The Professional Animal Scientist 21 (2005):352–360

Utilization by Cattle, Sheep, and Goats of Forage Harvested from Long-Term Bermudagrass Spray Fields Receiving Swine Lagoon Effluent[1]

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Abstract

*Bermudagrasses frequently serve as receivers of swine lagoon effluent in swine production confinement systems in the Southeast. This study evaluated DMI and digestion of field-chopped, dehydrated regrowth forage cut from mature Coastal bermudagrass spray fields following harvest in late July. Four treatments were evaluated in separate experiments each with cattle, sheep, and goats. The treatments consisted of forage harvested at 2 wk of regrowth and either fed chopped (**2-WC**) or pelleted (**2-WP**) and that harvested and pelleted at 3 wk (**3-WP**) and 4 wk (**4-WP**) of regrowth. The long-time established spray fields varied in the proportions of bermudagrass but averaged 45% for the 2-wk regrowth and 50% for the 4-wk regrowth; the balance was composed of annual grasses and broadleaved weeds. All three pelleted forages were readily consumed with DMI (kg/100 kg of BW) averaging 2.99 for steers, 4.35 for sheep, and 3.21 for goats. Steers and goats consumed all pelleted treatments similarly, whereas sheep consumed 2-WP and 3-WP similarly (4.41) but consumed less 4-WP (4.23) compared with 2-WP (4.49). Pelleting increased ($P \le 0.01$) DMI compared with chopping (3.01 vs 2.16 ± 0.087 for steers, 3.29 vs 2.37 ± 0.071 for goats, and 4.49 vs 2.54 ± 0.072 for sheep). Steers and sheep digested 2-WP and 4-WP similarly and digested both at rates greater ($P \le 0.05$) than 3-WP; goats digested all similarly ($P = 0.11$). These short-term responses indicate that forages from mature bermudagrass fields sprayed with swine effluent have potential as a feed in ruminant production systems.*

(Key Words: Swine-Lagoon Effluent, Bermudagrass, Steers, Sheep, Goats.)

Introduction

Waste generated from any industry becomes a liability unless it can be repackaged and used at an economic advantage. The hybrid bermudagrasses [*Cynodon dactylon* (L) *Pers.*], because of their perennial growth habit and response to irrigation and fertility (Carreker et al., 1977), have found favor as potential receivers of both confined animal and industrial wastes. The former ranges from swine lagoon effluent (Burns et al., 1985, 1990), to slurry cattle (*Bos taurus* L.) manure (Newton et al., 1977), to solid and liquid dairy manure (Lund et al., 1975) providing sources of water and nutrients. An example of industrial waste is coal combustion byproducts (fly and bottom ash) mixed with organic waste (Schlossberg et al., 2004), as a media for bermudagrass sod.

In a long-term study in the mid Atlantic region, Burns et al. (1990) reported 11- yr mean DM yields of 11.1, 15.2, and 17.2 Mg/ha when Coastal bermudagrass was sprayed with swine lagoon effluent to deliver, annually, 356, 670, and 1340 kg of N/ha, respectively, and was then harvested as hay. Compared with perennial, native grasses, Coastal bermudagrass produced as much as 15.0 *vs*

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[1] Cooperative investigation of the USDA-ARS and the North Carolina ARS, Raleigh 27695-7643. The use of trade names in this publication does not imply endorsement by the North Carolina ARS or by USDA-ARS of the products named or criticism of similar ones not mentioned.

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9.5 Mg/ha for ‘Pete’ eastern gamagrass (*Tripsacum dactyloides* L.) and 9.1 Mg/ha for ‘Alamo’ Switchgrass (*Panicum virgatum* L.) (McLaughlin et al., 2004). Associated with high DM yield is the beneficial uptake of large quantities of elements frequently present in the soil following long-term use of spray fields (King et al., 1990). These nutrients can be transported in harvested forage to areas remote to the spray fields that are nutrient deficient.

The integration, however, of haymaking [harvest required every 4 to 5 wk if forage is to remain of reasonable quality (Mandebvu et al., 1999)] into confined-hog operations has not occurred. Instead, forage produced on spray fields has frequently been viewed as a liability with infrequent harvests; baled forage is often left on the landscape to decay. Further, some herbivore producers have shown reluctance to use it as a feed source. The objective of this study was to determine the acceptance by cattle, sheep, and goats of forage that is direct-cut, dehydrated, and fed chopped or pelleted from mature bermudagrass spray fields. Estimates of DMI and the digestibilities of DM, CP, NDF, and constituent fiber fractions were determined by each ruminant species.

Materials and Methods

Forage Treatments. Two different producer fields, located in the Coastal Plain approximately 5 km east of Laurinburg, North Carolina and initially having well-established stands of Coastal bermudagrass, were selected as a source of forage. Both fields, having sandy loam soil and selected as representative of the region, had a history of serving as spray fields for swine lagoon effluent (>5 yr) and were in close proximity to each other. Typically, mature bermudagrass spray fields in the region are contaminated with annual weeds, these being mainly crabgrass (*Digitaria* spp.) with some pigweed (*Amaranthus retroflexus* L.).

Following harvest in late July, both fields were irrigated with swine lagoon effluent using a conventional traveling gun to deliver an estimated 56 kg of N/ha. Regrowth forage was managed to obtain feed of different nutritive value, which was achieved by harvesting forage, using a conventional mower set to leave a 7.6-cm stubble, of differing maturity and effluent application. One field, selected at random, was harvested after 2 wk of regrowth (2-W), and the same field was harvested again following a subsequent 3 wk of regrowth (3-W). In the latter case, effluent and, hence, N was not applied after the 2-wk regrowth was harvested or at the onset of the subsequent 3-wk regrowth. The second field was harvested after 4 wk of regrowth (4-W). This resulted in three forages that should differ in nutritive value, each being unique and characterized by its own composition.

Four random mower swaths 0.5 m × 6 m were taken to 7.6-cm stubble from each forage treatment prior to harvest using a small plot mower, and such swaths were weighed. A subsample was obtained and dried in a forced-draft oven at 75°C for DM yield determination. A second subsample was taken from mower swaths of the 2- and 4-wk harvest fields and hand-separated into bermudagrass, weeds (grassy and broadleaved), and dead tissue and placed in a forced-draft oven at 75°C. After drying, each fraction was weighed and expressed as a percentage of total DM.

After mowing, the three forage treatments were each windrowed, chopped with a conventional field chopper into 2- to 4-cm lengths, and hauled to a dehydrating plant in close proximity. The forage was passed through a dehydrator (100 to 110°C), immediately conveyed to a grinder (passed through a 6.3-mm screen), and delivered directly into a pelleter with a 12.5-mm dye. The pelleted (P) forage was subsequently augered into metal storage bins and held until bagged. A fourth forage treatment was generated using the 2-wk maturity forage by interrupting the forage flow after passing through the dehydrator and prior to grinding. This chopped, dehydrated forage (2-WC) was collected and placed into large burlap bags and stored on site. This resulted in three pelleted treatments (2-WP, 3-WP, and 4-WP) of different composition and a fourth treatment that compared the physical effect of chopping *vs* pelleting (2-WC *vs* 2-WP).

After all forage treatments had been obtained, the pelleted treatments were bagged in standard 23-kg paper sacks, stitched at the top, and placed on pallets for transportation. The four forage treatments were subsequently transported to Raleigh, North Carolina and stored at the Animal Metabolism Unit until fed in animal trials.

Intake and Digestion Trials. The four experimental forages were evaluated in separate experiments using steers (*Bos taurus* L.), wether sheep (*Ovis aries* L.), and wether goats (*Capra hircus* L.). The animal handling procedures were approved by the North Carolina State University Institutional Animal Care and Use Committee (approval number 03-047A). Each animal experiment was conducted in a 4 × 4 Latin square design. Animals in each of the three experiments were initially standardized for 14 d on Coastal bermudagrass forage that was produced at Raleigh, North Carolina using conventional production practices. Each experimental period consisted of a 21-d intake phase (Burns et al., 1994) followed by a 12-d digestion phase (7-d adjustment and 5-d collections). In both the intake and digestion phases, the forage treatments were fed twice daily, allowing a 15% excess. Adjustments were based on the previous day’s intake. Calculation of ad libitum DMI was based on the last 14 d of the 21-d period. A daily sample of the offered forage was obtained for each animal and was composited on a weekly basis in the intake phase and for the 5-d collection period in the digestion phase. Orts were taken twice daily, saved for each animal, and composited each week in the intake phase and for the 5-d collection period in the digestion phase. The weekly composite samples of the offered forage and orts were further composited for the intake period. All samples were thoroughly mixed, subsampled, oven-dried (55°C) for DM determination, and stored for grinding.

In each of the animal experiments, feces were collected and weighed for each of five consecutive 24-h periods. Feces were thoroughly mixed daily, and a proportion (5% of total) of the fresh weight was placed in a freezer (–14°C). Following the 5-d collection, the composite frozen samples were oven-dried (55°C), weighed for DM determination, and stored for grinding. The digestion data from each of the digestion trials are presented in decimal form.

Experimental Animals. Four Grade Angus steers weighing 235 to 258 kg were confined to an outdoor, covered, raised platform area equipped with electronic gates (Calan gate system; American Calan Inc., Northwood, NH) as previously described (Burns et al., 1997) for the intake phase of the study. Each steer was keyed to allow access to only one feeder, but animals could lounge together and had free access to mineralized salt blocks consisting of calcium periodate, not less or more than 970 and 985 g of NaCl/kg, and not less than 3.5 g of Zn (ZnO)/kg, 2.8 g of Mn (MnO)/kg, 1.7 g of Fe (FeO)/kg, 0.35 g of Cu (CuO)/kg, 0.07 g of I/kg, and 0.07 g of Co ($CoCO_3$)/kg and water. After conditioning to the gates and standardization, each animal was randomly assigned to one of the four forage treatments in a Latin square design. For the digestion phase (immediately following each period of the intake phase), the steers were moved indoors into digestion crates with free access to mineralized salt and water.

Four Katahdin wether sheep weighing 26 to 27 kg and four crossbred wether goats (Boer × Spanish) weighing 35 to 38 kg were placed into digestion crates located in an enclosed, but well-ventilated building. All animals had free access to mineralized salt blocks (just described) and water. When animals were initially placed in crates, they were fitted with a harness to allow future fecal collections. After initial conditioning to the crate and harness and following standardization, each animal was randomly assigned to one of the four forage treatments in the Latin square design. At initiation of the digestion phase, a canvas bag with a plastic insert was positioned on the collection harness for total fecal collection. The bags were emptied daily, and the feces was processed as noted previously.

Laboratory Analyses. All feed, ort, and fecal samples from the intake and digestion phases for each experiment were first ground in a Wiley mill to pass through a 1-mm screen and then scanned in a near-infrared reflectance spectrophotometer. The "H" statistic (0.6) was used to identify samples with different spectra. These samples were selected for use in laboratory analyses for the development of prediction equations.

In vitro true DM disappearance (**IVTDMD**) was determined in a batch fermentation vessel (ANKON Technology Corp., Fairport, NY) with artificial saliva (Burns and Cope, 1974) followed by neutral detergent extraction to remove microbial residues. Ruminal inoculum was obtained from a mature Hereford steer (*Bos taurus* L.) fed a mixed alfalfa (*Medicago sativa* L.) -orchardgrass (*Dactylis glomerata* L.) hay. Total N was determined by autoanalyzer (AOAC, 1990), and CP was estimated as 6.25 × total N. Fiber fractions consisting of NDF, ADF, and sulfuric acid lignin were estimated in a batch processor (ANKON Technology Corp.) using reagents according to Van Soest and Robertson (1980). Hemicellulose and cellulose were determined by difference [hemicellulose = NDF – ADF and cellulose = ADF – (lignin + ash)]. A second ADF sample was further analyzed for total N, as noted previously, to estimate ADIN and was expressed as grams of ADIN per kilogram of total N. Laboratory values were then used to develop near-infrared reflectance spectrophotometer calibration equations from which each observation was predicted (Table 1).

Nitrate nitrogen analysis was conducted on all feed samples and was determined on a water extract by weighing approximately 200 mg of DM into a 125-mL flask and adding 50 mL of deionized water. Nitrate was determined (day of extraction) colorimetrically with a Technicon autoanalyzer II (Bran+Luebbe, Inc., Buffalo Grove, IL) equipped with an automated hydrazine reduction method manifold (Pulse Instrumentation Ltd., Saskatoon, Saskatchewan, Canada). The hydrazine reduction method was carried out according to Kamphake et al. (1967) and is detailed by EPA method 353.1 (Mueller and Smith, 1991).

Statistical Analyses. All data from the intake and digestion phases were analyzed as a 4 × 4 Latin square design (SAS Inst., Inc., Cary, NC). In all cases, the model included terms for animal, period, and treatment. The three-way interaction was used to test all sources of variation for significance according to the *F*-test (Steel and Torrie, 1980). Treatments were considered significant at $P<0.05$, and means were separated using the Waller-Duncan K-ratio (k = 100) *t*-test, providing a minimum significant difference.

Results and Discussion

Agronomic. The DM yields at time of harvest varied within treatment, but yield averages were consistent with regrowth interval, averaging 880 kg/ha for 2-W, 7800 kg/ha for 3-W, and 9200 kg/ha for 4-W. Although pure stands of bermudagrass are sprigged when spray fields are initially established, they become extremely variable as spray fields age. Botanical composition of the spray fields reflected their heterogeneous nature. The composition of the least ma-

TABLE 1. The mean and range of each forage constituent predicted by near-infrared reflectance spectrophotometry, its standard error (SE) of calibration (SEC), and SE of cross-validation (SECV) for all intake and digestion trials (DM).

Item[a]	n	Mean	Range	SEC	SECV
		(g/kg)			
DM	117	932	894–966	3.5	4.5
OM	119	897	854–930	7.0	9.8
IVTDMD	72	691	616–750	11.7	14.1
CP	119	166	107–229	4.3	5.2
NDF	122	661	561–737	12.5	16.2
ADF	120	361	311–406	9.0	11.2
CELL	118	271	205–333	5.9	7.7
ADIN	118	5	1–11	0.4	0.5
Lignin	120	89	44–159	4.8	6.2

[a] IVTDMD = in vitro true DM disappearance; CELL = cellulose.

ture forage, 2-W, averaged 44.6% bermudagrass (range = 38 to 59%), 44% weeds (range = 22 to 60%), and 10.6% dead tissue (range = 2 to 20%). At the other extreme of maturity was 4-W, which averaged 50.1% bermudagrass (range = 18 to 83%), 47.3% weeds (range = 15 to 78%), and 2.8% dead (range = 2 to 3%). The major grassy weed was crabgrass (*Digitaria* L. spp.) with some goosegrass (*Eleusine indica* L.) present. The major broad-leafed weed was pigweed (*Amaranthus retroflexus* L.). In general, the three forage maturities consisted of about 50% bermudagrass and 50% weeds, if the dead material is ignored. All forages were readily dehydrated and pelleted, and operational conditions were standardized for all treatments.

Forage Nutritive Value. The composition of the feed samples from each forage treatment for the three intake trials was similar, and for ease of discussion, they were averaged then analyzed statistically (Table 2). In general, composition data of the offered forages are consistent with a warm-season grass—being relatively high in NDF and ADF as well as in hemicellulose and cellulose. Although no attempt was made to address the nutritive value of the weedy component of the harvested forage separately, previous work has shown warm-season, grassy weeds and broad-leafed weeds to be similar in IVDMD and CP within maturity stages and generally greater in nutritive value compared with bermudagrass (Hoveland et al., 1986).

Crude protein and NO$_3$ N concentrations would be a reflection of the N applied through the swine lagoon effluent at initiation of regrowth of each forage treatment as well as the soil N status and the maturity of the forage at harvest. Nitrogen concentrations in both the 2-WP and 4-WP forages were high as indicated by the CP values. The relatively low CP concentrations found in the 3-WP forage are consistent with no N applied (no waste application) at the onset of the 3-wk regrowth and are more than adequate to support daily BW gains of 1.6 kg when steers weigh >226 kg (NRC, 1984).

The pelleting process, which includes aspects of both grinding and steam treatment, physically reduces the fiber fraction and disrupts the cell wall through a hydrolytic process that cleaves lignocellulose bonds that resist digestion (Berger et al., 1994). This is reflected in greater IVTDMD and less NDF and constituent fiber fractions between the 2-WC and 2-WP treatments (Table 2). The greater CP and NO$_3$ N concentrations in the 2-WP treatment are attributed mainly to DM losses during pelleting (steam treatment), which can reach 200 g/kg under certain conditions (Walker, 1984).

Intake and Digestion.

Steer Trial. All three pelleted forages were readily consumed by steers (mean BW = 293 ± 4.7 kg), resulting in similar DMI that averaged 2.99 kg/100 kg of BW (Table 3). The DM digestibilities of the three forages, however, differed ($P\leq0.05$); the 3-WP treatment was least (0.48) compared with the 2-WP and 4-WP treatments, which were similar, averaging 0.59 (±0.016). Digestion coefficients showed the same relationship for CP, NDF, ADF, hemicellulose, and cellulose; the 3-WP treatment was significantly ($P\leq0.05$) less compared with the 2-WP and 4-WP treatments. An exception was noted for ADF digestion in which the 3-WP treatment was not different from the 2-WP treatment.

Digestible intakes (DMI × digestion coefficient × nutrient concentration) differed ($P\leq0.05$) among the pelleted forages for DM, CP, NDF, ADF, and cellulose and approached significance (P=0.07) for hemicellulose (Table 4). Digestible intakes of these fractions were least ($P\leq0.05$) for 3-WP compared with the 2-WP and 4-WP treatments. The exception was digestible intake of NDF, ADF, and cellulose in which the 2-WP and 3-WP treatments were similar.

Pelleting the forage, compared with the same forage chopped and dehydrated but not pelleted (2-WP *vs* 2-WC), increased DMI ($P\leq0.05$) of steers 39% (3.01 *vs* 2.16 ± 0.087 kg/100 kg of BW; Table 3). The pelleting effect on DMI is consistent with the literature reporting increased feed intake and BW gain and improved feed efficiencies (Hogan et al., 1962; Beardsley, 1964). This was attributed to decreased particle size (Osbourn et al., 1976) and shorter gastrointestinal tract residence time (Minson, 1963). Although the digestibilities of DM, CP, NDF, ADF, hemicellulose, and cellulose were numerically less for the

TABLE 2. In vitro true DM disappearance (IVTDMD) and composition[a] of forage harvested from effluent spray fields and fed to steers, sheep, and goats (DM basis).

Item	IVTDMD		CP		NDF							
	AF[b]	Orts	AF	Orts	AF	Orts	ADF	HEMI	CELL	Lignin	ADIN	NO_3 N
	(g/kg)											
Treatment[c]												
2 wk												
Chopped	689[d]	672	153	152	688	680	340	348	290	52	90	2.0
Pelleted (P)	728	716	202	202	659	655	319	340	262	61	120	2.7
3 wk, P	687	680	154	154	680	664	357	323	286	71	186	1.0
4 wk, P	720	712	181	181	675	671	347	328	281	66	150	2.0
Significance	*P*											
Treatment	<0.01	<0.01	<0.01	<0.01	<0.01	0.05	<0.01	0.03	<0.01	0.02	<0.01	<0.01
MSD[e]	12	16	12	12	10	19	12	17	7	11	31	0.3

[a] HEMI = hemicellulose; CELL = cellulose. ADIN is expressed as grams of ADIN/kg of total N.

[b] AF = as fed.

[c] Regrowth forage was harvested after 2 wk (2-W) and dehydrated; a portion was chopped (2-WC), and a portion was pelleted (2-WP). The 3-wk regrowth was harvested, dehydrated, and pelleted (3-WP), as was 4-wk regrowth (4-WP).

[d] Each value is the mean 12 samples (one from each of four animals from three intake trials).

[e] MSD = minimum significant difference from the Waller-Duncan k ratio (k = 100) *t*-test.

pelleted *vs* the chopped forage, the differences approached significance only for ADF and cellulose. Digestible intakes of the pelleted forage were greater for all fractions measured except ADF and cellulose (Table 4), which was associated with the greater DMI component. The reduced digestibility coefficients and increased digestible intakes from pelleting can be attributed to reduced cell wall digestion (Thomson and Beever, 1980) and shorter gastrointestinal tract residence time (Minson, 1963) with subsequent increased DMI (Beardsley, 1964). The end result is increased digestible energy intake and improved animal performance (Berger et al., 1994).

Sheep Trial. Sheep (mean BW = 36 ± 0.7 kg) consumed all three pelleted forages well, averaging 4.35 kg/100 kg of BW (Table 3). Intake was consistent with maturity of forage, being greater ($P \leq 0.05$) for the 2-WP treatment (4.49 kg/100 kg of BW), slightly reduced for the 3-WP treatment, but similar and least for the 4-WP treatment. Intake of the 4-WP treatment was similar to the 3-WP treatments but less compared with the 2-WP treatment.

Digestion coefficients for DM, CP, NDF, ADF, hemicellulose, and cellulose were similar between the 2-WP and 4-WP treatments. The coefficients for the 3-WP treatment were less ($P \leq 0.05$) than for the 2-WP treatment for DM, CP, NDF, and hemicellulose; only CP was less compared with the 4-WP forage.

Digestible intakes were greater ($P \leq 0.05$) for DM, CP, NDF, and hemicellulose from the 2-WP treatment compared with those from the 3-WP treatment and were greater for CP and hemicellulose for the 2-WP treatment than for the 4-WP treatment (Table 4). The 3-WP and 4-WP treatments had similar digestible intakes of DM, NDF, and hemicellulose, but the 3-WP treatment had the least ($P \leq 0.05$) digestible CP intake compared with the 4-WP treatment. All three treatments showed similar digestible intakes of ADF and cellulose.

Pelleted forage, when compared with chopped forage, increased the DMI of sheep as also noted for steers (Table 3). In this trial, DMI of pelleted forage was increased 77% (4.49 *vs* 2.54 ± 0.072 kg/100 kg of BW), whereas digestion coefficients were reduced ($P \leq 0.05$) for DM and all fiber constituents except hemicellulose. The large difference in DMI in favor of the pelleted forage also resulted in greater digestible intakes of DM, CP, and the fiber fractions (Table 4) as explained previously for steers.

Goat trial. Goats (mean BW = 43 ± 0.8 kg) readily consumed all three pelleted forages, and DMI were similar, averaging 3.21 kg/100 kg of BW (Table 3). Further, the goats digested the DM of the three forage treatments similarly with the digestion coefficient averaging 0.55. The digestion coefficients were also similar among the pelleted forage treatments, averaging 0.56 for NDF, 0.50 for ADF, 0.64 for hemicellulose, and 0.58 for cellulose. Crude protein digestion differed ($P \leq 0.05$) among the treatments; however, the 3-WP forage had the lowest digestion coefficient (0.52) compared with the 2-WP and 4-WP forage, which had similar digestion coefficients (0.65 ± 0.018).

Because of the similarity among the three pelleted forages in both

TABLE 3. Dry matter intake and apparent digestion coefficients for DM, CP, NDF, and constituent fiber fractions of forage harvested from effluent spray fields and fed to steers, sheep, and goats (DM basis).

		Digestion coefficient					
Item	DMI[a]	DM	CP	NDF	ADF	HEMI[b]	CELL[b]
Steers							
Treatment[c]							
2 wk (2-W)							
Chopped (C) (2-WC)	2.16[d]	0.62	0.65	0.67	0.61	0.72	0.70
Pelleted (P) (2-WP)	3.01	0.58	0.61	0.63	0.54	0.71	0.64
3 wk (3-WP)	2.90	0.48	0.41	0.54	0.47	0.63	0.57
4 wk (4-WP)	3.06	0.59	0.57	0.64	0.57	0.71	0.65
Significance		*P*					
Treatment	<0.01	<0.01	<0.01	0.01	0.05	0.05	0.01
MSD[e]	0.30	0.05	0.05	0.06	0.07	0.07	0.06
Sheep							
Treatment							
2-W							
2-WC	2.54	0.58	0.68	0.59	0.51	0.66	0.61
2-WP	4.49	0.52	0.63	0.52	0.41	0.61	0.50
3-WP	4.32	0.46	0.49	0.46	0.38	0.55	0.46
4-WP	4.23	0.51	0.61	0.49	0.42	0.56	0.47
Significance		*P*					
Treatment	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
MSD	0.24	0.05	0.05	0.05	0.06	0.05	0.05
Goats							
Treatment							
2-W							
2-WC	2.37	0.59	0.67	0.61	0.54	0.68	0.64
2-WP	3.29	0.57	0.66	0.57	0.49	0.65	0.58
3-WP	3.27	0.52	0.52	0.54	0.47	0.62	0.56
4-WP	3.07	0.56	0.64	0.58	0.53	0.64	0.60
Significance		*P*					
Treatment	<0.01	0.11	<0.01	0.11	0.19	0.08	0.09
MSD	0.24	—	0.06	—	—	0.05	0.07

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[a] Measured in kg/100 kg of BW.

[b] HEMI = hemicellulose; CELL = cellulose.

[c] Regrowth forage was harvested after 2 wk (2-W) and dehydrated; a portion was chopped (2-WC), and a portion was pelleted (2-WP). The 3-wk regrowth was harvested, dehydrated, and pelleted (3-WP), as was 4-wk regrowth (4-WP).

[d] Each value is the mean of four animals.

[e] MSD = minimum significant difference from the Waller-Duncan K-ratio (K = 100) *t*-test.

DMI and coefficients of digestion for most fractions analyzed, there was no difference in digestible intake (Table 4). An exception was digestible CP intake, which differed ($P \le 0.05$) among treatments. The 3-WP forage had the least digestible CP intake (0.26 kg/100 kg of BW), and the 2-WP and 4-WP forages were similar, averaging 0.41 (±0.022).

Pelleting, compared with chopping, increased ($P \le 0.05$) DMI of forage by goats as noted and discussed for steers and sheep (Table 3). Goats consumed 39% more pelleted forage than chopped forage (3.29 *vs* 2.37 ± 0.071 kg/100 kg of BW). However, greater intake of the pelleted forage had less influence than noted for steers and sheep on depressing the coefficients of digestion for DM, CP, and fiber fractions, resulting in no significant differences ($P > 0.05$). Consequently, the greater digestible intakes of DM, CP, NDF, and hemicellulose of the pelleted forage were primarily due to the greater DMI of pelleted *vs* chopped forage (Table 4).

General. The CP, NDF, and constituent fiber fraction concentrations in the forages agree, in general, with the numeric ranking obtained for DMI and digestion when evaluated by all three animal species. Animal response differences, however, were frequently not significant. Examining the nutritive value of the ort samples, compared with the offered forage, indicates that little preferential consumption occurred (Table 2), as the compositions were very similar.

The changes associated with pelleting (Table 2) increased DMI and are consistent with forage changes noted from grinding and steam treatment (Berger et al., 1994). Improved animal performance is expected from grinding and pelleting of forage high in cell walls and is attributed to increased daily digestible energy intake (Beardsley, 1964). This occurred in this study as animals fed pellets consistently showed short-term positive ADG (steers = 1.37 kg, sheep = 183 g, and goats = 119 g) when DM digestion coefficients were only moderate (0.46 to 0.59).

Although bermudagrass is not considered a nitrate-accumulating forage species (Hojjati et al., 1972), concentrations in the tissue can become excessive when grown in a N-rich environment and warrant special considerations. The NO_3 N concentration analyzed in the 3-WP treatment (Table 2) should be safe if the forage is fed as the sole diet to most animals (Murphy and Smith, 1967). The exception would be when feeding pregnant animals, in which case, to avoid slight risk of toxicity, the forage should make up ≤50% of the total

TABLE 4. Digestible intakes of DM, CP, NDF and constituent fiber fractions of forage harvested from effluent spray fields and fed to steers, sheep, and goats (DM basis).

Item	DM	CP	NDF	ADF	HEMI[a]	CELL[a]
Steers			(kg/100 kg of BW)			
Treatment[b]						
2 wk (2-W)						
Chopped (C) (2-WC)	1.34[c]	0.21	0.99	0.45	0.54	0.44
Pelleted (P) (2-WP)	1.75	0.35	1.25	0.53	0.72	0.52
3 wk (3-WP)	1.39	0.18	1.07	0.50	0.58	0.48
4 wk (4-WP)	1.81	0.29	1.32	0.63	0.68	0.58
Significance				*P*		
Treatment	0.01	<0.01	0.03	0.02	0.07	0.05
MSD[d]	0.27	0.05	0.22	0.10	0.16	0.10
Sheep						
Treatment						
2-W						
2-WC	1.48	0.26	1.03	0.44	0.59	0.45
2-WP	2.34	0.58	1.51	0.57	0.94	0.57
3-WP	1.97	0.32	1.36	0.57	0.78	0.56
4-WP	2.15	0.48	1.40	0.59	0.80	0.55
Significance				*P*		
Treatment	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
MSD	0.20	0.06	0.14	0.06	0.10	0.06
Goats						
Treatment						
2-W						
2-WC	1.41	0.25	1.01	0.44	0.56	0.44
2-WP	1.86	0.44	1.24	0.50	0.74	0.49
3-WP	1.68	0.26	1.21	0.55	0.66	0.52
4-WP	1.73	0.37	1.21	0.55	0.66	0.51
Significance				*P*		
Treatment	0.04	<0.01	0.07	0.08	0.04	0.14
MSD	0.30	0.07	0.19	0.10	0.11	—

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[a] HEMI = hemicellulose; CELL = cellulose.

[b] Regrowth forage was harvested after 2 wk (2-W) and dehydrated; a portion was chopped (2-WC), and a portion was pelleted (2-WP). The 3-wk regrowth was harvested, dehydrated, and pelleted (3-WP), as was 4-wk regrowth (4-WP).

[c] Each value is the mean of four animals.

[d] MSD = minimum significant difference from the Waller-Duncan k-ratio (K = 100) *t*-test.

daily intake (Parsons, 1974). The other three forages, however, carry increasing risks of nitrate toxicity, and special care needs to be exercised regarding the quantity of these forages that are fed daily. There were no visual symptoms of nitrate toxicity during these short-term trials. The practice of supplementing pelleted diets with long fiber (hay) has been suggested by Cullison (1961) to maintain healthy rumen conditions; such practice also could reduce the risk associated with potential nitrate toxicity. The NO_3 N concentrations in these forages are in the range reported by Burns et al. (1990) in forage harvested in the eleventh year following repeated annual applications of swine lagoon effluent to a pure stand of Coastal bermudagrass. In that trial, the NO_3 N concentrations ranged from 1.7 to 2.4 g/kg among the summer harvests from plots receiving an annual application of 670 kg of N/ha and from 2.7 to 3.2 g/kg among the summer harvest from plots receiving an annual application of 1340 kg of N/ha.

Although not an issue in these short-term experiments, it is worth noting that continued application of swine lagoon effluent to bermudagrass spray fields can result in the accumulation of minerals in the soil profile (King et al., 1990). Excessive accumulation of some elements, while site specific, may influence their concentrations found in the harvested forage and should be assayed prior to feeding.

Relationship Among Species. Sheep and goats generally ranked the pelleted forages similarly for DMI. All three animal species ranked the digestion coefficients for CP, NDF, and constituent fiber fractions similarly for all forages. In vitro true DM disappearance for the fed forage samples (Table 2) was not well correlated with apparent DM digestion coefficients (n = 4) from any of the digestion trials (r = 0.40 for steers, r = 0.22 for goats, and r = 0.14 for sheep). This lack of correlation is attributed, in part, to the disagreement noted between IVTDMD and apparent DM digestion for the chopped and pelleted forage of the W-2 treatment. This discrepancy has been reported in the literature with increased cell wall digestion of ground forage in in vitro studies (Dehority and Johnson, 1961) but reduced cell wall digestion in in vivo studies (Thomson and Beever, 1980). Omitting the chopped hay greatly improved the correlation within each trial with r = 0.84 (*P*=0.37) for steers, r = 0.99 (*P*=0.7) for goats, and r = 0.99 (*P*=0.07) for sheep, confirming biological importance. When animal species were combined (n = 9), however, the correlation was reduced to r = 0.59 (*P*=0.09).

The relationship among the three animal species when considering all four treatments for DMI and digestion of DM, CP, and NDF showed

TABLE 5. Simple correlation coefficient (r) showing the relationship among steers, sheep, and goats in estimating DMI and digestion coefficients for DM (DMD), CP (CPD), and NDF (NDFD) over all four forage treatments.

Item	Steer × sheep	Steer × goats	Sheep × goats
DMI	0.98 (0.02)[a]	0.94 (0.06)	0.99 (0.01)
DMD	0.91 (0.09)	0.97 (0.03)	0.97 (0.03)
CPD	0.99 (0.01)	0.99 (0.01)	0.98 (0.03)
NDFD	0.83 (0.18)	0.95 (0.05)	0.91 (0.09)

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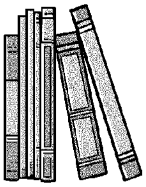
[a] Significance level presented in parentheses are based on n = 4.

strong (r = 0.91 to 0.99) agreement (Table 5). The exception was between steers and sheep for NDF digestion, which was less (r = 0.83), but still of biological significance. These relationships indicate that intake and digestion responses from any one of the three animal species could be used to rank the quality of the four forage treatments.

A numerical comparison of actual DMI and digestion values for the three pelleted treatments showed that sheep consumed 45.4% more DM/100 kg of BW than did steers. This difference in favor of sheep *vs* steers was also reported by Greenhalgh and Reid (1973). The DMI of steers and goats were numerically more similar; goats consumed only 7.4% more DM/100 kg of BW than steers. The mean digestion coefficients among the pelleted treatments for DM were similar for steers and goats, whereas coefficients from sheep were 10% less. Both sheep and goats digested CP better than steers with coefficients averaging 9.4% greater for sheep and 15.1% greater for goats. Conversely, steers digested NDF better with digestion coefficients averaging 23.1% greater than those obtained for sheep and 7.1% better than those obtained for goats.

Implications

Forage produced from fields of bermudagrass serving as receivers of swine lagoon effluent is a potential feed source for ruminants. Forages that were direct chopped, dehydrated, and pelleted were readily consumed (>2.8 kg/100 kg of BW) by steers, sheep, and goats, regardless of forage maturity. Immature forage was consumed at >2 kg/100 kg of BW when dehydrated and fed chopped. Nitrate N status of the forage needs to be monitored. Regrowth forage not receiving effluent at the onset of growth could be safely fed as a sole diet. Forages receiving effluent at initiation of regrowth poses risk of nitrate toxicity and should be fed as only a portion of the daily diet. Timely harvesting of spray fields and packaging of the forage, such as pelleting and bagging to add convenience for handling and transportation, will enhance its use for off-site feeding. Such innovation will make spray fields a ready source of nutrients for ruminants and a method of redistributing excess nutrients over the landscape and away from nutrient-rich sites.



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