VOLUNTARY INTAKE OF ROUGHAGE DIETS BY DONKEYS

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1. INTRODUCTION

Donkeys are extensively worked as draft, riding and pack animals in many developing nations. Despite their importance as agricultural laborers, however, their nutritional needs are often neglected. They may be left to forage for themselves (Pradhan *et al.*, 1991; Upadhay, 1991), or if fed, are typically provided only with cereal crop residues such as maize stover, millet stover, teff or wheat straw, or other low quality roughage (Aluja and Lopez, 1991; Mohammed, 1991). In the ruminant, intake of fibrous forage is limited by the relationship between gut fill and passage, and animals requiring high energy inputs may not be able to meet their requirements from forage alone. Janis (1976) has suggested that equids are not similarly constrained, and may increase their level of intake when eating poor quality forage in order to compensate for low energy density of the diet. Very little is known about the nutrient requirements and feeding behavior of donkeys. This paper reports the results of three separate studies investigating feed and water intake by donkeys fed diets comprised entirely, or nearly entirely, of forages of various quality.

2. MATERIAL AND METHODS

Experiments 1 and 2 involved 6 and 5 donkeys, respectively, and were conducted at Cornell University in New York State, a temperate location, during summer, fall and spring. Experiment 3 was conducted with 6 donkeys at the Institute for Crops Research in the Semi-Arid Tropics (ICRISAT) at Sadore, in southwest Niger, West Africa, during the summer months. All animals were treated against parasites with Ivermectin before experiments began.

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2.1. Experiment 1

Six American Standard donkeys (4 male, 2 female, body weight (BW) 192 ± 25 kg, aged 3 to 12 years) were used in a cross-over design. Animals were housed in individual stalls and turned out to a dirt paddock for 6 hours per day. Donkeys were randomly allocated to one of 2 diets, adapted to the diet for 3 weeks, then fed the diet during 9 weeks of measurement. After a 4 week rest period, diets were reversed and the measurements repeated. Diet 1 consisted of a high quality grass hay (HQH); diet 2 was a high fiber, low protein wheat straw (WS) (Table 1).

Table 1. Composition of forages offered. All values (apart from dry matter) calculated on a dry matter (DM) basis

Diet	DM (%)	DE* (MJ/kg)	CP (%)	ADF (%)	NDF (%)	Lignin (%)
High Quality Grass Hay (HQH)	92.10	9.46	13.9	33.4	53.25	5.58
Wheat Straw (WS)	93.83	6.91	3.8	51.88	82.73	7.52
Grass/Legume Hay (GLH)	90.69	8.75	15.5	42.34	61.62	8.12
Grass Hay (GH)	91.01	7.66	7.4	41.43	66.17	7.34
Millet Stover**	86.56	6.90	3.6	52.10	78.48	9.25
Millet Stover***	91.02	6.89	3.1	53.81	80.48	9.57

* DE estimated by NRC (1989) predictive equation for forages:
$DE(Mcal/kg) = 4.22 - 0.11 (\%ADF) + 0.0332 (\%CP) + 0.00112 (\%ADF)^2$; 1 Mcal = 4.184 MJ
**fed with concentrate
*** fed alone

Both forages were chopped to approximately 10 cm in length to prevent wastage. Feed and water intake and animal body weight were measured and recorded daily. Animals received approximately 2 hours per week of treadmill exercise during most of the study period. Daytime temperature in the barn ranged from 9° C to 24° C.

2.2. Experiment 2

Five of the same animals (3 males, 2 females) and the same protocol as in Exp. 1 were used, except that measurements were made during two 2-week periods following 2 weeks of adaptation, and animals received no forced exercise but were turned out for 6 hours daily. Diets were a mixed grass and legume hay (GLH) and a grass hay (GH); both were moderately high in cell wall (neutral detergent fiber: NDF) (Table 1); GLH was high in protein. Hay was fed unchopped. Daytime temperature in the barn during the experimental period ranged from 10° C to 21°C .

2.3. Experiment 3

Six female West African donkeys (BW 133 ± 12 kg) aged 3 to 10 years were kept tied in an open shed at the ICRISAT research station farm, with individual, calibrated containers for feed and water. Animals were turned out 2 hours each day in a dirt paddock. Additionally, animals worked an average of 6 hours per week pulling a loaded sled along level dirt tracks. Millet stover, obtained from local farmers, was fed during a 3 week adaptation and 8 week measurement period. Stover, containing stalks, leaves and occasionally residual heads of pearl millet (Pennisetum americanum) was chopped to approximately 20 cm lengths. Each animal also received 600 g/day of a concentrate mixture of 60% wheat bran, 30% peanut meal and 10% minerals; this diet is termed millet stover plus concentrate (MSC).

During the 9th and final week of measuring, the concentrate was removed and animals fed millet stover only (MS). Animals were weighed 3 times per week. Daytime shade temperature at the study site during the experimental period ranged from 25°C to 37° C.

For all diets in all experiments, forage was provided ad libitum with refusals allowed at 20%; animals received salt and fresh water *ad libitum*.

2.4. Chemical Analyses

Representative feed samples were dried, ground to pass through a 1 mm screen, and assayed for nutrient components. Dry matter (DM) concentration was determined at 105°C. Neutral detergent fiber (NDF), acid detergent fiber (ADF) and sulfuric acid lignin were determined according to Robertson and Van Soest (1981). Crude protein (CP) was determined by Kjeldhal method. Digestible energy (DE) of forages was estimated by the formula : DE (Mcal/kg) = 4.22 - 0.11 (% ADF) + 0.0332 (%CP) + 0.0011(%ADF)^2 (National Research Council, 1989). All components are expressed on a DM basis.

3. RESULTS

Since these 3 experiments involved different locations, feeds and animals, direct comparisons among diets cannot be made and each experiment should be viewed independently. Consideration of all the data, however, may suggest interesting patterns and points for future investigation. Intakes (mean ± SE) of forage DM as well as NDF for the 6 diets are given in Table 2, expressed in several ways. Daily dry matter intake was highest in animals eating high quality grass hay, and lowest in animals eating wheat straw. Intake of millet stover by Nigerien donkeys was moderate when animals were supplemented with concentrate but increased significantly ($p < 0.05$) when concentrate was removed. Although forage intake increased, total DM intake (forage plus concentrate) was not significantly different between MSC and MS. In Exp. 2, the mixed grass and grass/legume hay, each containing moderately high fiber, were consumed at equal levels, although there was considerable variation among animals. The crude protein (CP) content of GLH, twice that of the otherwise similar GH, appeared to have no effect on intake.

Table 2. Mean ± SE dry matter (DM), digestible energy (DE) and neutral detergent fiber (NDF) intakes from forage in donkeys

Diet	High Quality Grass Hay (HQH)	Wheat Straw (WS)	Grass/ Legume Hay (GLH)	Grass Hay (GH)	Millet Stover* (MSC)	Millet Stover** (MS)
n	6	6	5	5	6	5
Average Body Weight (kg)	**201 ± 10**	**184 ± 11**	**198 ± 14**	**197± 14**	**133 ± 6**	**132 ± 6**
DM intake (kg/animal/day)	4.59 ± 0.32	1.96 ± 0.20	3.89 ± 0.22	3.52 ± 0.18	2.37 ± 0.11	3.07 ± 0.26
DM intake (g/kg $BW^{.75}$/day)	85 ± 5	39 ± 3	72 ± 8	67 ± 6	60 ± 5	77 ± 7
DM intake/day as % BW	2.28 ± 0.12	1.07 ± 0.09	1.92 ± 0.18	1.80 ± 0.13	1.84 ± 0.11	2.11 ± 0.17
DE intake (kJ/kg BW/day	215 ± 11	79 ± 8	168 ± 17	138 ± 11	127 ± 8	145 ± 12
NDF intake (g/kg $BW^{.75}$/day)	47.5 ± 4.3	32.4 ± 1.5	45.2 ± 4.2	40.6 ± 3.6	46.1 ± 4.7	61.6 ± 6.0
NDF intake/day as % BW	**1.26 ± 0.10**	**0.88 ± 0.06**	**1.12 ± 0.01**	**1.08 ± 0.08**	**1.36 ± 0.15**	1.83 ± 0.19

* Diet 5 comprised *ad libitum* millet stover + 0.6 kg concentrate (containing 0.54 kg DM, 8.4 MJ DE** and 170 g NDF) per animal per day, hence when fed this diet animals consumed a total of 2.86 kg DM (2.15 % of BW); total DE consumed was 191 kJ/kg BW/day

** DE estimated from NRC (1989) predictive equation for concentrates: DE (Mcal/kg) = 4.07 - 0.055 (%ADF); 1 Mcal = 4.184 MJ

n: number of animals per diet

Daily water intake is shown in Table 3. Under temperate conditions (Diets 1 through 4), daily ad libitum water intake varied from 2.1 ± 0.4 kg per kg DM consumed to 3.0 ± 0.8 kg/kg DM. In the hot tropical location, however, water intake reached 4.2 ± 0.2 kg/kg DM, probably reflecting the increased water requirement necessary for thermoregulation.

Table 3. Mean ± SE water intakes in donkeys eating forage diets under temperate (hay, wheat straw) and tropical (millet stover) conditions

Diet	Water intake (kg/animal/day)	Water intake as % of BW	Water intake Water intake (kg/kg DM)
High Quality Grass Hay (HQH)	11.4 ± 3.9	5.6 ± 0.6	2.1 ± 0.4
Wheat Straw (WS)	6.6 ± 3.0	3.5 ± 0.6	3.0 ± 0.8
Grass/Legume Hay (GLH)	8.7 ± 3.6	4.3 ± 0.8	2.2 ± 0.6
Grass Hay (GH)	8.7 ± 3.1	4.4 ± 0.6	2.4 ± 0.5
Millet Stover + Concentrate (MSC)	11.9 ± 0.9	9.1 ± 0.6	4.2 ± 0.2
Millet Stover (MS)	11.6 ± 1.7	8.9 ± 0.8	3.9 ± 0.4

Body weight fluctuations when animals were fed the different diets are shown in Figure 1. All animals maintained body weight except those fed the wheat straw diet; these animals lost 12 ± 4% of BW after 9 weeks, and were

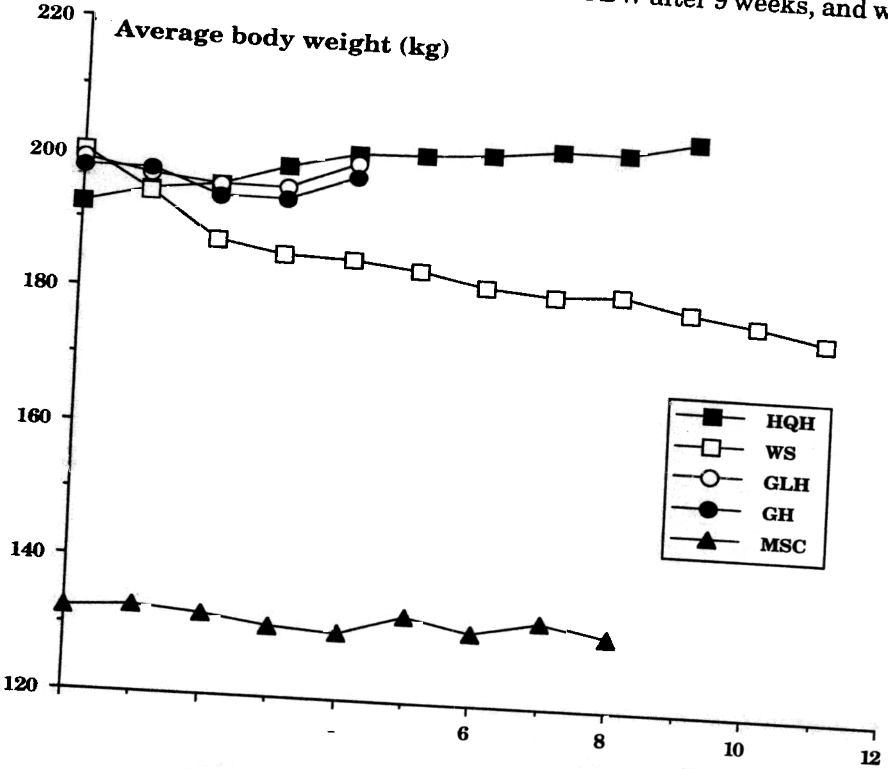

Figure 1. Body weight changes in 6 (HQH, WS, MSC) or 5 (GLH, GH) donkeys fed different forage diets over 4 to 11 week periods
HQH: high quality hay; WS; wheat straw; GLH: grass/legume hay; GH: grass hay; MSC: millet stover + concentrate. See text for description of diets

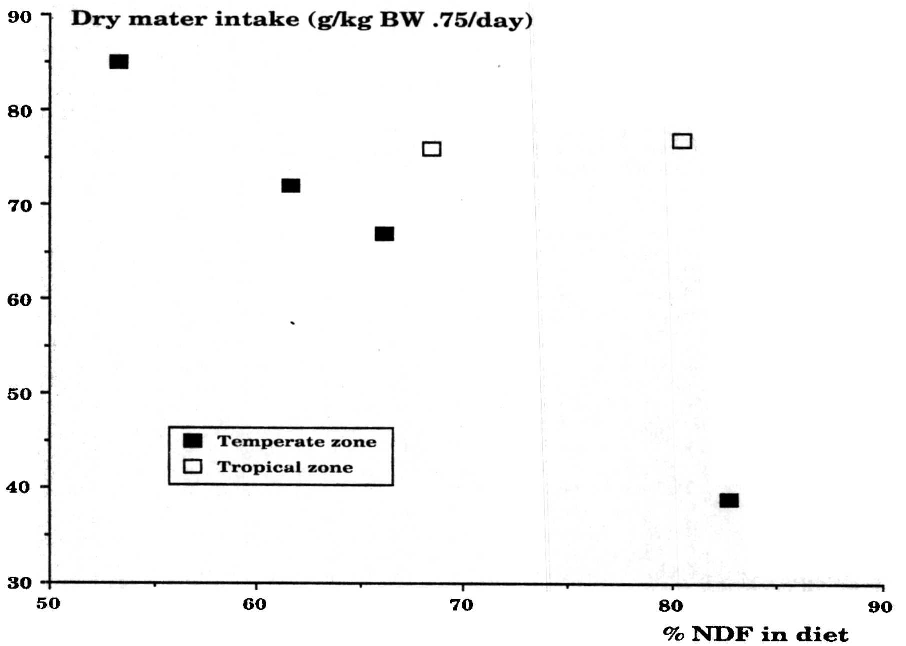

Figure 2. The relationship between total dry matter intake and dietary NDF content for donkeys eating 5 different diets

Each point is a mean ± se of 5 or 6 animals. Temperate studies were conducted in New York, USA, tropical studies in Niger, W. Africa, each with locally grown forages

reluctant to perform work. Animals consuming in excess of maintenance (HQH) gained an average of 7 ± 3% of BW. Millet stover alone (MS) was fed for insufficient time to assess BW changes.

The relationship between DM intake and dietary NDF concentration is shown in Figure 2.

Although donkeys fed HQH, WS, GLH and GH consistently rejected the most fibrous stems and chose to eat a diet slightly (1-2%) lower in NDF than the diet offered, the difference in NDF content between feed offered and consumed was not significant ($p > .05$). For MSC and MS diets, insufficient data is available to determine the degree of selectivity.

4. DISCUSSION

Feral donkeys are known to be highly adaptable feeders: they will forage widely and consume a variety of grasses, browse and forbs in order to obtain sufficient nutrients (Rudman, 1990). Domestic donkeys, however, who are expected to work during the day or are kept confined, are usually unable to find sufficient food on their own. Since it may be difficult for owners to provide supplementary feed to animals in regions where food resources are scarce even for humans, a more complete understanding of the feeding requirements and behavior of donkeys can suggest what options are available for proper nourishment.

These studies show that donkeys willingly consume large amounts of forage, especially if it is of medium to high quality. Contrary to the proposal of Janis (1976) and others regarding equine feeding strategy, the donkey is not always capable of increasing intake in order to compensate for reductions in dietary energy density. Rather, as proposed by Van Soest (1994), poor quality feed can have the effect of limiting intake, either through its bulk, leading to gastrointestinal fill, or because of some dietary deficiency. The New York donkeys in Exp. 1, for example, ate substantially less wheat straw than they did hay, even though this behavior resulted in negative energy balance and they lost weight. This contrasts with the behavior of donkeys studied by Pearson *et al.* (1992) in Scotland, which, when fed a mixture of alfalfa and oat straw, increased intake as the concentration of straw in the diet increased, in keeping with the postulates of Janis (1976). These animals were apparently able to eat to maintenance and did not lose weight. The oat straw was, however, lower in fiber, slightly higher in protein and more digestible than the wheat straw used in our study. Donkeys in a study in Morocco (N. Rihani, pers. comm.) ate 50% more when offered bersim (*Trifolium alexandrinum*), a nutritious clover, then when offered 70% NDF wheat straw. However, their intake of straw still exceeded that of donkeys reported here (WS diet) (1.7% of BW vs. 1.1% of BW).

Similarly, the Nigerien donkeys were able to increase their intake of millet stover when their energy-dense concentrate food was removed, and although the total DM intake did not increase, NDF intake did. This suggests that forage intake of these animals when fed MSC had not been constrained by NDF content of the diet. It is doubtful, however, that the animals were able to meet maintenance requirements simply by replacing concentrate with stover, for their DE intake was lower when they ate forage only (MS). Since animals were worked twice per week when supplemented (MSC) but were idle when unsupplemented (MS), direct comparisons of DE intake and requirements cannot be made. One animal had stopped eating by the end of the MS measurement period; a longer study would be necessary to assess the effect on body condition of unsupplemented millet stover and to know if such a diet can support maintenance in working or non-working donkeys.

Horses eat approximately 2% of BW if fed forage only. Donkeys did not eat appreciably more than 2% of their BW except on the very high quality, very palatable hay (HQH). When fed this hay, 2 animals ate 2.5 % of BW and were able to increase their BW by 10% in 8 weeks (4 animals ate slightly less). Lower quality forage did not elicit such high rates of intake. These findings differ from those of Maloiy (1970), who observed 4 Kenyan donkeys to eat 3% of BW when fed "poor quality hay".

If the National Research Council (NRC, 1989) formula for calculating energy requirements of horses and ponies (DE (Mcal/day) = 1.4 + 0.03 BW), is used to estimate requirements for a donkey, the requirement would be 36 kcal/kg BW (153 kJ) of DE/day for maintenance, or 46 kcal (192 kJ) if donkeys performed light work. McCarthy (1986), as well as anecdotal evidence from donkey managers, suggests that this formula may overestimate the daily energy requirement for donkeys, but precise information is lacking. If the estimates of DE are correct, it appears that donkeys were just able to meet maintenance requirements (although not a provision for work) when fed GLH, GH and MS, ate sufficient energy for maintenance and work when fed HQH and MSC, and failed to meet maintenance requirements when fed wheat straw (WS). These interpretations are supported by the body weight data (Figure 1).

The results presented here (Table 2) are comparable to those of Pearson and Merritt (1989), who found that donkeys consumed DM at a rate of 81 and 36 g/kg BW.75/day for meadow hay and barley straw diets, respectively. For HQH diet of this study, however, although the donkeys ate a similar amount of DM, they consumed far more calories because of the high quality, i.e. large percentage of cell solubles in this feed. Donkeys on some occasions voluntarily consumed nearly two times their postulated maintenance requirement, demonstrating the power of palatability to drive intake even for forages.

Poor quality forage often restricts intake through cell wall content (measured as % NDF). Thus it may be intake of grams of NDF rather than DM itself which is limiting. In ruminants, intake of NDF varies with forage type (grass vs. legume, temperate vs. tropical) and animal species, averaging about 65 g/kg BW.75/day for cattle and 45 g/kg BW.75/day for sheep (Reid *et al.*, 1988). The greater intake in cattle may result from their large rumen size relative to body size. The New York donkeys would thus appear to resemble sheep, but the Nigerien donkeys, despite smaller body size, demonstrated NDF intakes comparable to cattle, especially when diet quality was low (MS). It is likely that different groups of donkeys vary in digestive tract capacity.

The reason for the very low intake of wheat straw by North American donkeys is unclear. The high NDF content of the straw might limit gut fill, similar to the constraint observed in ruminants. However, the amount of NDF consumed by donkeys on this diet (WS) was significantly lower than that consumed by the same donkeys on other diets (HQH, GLH, GH) suggesting that some other factor is involved. The straw diet was clearly unpalatable: at the beginning of the adaptation period, one female donkey completely refused to consume it. However, all animals eventually learned to eat this diet, and, while high palatability probably accounted for the very high intakes seen on HQH, it seems unlikely that unpalatability alone would result in sub-maintenance intakes. Insufficient dietary protein may be a factor, as wheat straw contained only 3.8% CP, while the NRC minimum requirement for idle mature horses is 8.0% (NRC). Diets containing less than 8.0% protein depress intake in ruminants (Van Soest, 1994).

In Exp. 2, intake of hay containing 7.4% CP was not lower than that of hay with 15.5% CP, suggesting that the protein requirement of donkeys lies between 3.8% and 7.4%. In other studies, however, donkeys have been fed diets of straw containing 2.8 % (Izraely *et al.*, 1989b) and 4.8% CP (Pearson *et al.*, 1992) and intake was not depressed. The protein requirement of the donkey certainly deserves further study.

An experiment similar to ours but with divergent results was performed by Izraely *et al.* (1989a). They fed small Middle Eastern donkeys ad libitum alfalfa or a very low protein wheat straw and found that animals maintained body weight on both diets although they ate 50% more DM and twice as much energy when fed alfalfa (notably, the period of measurement is unclear). These donkeys were willing to consume much greater amounts of NDF in straw (Izrealy, 1989b) than were our New York donkeys (47± 11 g/kg $BW^{.75}$/day vs. 30 ± 2 g/kg $BW^{.75}$/day). Moroccan donkeys fed high fiber wheat straw also ate about 40 g/kg $BW^{.75}$ of NDF daily (N. Rihani, pers. comm.). It may be that there are differences among widely separated populations of donkeys (North American, African) that have yet to be formally recognized.

Figure 2, showing the intake response to increasing dietary fiber for both New York and Nigerien donkeys, lends some support to this hypothesis. The response of New York donkeys resembles that of ruminants, namely, decreasing DM intake as dietary NDF concentration increases. The Nigerien donkeys, however, although smaller, were able (or willing) to consume a greater percent of their BW in NDF, and apparently reacted to increasing dietary NDF, synonymous with decreasing energy density, by increasing intake. Nonetheless, total intake of both DM and DE was lower when dietary energy density was lower (MS). Donkeys were unable to completely substitute high fiber forage for concentrate. Further studies are necessary to verify and clarify this point. Whether the difference between populations is due to the nature of the forages fed, inherent animal differences or simply differential adaptation to circumstances remains unknown.

It has been suggested that donkeys, by feeding selectively on the most nutritious plant parts, can restrict their fiber intake and hence improve diet digestibility (Tisserand *et al.,* 1991). The relatively narrow muzzle of the donkey as compared to the horse would indicate selectivity to be a characteristic of their feeding strategy (Van Soest, 1994). However, when fed HQH, WS, GLH and GH in the present study, donkeys were not selective in a way that influenced NDF intake. The animals did leave the high fiber stems in the refusals, which led to a higher % NDF in the refusals than the diet offered, but the diet actually consumed was not significantly lower in NDF than the diet offered. High quality hay and wheat straw, however, were fed chopped, which may have reduced the animals' ability to sort; animals grazing or browsing on growing plants may be able to practice more selection, especially in the tropics where plant parts are highly differentiated (Van Soest, 1994).

Horses fed a diet of forage only are thought to require 2 to 3 kg of water for every kg of DM consumed (NRC, 1989), with requirements increasing as dietary NDF concentration increases. This means animals fed forage should on average drink water equivalent to 4-5% of their BW per day. Donkeys, animals adapted to arid areas and possessing water conservation strategies, might be expected to require less. Some studies performed in temperate zones show donkeys to drink slightly less than ponies eating the same food (Mueller & Houpt, 1991; Pearson *et al.*, 1992), while another found the species not to differ (Pearson & Merritt, 1991) However, data presented here shows, not surprisingly, that under conditions of high ambient temperature (25 -37° C) such as prevails during the West African summer, donkeys will freely consume 4 kg of water per kg DM. They drank water at a rate of 9% of BW per day, compared to temperate zone donkeys who drank only 4 -5 % even if eating large amounts of DM (HQH duet) and NDF (WS diet). Maloiy (1970) similarly observed donkeys in Kenya to drink 8% of BW per day when ambient temperature was between 22 and 40 ° C. Dehydration can depress feed intake in donkeys (Maloiy, 1970), as in other species. It is important, therefore, that persons working donkeys make proper provision for them to have sufficient water each day.

This report suggests that donkeys have a good but not limitless capacity to utilize forage diets of varying quality. Results presented in Table 2 along with Figure 2 show that donkeys will over-indulge on palatable food if given the opportunity, and they may become obese. However, poor quality forages such as wheat straw are unlikely to provide nutrients sufficient for maintenance let alone any desired productive functions. Tropical crop residues such as millet stover, if fed ad libitum and supplemented with a small amount of concentrate, may sustain donkeys, although additional diets and forages require testing to form a complete picture.

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