[2]							
Vegetative	909.67[f]	60.98[e]	61.66[e]	49.19	66.09[e]	57.85[f]	63.41[e]
Boot	1114.17[e]	63.18[e]	65.76[e]	53.67	65.41[e]	66.74[e]	64.09[e]
Late-dough	888.17[f]	48.42[f]	49.51[f]	55.82	47.89[f]	53.01[f]	32.28[f]
Forage form[3]							
Silage	888.00[h]	56.03	57.48	54.56	59.41	56.75[h]	53.58[g]
Hay	1125.17[g]	58.06	59.87	52.24	57.23	63.54[g]	47.71[h]

[1] Three observations per treatment mean.
[2] Six observations per treatment mean except for vegetative silage which has three.
[3] Nine observations for silage means and six observations for hay means.
[a,b,c,d] Means in the same column with different superscripts differ significantly ($P<.05$).
[e,f] Means in the same column with different superscripts differ significantly ($P<.05$).
[g,h] Means in the same column with different superscripts differ significantly ($P<.05$).

TABLE 7. NITROGEN INTAKES AND RETENTIONS IN LAMB DIGESTION TRIAL 1.

Item	N-intake, g/day	N-retained, g/day	N-retained, % of intake
Silages and hays[1]			
Vegetative silage	10.92	-0.59[a]	- 5.43[a]
Boot silage	9.17	-0.13[a]	- 1.42[a]
Boot hay	9.01	-0.75[a]	- 8.32[a]
Late-dough silage	5.63	-1.39[a]	-24.75[a,b]
Late-dough hay	4.09	-1.81[a]	-43.92[b]
Forage stage of growth[2]			
Vegetative	10.92	-0.593[c]	- 5.433[c]
Boot	9.09	-0.440[c]	- 4.870[c]
Late-dough	4.86	-1.602[c]	-34.335[d]
Forage form[3]			
Silage	8.57	-0.71[e]	-10.53[e]
Hay	6.55	-1.28[e]	-26.12[f]

[1] Three observations per treatment mean.

[2] Six observations per treatment mean except for vegetative silage which has three.

[3] Nine observations for silage means and six observations for hay means.

[a,b] Means in the same column with different superscripts differ significantly (P<.05).

[c,d] Means in the same column with different superscripts differ significantly (P<.05).

[e,f] Means in the same column with different superscripts differ significantly (P<.05).

Experiment 4: Lamb Digestion Trial 2

The purpose of this trial was the same as that stated for Experiment 3. After completion of Lamb Digestion Trial 1, all lambs were re-randomized and re-assigned to the five pearl millet forages. Experimental procedures followed in Experiments 3 and 4 were identical.

Forage voluntary intakes and digestion coefficients are shown in Table 8 and nitrogen retention by lambs is shown in Table 9.

Lambs fed boot hay consumed the most (P<.05) dry matter; lambs fed late-dough silage the least (P<.05). Dry matter, crude fiber, crude protein, and organic matter digestion coefficients were higher (P<.05) for vegetative and boot silages or boot hay forages than for late-dough forages. Lambs fed boot forages consumed more (P<.05) dry matter than lambs fed vegetative or late-dough forages. Digestibilities of dry matter, crude fiber, crude protein and organic matter were lowest (P<.05) for late-dough forages. Hays had higher (P<.05) voluntary intakes and higher (P<.05) crude fiber digestibilities than silages.

All forages resulted in negative nitrogen balances in lambs, except for boot silage. Nitrogen retention as a percent of nitrogen consumed was higher (P<.05) for vegetative and boot stage forages than for late-dough stage forages. Lambs fed hays had lower nitrogen retention than lambs fed silage (P<.05).

TABLE 8. VOLUNTARY INTAKES AND DIGESTION COEFFICIENTS FOR FORAGES IN LAMB DIGESTION TRIAL 2

Item	Dry matter intake, g/day	Digestion coefficient (%)					
		Dry matter	Organic matter	Ether extract	Crude fiber	Nitrogen-free extract	Crude protein
Silages and hays[1]							
Vegetative	855.33[b,c]	64.03[a]	64.13[a]	66.94[a,b]	66.73[b]	60.54[a]	65.80[a]
Boot silage	931.00[b]	61.23[a]	62.31[a]	72.83[a]	68.73[a,b]	60.86[a]	61.35[b]
Boot hay	1359.00[a]	63.62[a]	65.39[a]	58.49[b]	71.38[a]	60.06[a]	66.59[a]
Late-dough silage	768.67[c]	52.04[c]	52.09[c]	61.36[b]	47.21[d]	55.91[b]	45.81[c]
Late-dough hay	926.33[b]	56.51[b]	56.83[b]	64.97[a,b]	56.91[c]	58.09[a,b]	43.78[c]
Forage stage of growth[2]							
Vegetative	855.33[f]	64.03[e]	64.11[e]	66.94[e]	66.73[e]	60.54[e]	65.80[e]
Boot	1145.00[e]	62.42[e]	64.85[e]	65.66[e]	70.06[e]	60.46[e]	63.96[e]
Late-dough	847.50[f]	54.28[f]	54.46[f]	63.16[e]	52.06[f]	56.99[f]	44.79[f]
Forage form[3]							
Silage	851.67[h]	59.11[g]	60.12[g]	67.04[g]	60.89[h]	59.10[g]	57.64[g]
Hay	1142.67[g]	60.06[g]	61.11[g]	61.73[g]	64.15[g]	59.08[g]	55.18[g]

[1] Three observations per treatment mean.

[2] Six observations per treatment mean except for vegetative silage which has three.

[3] Nine observations for silage means and six observations for hay means.

[a,b,c,d] Means in the same column with different superscripts differ significantly ($P<.05$).

[e,f] Means in the same column with different superscripts differ significantly ($P<.05$).

[g,h] Means in the same column with different superscripts differ significantly ($P<.05$).

TABLE 9. NITROGEN INTAKES AND RETENTIONS IN LAMB DIGESTION TRIAL 2

Item	N-intake g/day	N-retained g/day	N-retained, % of intake
Silages and hays[1]			
Vegetative silage	10.76	-0.74[a]	- 6.88[a,b]
Boot silage	9.42	0.22[a]	2.26[a]
Boot hay	9.13	-0.89[a]	- 9.78[a,b]
Late-dough silage	5.72	-1.15[a]	-20.16[a,b]
Late-dough hay	4.53	-1.35[a]	-29.80[b]
Forage stage of growth[2]			
Vegetative	10.76	-0.74[c]	- 6.88[c,d]
Boot	9.28	-0.34[c]	- 3.76[c]
Late-dough	5.13	-1.25[c]	-24.98[d]
Forage form[3]			
Silage	8.63	-0.56	- 8.26
Hay	6.83	-1.12	-19.79

[1] Three observations per treatment mean.

[2] Six observations per treatment mean except for vegetative silage which has three.

[3] Nine observations for silage means and six observations for hay means.

[a,b] Means in the same column with different superscripts differ significantly ($P<.05$).

[c,d] Means in the same column with different superscripts differ significantly ($P<.05$).

DISCUSSION

Objectives of this research were to measure the feeding value of pearl millet harvested as silage and hay and to determine the effect of stage of growth on its nutritive value.

Chemical analyses of vegetative, boot and late-dough silage and hays indicated that as forage maturity increased, changes occurred in proximate and Van Soest components. Greatest changes were obtained in crude protein and crude fiber. These results agree closely with pearl millet data reported by Nuwanyakpa (1979) and sorghum data reported by Owen et al. (1963) and Burger et al. (1967). Analyses here also showed that cell wall constituents, cellulose, and lignin were highest in the late-dough forages.

Results of the Lamb Growth Trial showed boot hay to be superior to the other four pearl millet forages. Nuwanyakpa (1979) fed lambs pearl millet boot hay or silage and the hay supported slightly faster (.16 vs .15 kg) and more efficient (7.40 vs 8.15 kg) gains than silage. In the trial reported here lambs fed vegetative and boot silages had significantly faster gains and consumed more dry matter than lambs fed late-dough silage or hay. However late-dough silage produced a more efficient gain than late-dough hay. Data are conflicting as to the feeding value of forages harvested as silage or hay at the same stage of growth. Thomas et al. (1961) showed that alfalfa hay gave superior performance compared to alfalfa silage in a trial with growing dairy heifers. Brown et al. (1963) showed a higher efficiency of dry matter utilization for milk production when cows were fed silage rather than hay. Still other workers have found silages and hays to give equal performance. Brown (1960) and Slack et al. (1960[b]) observed no differences in production when comparing silage and hay. In another trial, Waldo et al. (1965) reported consistently greater gains by alfalfa hay fed Holstein heifers than silage-fed animals. Results of Gordon et al. (1961) and Wellmann (1969) agree that alfalfa hay has a higher feeding value than silage.

Ademosum (1968); Jung et al. (1964), Hosterman and Hall (1938) and McDonald (1946) all have shown that chemical composition of forages changes with stage of plant growth, there by affecting voluntary intake and digestibility. McCullough and Sisk (1966) studied the influence of stage of growth of wheat on the voluntary intake of silage fed to dairy cows. Boot silage was consumed in significantly greater quantities at all levels of grain feeding. When no grain was fed, 20% more boot silage dry matter was consumed than milk or dough silage dry matter. In a similar study boot stage barley and oat silages were compared to alfalfa haylage (Marx et al. 1974). No differences in milk yield, milk fat or weight gain were observed when lactating dairy cows were fed each silage free choice.

Results of Lamb Digestion Trials show crude protein, crude fiber, organic matter and dry matter digestibilities were lowest for late-dough stage forages. Nitrogen retention (grams per day and percent of nitrogen intake) was highest for vegetative and boot forages. These results agree with results from the Lamb Growth Trial that showed a faster and more efficient gains for the less mature forages. Similar data by Minson et al. (1960); Reid (1959); Culpin (1962); Gordon et al. (1963[a]) show digestibility of a forage is determined by stage of growth. Meyer et al. (1957) showed oat hay crude protein digestibility decreased with each successive increase in stage of growth. Research by Berger (1975) showed crude fiber digestibility decreased significantly as stage of growth increased from boot to dough stage in wheat and barley silages.

In the trial here dry matter intake tended to be higher for hays than silages. Sykes et al. (1955) and Moore et al. (1960) had similar results with cattle fed silages or hays made from crops at the same stage of growth.

Digestion coefficients here were similar for silages and hays. Results by Harris and Raymond (1963) agree, showing ryegrass silage digestibility similar to ryegrass hay. However, Waldo et al. (1965) and Ekern and Reid (1963) using grass-legume mixture report lower dry matter digestibility for silage than for hay. Nuwanyakpa (1979) showed sudangrass and sorghum-sudangrass silages had higher in vitro dry matter digestibility than hays.

There was a positive correlation between Lamb Growth Trial results and digestion coefficients in the digestion trials. An increase in average daily gain and improved feed efficiency were associated with higher dry matter, crude protein, and crude fiber digestibilities in the vegetative and boot stage pearl millet forages.

Supplements fed in the growth trial were removed from the forage rations for the digestion trials to avoid interactions between supplements and forages. Murdoch, (1960) fed cattle lucerne and meadow fescue silage or hay and dry matter intake of hay decreased but silage intake increased when concentrates were fed. Campling, (1966) reported similar findings with dairy cows fed timothy, meadow fescue and white clover. He observed a smaller change in digestible crude fiber when concentrates were added to silage than to hay.

In the silage aerobic stability trial deterioration was slow and characterized by gradually decreasing acetic acid and crude protein values and increasing ammonia-nitrogen, temperature and pH. Dry matter losses resulting from this aerobic microorganism activity ranged from 2 to 9 percent. Research by Ohyama et al. (1975[a]) and Woolford et al. (1977) showed similar chemical changes occurred when corn silage was exposed to air. But these workers found that temperature rise occurred much sooner and dry matter losses were much greater than temperatures and losses reported here. Results herein demonstrate that these individual silages were relatively stable in air up to 8 days exposure.

Ohyama et al. (1975[a]) showed gradual chemical changes in ryegrass silage from slow growth of fungi and yeasts and other aerobic microorganisms. Beck and Gross (1964) suggested that the aerobic stability of silage was dependent on initial yeast counts in the silage. Results here and of many others indicate that the mechanism of aerobic deterioration of silage is complex and variable. On farms where heat can be more easily dissipated, nutrient losses can occur without visual changes in a silage.

Energy deficiency is a very common cause of low production in sheep (NCR, 1968). Folke (1952), working with dairy cows, assessed milk production results and found that forages were primarily used as sources of energy and not protein, and he suggested that forages be classified on the basis of available energy yield. Results of the trial here show digestible energy and total digestible nutrient (TDN) values (Table 10) were higher for vegetative and boot stage forages than for late-dough stage forages. Supportive research by Axelsson (1950); and Drapala (1947) show that differences in stage of growth and methods of harvest for grasses do not affect gross energy values, but do affect voluntary intake and digestibility. Crampton (1957) suggested that voluntary intake and digestible energy be used to as an indication of feeding value of a forage. Donefer et al. (1960) and (1966) showed how TDN, and digestible energy measure available energy. These results illustrate the usefulness of TDN and digestible energy in assessing the ability of a forage to meet the energy requirement of sheep.

To conclude, chemical composition of pearl millet changes dramatically from vegetative to late-dough stages of growth, and these changes decrease the feeding value of pearl millet silage or hay.

TABLE 10. CALORIC YIELD AND TOTAL DIGESTIBLE NUTRIENTS FOR THE FORAGES FED IN THE LAMB GROWTH TRIAL

		Gross energy Kcal[a]		Digestible energy Kcal	TDN
Vegetative silage	Total	3,994 (3,870)		2,502	53.1
	% digestible energy (as calories)		62.8		
Boot silage	Total	4,105 (4,038)		2,613	56.3
	% digestible energy (as calories)		63.7		
Boot hay	Total	4,091 (4,039)		2,701	59.3
	% digestible energy (as calories)		66.1		
Late-dough silage	Total	4,120 (4,034)		2,051	45.2
	% digestible energy (as calories)		50.9		
Late-dough hay	Total	4,084 (4,041)		2,216	49.8
	% digestible energy (as calories)		54.2		

100% dry matter basis

[a]Actual gross energy analyses shown in parentheses.

SUMMARY

Lamb growth and digestion trials were conducted to measure the feeding value of pearl millet (Millex 23) harvested as silage and hay and to determine the effect of stage of growth on its nutritive value.

In the Lamb Growth Trial, 60 wether lambs were used to evaluate five pearl millet forages: (1) vegetative silage, (2) boot silage, (3) boot hay, (4) late-dough silage and (5) late-dough hay. Lambs were randomly alotted by weight to three pen replications of four lambs for each of the five forages. The basal ration was 85.5% silage or hay, 4.5% cane molasses, and 10.0% supplement on a dry matter (DM) basis. Percents DM, crude protein (CP) and crude fiber (CF), respectively, for the pearl millet forages were: (1) 29.7, 14.7, 31.0; (2) 33.4, 11.8, 30.0; (3) 87.5, 11.1, 27.4; (4) 34.4, 7.3, 35.2; (5) 86.5, 5.3, 35.0. Chemical composition of pearl millet was affected ($P<.05$) by stage of growth. Average daily gain (kg) and DM intake (kg), respectively, for the five forage rations during the 42-day trial were: (1) .05, 1.07; (2) .06, 1.04; (3) .10, 1.30; (4) .03, .88 and (5) .02, .95. Lambs fed boot hay consumed more DM ($P<.05$) and gained faster ($P<.05$) than lambs fed the other four forages. Lambs fed vegetative or boot silages had higher daily gains ($P<.05$) than lambs fed either late-dough silage or hay. After the growing trial, two consecutive 5-day voluntary intake and 5-day total collection periods were conducted using three lambs fed each of the five forages. Digestion coefficients for DM, organic matter, CP, and CF, respectively, for pearl millet forages were: (1) 62.5, 62.9, 64.6, 66.4; (2) 60.9, 63.8, 60.9, 67.3; (3) 64.6, 66.8, 67.2,

68.2; (4) 49.2, 49.8, 41.3, 46.7 and (5) 53.5, 54.2, 35.7, 53.3. Digestibilities were lower ($P<.05$) for late-dough stage forages than vegetative or boot stage forages. Digestion coefficients were similar for silages and hays. Combined results of the growth trial and the digestion trials showed a positive relationship between gain and digestibility of DM, CP and CF.

A silage aerobic stability trial was conducted using pearl millet vegetative, boot and late-dough silages. All three silages were relatively stable in air. Results showed a gradual decrease in acetic acid and CP and a gradual increase in ammonia-nitrogen and pH as air exposure time increased. Losses of silage DM ranged from 2 to 9% after 12 days exposure to air.

Digestible energy (DE) and total digestible nutrient (TDN) values were highest for immature stages of growth. Percent digestible energy and TDN values respectively, for the five pearl millet forages were: (1) 62.8, 53.1; (2) 63.7, 56.3; (3) 66.1, 59.3; (4) 50.9, 45.2 and (5) 54.2, 49.8.

These trials show chemical composition of pearl millet changes as stage of growth advances from the vegetative to the late-dough stages and these changes result in marked decreases in the feeding value of pearl millet silages and hays.

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APPENDIX

TABLE 1. ANALYSIS OF VARIANCE FOR LAMB GROWTH DATA EXPERIMENT I

Source of variation	d.f.	Mean square Average daily gain
Total	59	.0059
Error	45	.0017
Treatment	4	.0615[a]
Replications	10	.0028

[a]$P<.01$

TABLE 2. ANALYSIS OF VARIANCE FOR LAMB GROWTH DATA EXPERIMENT I

Source of variation	d.f.	Mean square	
		Average daily feed	Gain per unit of feed
Total	14	.1179	300.60
Error	10	.0101	58.49
Treatment	4	3.88[a]	905.86[a]

[a]$P<.01$

TABLE 3. ANALYSIS OF VARIANCE OF VOLUNTARY INTAKE AND DIGESTIBILITIES IN LAMBS IN EXPERIMENT I

Source of variation	d.f.	Voluntary intake	Crude protein	Nitrogen free extract	Dry matter	Organic matter	Ether extract	Crude fiber
Total	14	34278.55	282.96	59.88	60.89	69.18	137.27	89.48
Error	10	7367.94	16.68	9.66	7.32	7.62	166.89	10.02
Treatment	4	101555.10^{b}	948.66^{b}	185.41^{b}	194.83^{b}	223.07^{b}	63.22	288.13^{b}
Stage	2	86660.50^{b}	1795.42^{b}	288.11^{b}	358.86^{b}	415.74^{b}	43.94	566.99^{b}
Form	1	184512.00^{b}	2.75	161.63^{b}	60.97^{a}	60.22^{a}	74.91	4.08
Stage x Form	1	48387.00^{a}	201.06^{b}	3.76	0.59^{a}	0.63^{a}	90.09	14.48

$^{a}P<.05$

$^{b}P<.01$

TABLE 4. ANALYSIS OF VARIANCE OF NITROGEN RETENTION IN LAMBS IN EXPERIMENT III

Source of variation	d.f.	Mean square N-retained g/day	N-retained % of intake
Total	14	1.39	372.67
Error	10	1.42	150.83
Treatment	4	1.33	927.29
Stage	2	2.25	1543.19
Form	1	.81	509.99
Stage x Form	1	.03	112.79

TABLE 5. ANALYSIS OF VARIANCE OF VOLUNTARY INTAKE AND DIGESTIBILITIES IN LAMBS IN EXPERIMENT IV

Source of variation	d.f.	Mean square						
		Voluntary intake	Crude protein	Nitrogen free extract	Dry matter	Organic matter	Ether extract	Crude fiber
Total	14	50336.93	108.04	6.36	24.95	31.28	42.34	89.03
Error	10	7947.60	4.97	3.72	3.43	3.12	23.07	45.78
Treatment	4	156310.24[b]	365.73[b]	12.98[a]	78.77[b]	101.69[b]	90.49[a]	300.16[b]
Stage	2	156588.39[b]	707.56[b]	21.89[a]	138.29[b]	185.62[b]	17.05	524.43[b]
Form	1	257254.08[b]	7.92	1.46	35.26[b]	25.55[a]	86.24	114.52[b]
Stage x Form	1	54810.08[a]	39.86[a]	6.69	3.24	9.99	241.65[a]	37.28[a]

[a] $P < .05$

[b] $P < .01$

TABLE 6. ANALYSIS OF VARIANCE OF NITROGEN RETENTION IN LAMBS IN EXPERIMENT IV

Source of variation	d.f.	Mean square N-retained g/day	Mean square N-retained % of intake
Total	14	.88	256.06
Error	10	.79	174.21
Treatment	4	1.09	460.72
Stage	2	1.26	742.94
Form	1	1.27	352.63
Stage x Form	1	.62	4.36

EFFECT OF STAGE OF MATURITY ON NUTRITIONAL VALUE OF PEARL MILLET HARVESTED AS SILAGE OR HAY

by

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ABSTRACT

Lamb growth and digestion trials were conducted to measure the feeding value of pearl millet (Millex 23) harvested as silage and hay and to determine the effect of stage of growth on its nutritive value.

In the Lamb Growth Trial, 60 wether lambs were used to evaluate five pearl millet forages: (1) vegetative silage, (2) boot silage, (3) boot hay, (4) late-dough silage and (5) late-dough hay. Lambs were randomly alotted by weight to three pen replications of four lambs for each of the five forages. The basal ration was 85.5% silage or hay, 4.5% cane molasses, and 10.0% supplement on a dry matter (DM) basis. Percents DM, crude protein (CP) and crude fiber (CF), respectively, for the pearl millet forages were: (1) 29.7, 14.7, 31.0; (2) 33.4, 11.8, 30.0; (3) 87.5, 11.1, 27.4; (4) 34.4, 7.3, 35.2; (5) 86.5, 5.3, 35.0. Chemical composition of pearl millet was affected ($P<.05$) by stage of growth. Average daily gain (kg) and DM intake (kg), respectively, for the five forage rations during the 42-day trial were: (1) .05, 1.07; (2) .06, 1.04; (3) .10, 1.30; (4) .03, .88 and (5) .02, .95. Lambs fed boot hay consumed more DM ($P<.05$) and gained faster ($P<.05$) than lambs fed the other four forages. Lambs fed vegetative or boot silages had higher daily gains ($P<.05$) than lambs fed either late-dough silage or hay. After the growing trial, two consecutive 5-day voluntary intake and 5-day total collection periods were conducted using three lambs fed each of the five forages. Digestion coefficients for DM, organic matter, CP, and CF, respectively, for pearl millet forages were: (1) 62.5, 62.9, 64.6, 66.4;

(2) 60.9, 63.8, 60.9, 67.3; (3) 64.6, 66.8, 67.2, 68.2; (4) 49.2, 49.8, 41.3, 46.7 and (5) 53.5, 54.2, 35.7, 53.3. Digestibilities were lower ($P<.05$) for late-dough stage forages than vegetative or boot stage forages. Digestion coefficients were similar for silages and hays. Combined results of the growth trial and the digestion trials showed a positive relationship between gain and digestibility of DM, CP and CF.

A silage aerobic stability trial was conducted using pearl millet vegetative, boot and late-dough silages. All three silages were relatively stable in air. Results showed a gradual decrease in acetic acid and CP and a gradual increase in ammonia-nitrogen and pH as air exposure time increased. Losses of silage DM ranged from 2 to 9% after 12 days exposure to air.

Digestible energy (DE) and total digestible nutrient (TDN) values were highest for immature stages of growth. Percent digestible energy and TDN values respectively, for the five pearl millet forages were: (1) 62.8, 53.1; (2) 63.7, 56.3; (3) 66.1, 59.3; (4) 50.9, 45.2 and (5) 54.2, 49.8.

These trials show chemical composition of pearl millet changes as stage of growth advances from the vegetative to the late-dough stages and these changes result in marked decreases in the feeding value of pearl millet silages and hays.