Recovery of seed of four African browse shrubs ingested by cattle, sheep and goats and the effect of ingestion, hot water and acid treatment on the viability of the seeds

C.M. SHAYO[1,2] AND P. UDÉN[2]
[1]*Zonal Research and Training Centre, Livestock Production Research Institute, Mpwapwa, Tanzania*
[2]*Department of Animal Nutrition and Management, Swedish University of Agricultural Sciences, Uppsala, Sweden*

Abstract

An investigation was made of: the voluntary intake of pods of 4 tropical browse trees by different classes of domestic ruminants; and the proportion of intact seeds that passed through the digestive tracts. Germination of undigested whole seeds recovered from faeces and uningested seeds treated with hot water and acid or untreated was also determined. Pods of *Faidherbia albida (Acacia albida), Acacia tortilis, Acacia nilotica* and *Dichrostachys cinerea* were opened to estimate the percent by weight of intact and damaged seeds in the pods. Whole pods from each species were fed to heifers, calves and mature and young sheep and goats for 2 weeks. Faeces from the animals were collected daily during the second week and washed through a sieve to retrieve the undamaged seeds. Uningested seeds were also soaked either in hot water for 2, 4 or 6 min or in H_2SO_4 (70% v/v) for 0.5, 1.5 or 3 h. Germination rates of treated and untreated seeds and seeds collected from faeces were determined over a period of 13 weeks.

Pods of *Acacia tortilis* had a significantly ($P<0.05$) higher percentage by weight of seeds (33%) than those of other species, with *F. albida* and *D. cinerea* having the lowest percentage of seeds (10%). Intakes of *F. albida* and *A. tortilis* pods for all classes of animal were similar and significantly ($P<0.05$) higher than intakes of pods of other species. Intakes of *D. cinerea* pods were significantly ($P<0.05$) higher than those of *A. nilotica* pods, except for young sheep and young goats, and similar to those of *F. albida* and *A. tortilis*, except for heifers and mature sheep. Animal age had no effect on pod intake as % body weight (BW). Average intake (% BW) of pods was highest for *F. albida* (2.4%) and *A. tortilis* (2.4%) followed by *D. cinerea* (1.8%) and *A. nilotica* (0.9%). Both classes of cattle passed a significantly ($P<0.05$) higher percentage of ingested seeds than did sheep and goats. Sheep and goats digested considerably higher amounts of the seeds, particularly those of *F. albida* and *A. tortilis,* suggesting that cattle would benefit nutritionally from grinding of the pods. Germination was not improved by passage of seeds through the digestive tract of any animal, whereas hot water and acid treatments generally reduced or had no effect on germination. Germination of *A. nilotica* seeds treated with acid for 1.5 and 3 h was significantly ($P<0.05$) enhanced.

Correspondence: Mr C.M. Shayo, Department of Animal Nutrition and Management, Swedish University of Agricultural Sciences, P O Box 7024, S-750 07, Uppsala, Sweden

Introduction

Faidherbia albida (Acacia albida), Acacia tortilis, Acacia nilotica and *Dichrostachys cinerea* are common trees in the semi-arid tropical and subtropical zones of east Africa, especially in the drier areas. Their value as sources of feed for livestock lies in the leaves and pods. Seed pods are indehiscent and remain on the trees until removed by browsers, natural senescence or mechanical action such as wind and rain. *Acacia* and *Dichrostachys* pods have a higher nutritive value than the pasture plants available during the dry season and the seeds contain higher levels of crude protein and digestible nutrients than empty pods (Gwynne 1969; Tanner *et al.* 1990; Shayo *et al.* 1997). However, a considerable percentage of ingested seeds of various *Acacia* species pass through the digestive tracts of domestic and wild grazing animals undigested (Lamprey 1967; Lamprey *et al.* 1974; Tanner *et al.* 1990). Undigested seeds represent a loss of nutrients which may be important for survival during periods of food scarcity. The proportion of undigested seeds would depend on the hardness of the seed coat, seed size and shape (Lamprey 1967) and also on animal species and size (Jarman 1976). *Acacia tortilis, A. nilotica, F. albida* and *D. cinerea* species have hard seed coats. High proportions of small and roundish seeds which are ingested escape digestion, whereas usually only a small proportion of seeds ingested by small animals survive damage in the gut.

Lamprey (1967), Lamprey *et al.* (1974) and Halevy (1974) suggested that seeds which escape digestion have an enhanced ability to germinate due to scarification of the seed coat by abrasive actions and gut acids although some observations do not support this (*e.g.* Coe and Coe 1987; Hashim 1990). Methods of treatment to enhance germination rates of seeds from pod-bearing trees and browses of the semi-arid areas have not been given due attention.

In this context, this study investigated: intake of pods of 4 tropical browse trees (*F. albida, A. tortilis, A. nilotica* and *D. cinerea*); the extent to which the ingested seeds would pass intact through the alimentary tract of different species and age classes of ruminants; and the effect of treatment with hot water and sulphuric acid on the germination of uningested seeds.

Materials and methods

Study area

The study was conducted at the Livestock Production Research Institute, Mpwapwa, in the semi-arid area of central Tanzania (36°30′E, 6°20′S; altitude 1100 m), where average annual rainfall of 550 mm varies greatly in distribution and amount from year to year.

Weight, size and proportion of seeds in pods

Pods of *F. albida, A. tortilis, A. nilotica* and *D. cinerea* were collected in villages around the Institute during the period of shedding in August 1995. Samples of pods of each species were weighed and opened to obtain the seeds. The weight of the seeds was used to estimate the percentage by weight of seeds in the pods. Intact seeds were separated from the rest of the seeds and weighed. A sample of 100 seeds was measured to estimate mean length, width and thickness. Intact seeds were those which were not rotten or extensively deformed and which had no visible exit holes and/or circular transparent "windows" in the testa caused by emerging bruchids (*Bruchidius spadiceus*).

Intake of pods

The experiment involved 6 heifers (153 ± 9.2 kg), 6 female calves (73 ± 4.6 kg), 3 mature male goats (39 ± 0.3 kg), 3 young male goats (10 ± 0.3 kg), 3 mature male sheep (32 ± 1.5 kg) and 3 young male sheep (13 ± 0.7 kg). The animals were fed individually in cages (sheep and goats) or pens (cattle). Water and mineral licks were available throughout the experimental period. At 0800 h, the animals were provided with pods at 2.5% of body weight (BW). At 1400 h, unconsumed pods were collected and weighed. Hay was then provided to the animals and unconsumed hay was removed at 0800 h the following morning. The experimental period was divided into 4 periods of 14 d, 1 period for each plant species. Intake of pods was recorded as the amount consumed (*i.e.* difference between amount of pods provided and amount refused). Faeces of all animals were collected for the final 7 d of each 14-d period.

Recovery of seed from faeces

Ten percent of the faeces from each day was taken and washed with water on a 3 mm sieve. The undigested seeds could not pass through the sieve and were collected. The collected seeds were sun dried and the intact seeds were separated from partially chewed, broken or germinated seeds, then weighed.

Germination

Intact seeds obtained directly from pods were either soaked in hot water or acid, for different lengths of time or left untreated. After acid treatment, acid-treated seeds were washed in running water for about 5 minutes. Untreated and treated seeds and intact seeds that had passed through animals were then soaked in water for 2 h.

Floating seeds were considered to be unsuitable and were discarded.

There were 13 treatments, as follows: intact seeds from pods (control); seeds soaked in acid (H_2SO_4–70% v/v) for 0.5, 1.5 and 3 h; seeds soaked in hot water (90°C) for 2, 4 and 6 minutes; and the undigested seeds from faeces of heifers, calves and mature and young sheep and goats. There were 4 replicates of 25 seeds for each treatment, laid out in a fully randomised design. The seeds were covered by soil in petri dishes and water added daily to keep the soil constantly moist. Seeds were considered to have germinated when the cotyledons had emerged from the soil or seeds had radicles more than 3 mm long. Germinated seeds were counted daily and removed.

Statistical analysis

The data on the proportion of seeds in the pods and the effect of animal species and age classes on the percentage of ingested seeds that were voided intact were analysed by one-way analysis of variance. Data from the germination trial were analysed by analysis of variance for differences between species and treatments. For the treatments which showed significant differences, the means were compared using Tukey's procedure at $P<0.05$ as described by Steel and Torrie (1980).

Results

Weight, size and proportion of seeds

Weights of *Faidherbia albida* and *A. nilotica* seeds were similar ($P>0.05$) but significantly ($P<0.05$) higher than the weight of *A. tortilis* seeds (Table 1). *Dichrostachys cinerea* seeds were significantly ($P<0.05$) lighter than *A. tortilis* seeds. *Dichrostachys cinerea* seeds were smallest ($P<0.05$) followed by *A. tortilis* ($P<0.05$), *A. nilotica* ($P<0.05$) and *F. albida* seeds ($P<0.05$). The proportion by weight of seeds in *A. tortilis* pods was significantly ($P<0.05$) higher than the proportion in pods of other species (Table 1). *Faidherbia albida* and *D. cinerea* pods had lower percentage of intact seeds than *A. nilotica* pods. The proportion of total seeds which were intact was highest in *A. nilotica* ($P<0.05$) followed by *A. tortilis, D. cinerea* ($P<0.05$) and *F. albida* ($P<0.05$).

Intake of pods

Intakes of *F. albida* and *A. tortilis* pods were similar and significantly ($P<0.05$) higher in all classes of animal than intakes of *A. nilotica* pods (Table 2). Intakes of *D. cinerea* pods were significantly ($P<0.05$) higher than those of *A. nilotica* pods in most animal classes, and were lower than those of *F. albida* and *A. tortilis* but not always significantly so.

Table 2. Daily intakes of pods of 4 tropical browse species by 6 classes of livestock.

Animal class	Species				Mean
	F. albida	*A. tortilis*	*A. nilotica*	*D. cinerea*	
	(% BW)[1]				
Calves	2.51a[2]	2.49a	0.35bA[3]	1.90a	1.82
Heifers	2.37a	2.18a	0.84bB	1.60c	1.75
Young sheep	2.35a	2.41a	1.15bB	1.41b	1.85
Mature sheep	2.41a	2.34a	0.43bA	1.74c	1.73
Young goats	2.52a	2.42a	1.82bC	2.17ab	2.23
Mature goats	2.12a	2.50a	0.87bB	1.94a	1.86
Mean	2.39	2.37	0.91	1.78	

[1]Percent of body weight.
[2]Means in the same row (except for the mean) followed by different lower case letters are significantly different ($P<0.05$).
[3]Means in the same column (except for the mean) followed by different upper case letters are significantly different ($P<0.05$).

Table 1. Seed weight and size and percentage (± s.e.) by weight of seeds in whole pods and intact seeds as a percentage of total seeds.

Species	All seeds	Intact seeds	Intact seeds	Seed weight	Seed size		
					Length	Width	Thickness
	(% of whole pods)		(% of total seeds)	(g)	(mm)		
F. albida	11.5c[1] ± 0.5	6.2b ± 0.3	53.9c ± 1.4	0.12a ± 0.004	9.9a ± 0.1	6.4a ± 0.1	6.0a ± 0.1
A. tortilis	32.8a ± 1.1	22.2a ± 1.2	67.7b ± 2.3	0.05b ± 0.002	6.2c ± 0.1	5.0c ± 0.1	4.5c ± 0.1
A. nilotica	25.9b ± 0.9	19.9a ± 0.8	76.8a ± 1.1	0.13a ± 0.004	6.9b ± 0.1	5.7b ± 0.1	5.6b ± 0.1
D. cinerea	9.5c ± 1.0	5.8b ± 0.7	61.1b ± 3.3	0.02c ± 0.001	4.2d ± 0.1	4.2d ± 0.1	2.7d ± 0.1

[1]Means in the same column followed by different letters are significantly different ($P<0.05$).

Percentage of undigested seeds

Cattle passed a higher (P<0.05) percentage of ingested intact seeds than both sheep and goats (Table 3). Mean percentages of ingested seeds voided by calves, heifers, young sheep, mature sheep, young goats and mature goats were 70, 64, 12, 18, 21 and 24%, respectively. There was no evidence that the percentage of seeds defaecated differed between young and mature animals. The average percentages of seeds voided by all animals were ranked as *D. cinerea* > *A. nilotica* > *A. tortilis* > *F. albida* (Table 3).

Table 3. The percentages of intact ingested seeds which were defaecated by different animal classes.

Animal	Species			
	F. albida	*A. tortilis*	*A. nilotica*	*D.cinerea*
		(%)		
Calves	57a[1]A[2]	75bA	72bA	76bA
Heifers	55aA	58aB	75bA	67abAB
Young sheep	2B	7C	18B	20C
Mature sheep	4aB	10aC	11aB	47bBC
Young goats	2aB	17bC	32cB	31cC
Mature goats	5aB	24bC	16aB	49bAC
Mean	21	32	37	48

[1]Means in the same row followed by different lower case letters are significantly different (P<0.05).
[2]Means in the same column (except for the mean) followed by different upper case letters are significantly different (P<0.05).

Germination

In all treatments, more than 50% of the seeds which germinated did so within the first 5–7 weeks, although some intact seeds of *A. tortilis* and *A. nilotica* germinated after 13 weeks. Germination percentages of the seeds at 13 weeks are presented in Table 4.

Undigested *F. albida* seeds and intact seeds of *F. albida* voided by animals had higher germination percentages (72–98%) (P<0.05) than seeds of other species. Untreated seeds of *D. cinerea* had very low germination percentage (5%). Both hot water and acid treatment of *F. albida* seeds lowered (P<0.05) germination percentage. Soaking of *A. nilotica* seeds in acid for 1.5 or 3 h and *D. cinerea* seeds for 0.5 h were the only treatments which increased germination significantly (P<0.05).

Passage of seeds through the animals had no significant effect on germination percentage although there was a tendency for reduced germination in *A. tortilis* and *A. nilotica* seeds.

Table 4. Percent germination of seeds after 13 weeks as affected by hot water or acid treatment and ingestion by animals.

Treatment	Species			
	F. albida	*A. tortilis*	*A. nilotica*	*D. cinerea*
		(%)		
Intact seeds	78a[1]AD[2]	42bAC	20bcAB	5cA
Hot water 2 min	22aBC	12abB	2bA	15aAB
Hot water 4 min	30B	23AB	9AB	12AB
Hot water 6 min	23aBC	18aAB	2bA	12aAB
Acid 0.5 h	22BC	51C	36BC	27B
Acid 1.5 h	0aC	20aAB	52bC	9aAB
Acid 3 h	0aC	5aB	57bC	21aAB
Intact seeds voided by:				
Calves	82aAD	19bAB	7bA	6bA
Heifers	98aA	8bB	8bA	13bAB
Young sheep	na[3]	24aAB	12abA	5bA
Mature sheep	na	27aABC	5bA	8bA
Young goats	na	19aAB	6abA	1bA
Mature goats	72aD	22bAB	6bA	12bAB

[1]Means in the same row followed by different lower case letters are significantly different (P<0.05).
[2]Means in the same column followed by different upper case letters are significantly different (P<0.05).
[3]Not available.

Discussion

There have been suggestions (Gwynne 1969) that the indehiscent *Acacia* pods have a strong smell, attracting ungulates to eat them. However, in spite of this scent, intake of *A. nilotica* pods was low for all classes of animals. The reason for the low intake is not clear, but may be related to a higher concentration of soluble phenolics and insoluble proanthocyanidins in *A. nilotica* pods than in pods of the other species (Tanner *et al.* 1990; authors, unpublished data). Phenolic compounds are known to reduce intake of feeds by various herbivores (Coley *et al.* 1985).

In this study, cattle voided a higher proportion of whole seeds than did sheep and goats. This may be in part a function of animal size as Miller (1993; 1995) found that seed survival through the digestive tract increased linearly with body mass. Halevy (1974), Jarman (1976) and Senzota (1984) also showed that small proportions of *Acacia* seeds survived digestion in small ungulates, *e.g.* Impala and Thomson's gazelle, whereas the proportion was greater in larger ungulates (Spinage *et al.* 1980). However, the absence of evidence that the proportion of *Acacia* seeds voided by mature animals was different from that voided by younger animals suggests that species differences may have contributed to the higher passage of intact seed by cattle. The low levels of intact seeds voided by sheep and goats contradict the statement by Lamprey *et al.* (1974), that most seeds ingested by ruminants are voided without being damaged.

The percentage of ingested seeds that were voided intact was highest for *D. cinerea* and *A. nilotica,* followed by *A. tortilis* and *F. albida.* There was evidence that the average percentage of seeds voided intact was inversely proportional to the weight and size of the seeds. This is consistent with the findings of Lamprey (1967) that smaller seeds often pass through the digestive tracts of ruminants without being damaged. Previous studies (Tanner *et al.* 1990; Shayo 1992; Shayo *et al.* 1997) have shown that crude protein concentration and total *in sacco* degradable material in *A. tortilis, F. albida, A. nilotica* and *D. cinerea* seeds were higher than for empty pods. It would therefore be important to grind the pods before feeding to cattle so that they could benefit from the nutrients in the seeds. However, there is probably little or no advantage from grinding the pods for supplementation of sheep and goats as most of the ingested seeds are digested, particularly those of *F. albida* and *A. tortilis.*

Although Lamprey (1967), Lamprey *et al.* (1974) and Halevy (1974) suggested that passage of *Acacia* seeds through ungulates accelerates seed germination by scarification of the seed coat, our results do not support this. Germination percentages of seeds which had passed through the gut of all animals were similar to/or less than those of uningested seeds. This supports the findings of Coe and Coe (1987) and Hashim (1990) that germination of *Acacia* and *Dichrostachys* seeds was not enhanced by passage through digestive systems of animals. Lamprey (1967) and Mwalyosi (1990) observed that *Acacia* seeds readily establish within the dung of wild and domestic animals. Our study suggests that the high numbers of germinated seeds observed in the dung of animals during the rainy season may not be a result of gut acids and abrasive actions enhancing germination. Instead, it could be because bruchid larvae within the seeds are killed during passage through the gut and/or because dung protects against further bruchid infestation. Seeds of *Acacia* species are hosts for the developing stages of bruchid beetle larvae (Halevy 1974; Lamprey *et al.* 1974; Pellew and Southgate 1984) that are known to cause up to 100% damage to them (Ernst 1992). Seeds ingested at the initial stages of bruchid infestation could still be viable (Miller 1994), the extent depending on how much of the embryo has been consumed (Coe and Coe 1987). Therefore, ingested seeds in the dung may remain protected until the start of the rainy season, whereas uningested seeds lying on the ground succumb to bruchid damage. The period between pod maturity (April–June) and the onset of the rainy season (November–December) in central Tanzania is probably long enough for the bruchids to cause substantial damage to uningested seeds.

Despite the fact that acid and heat treatments are used for seed scarification, failure of these methods to enhance germination of the seeds in our study (with the exception of *A. nilotica* seeds in acid for 1.5 and 3 h) could probably be associated with the nature of the seed coat and extended duration of soaking, which could have damaged the embryo. Zodape (1991) observed enhanced germination of *A. nilotica* and *D. cinerea* and seeds from related species soaked in concentrated acid for 5–75 minutes, whereas in our study, soaking time was 0.5–3 h. *A. nilotica* seeds have been reported to have higher proportions of cell wall than *F. albida* and *A. tortilis* seeds (Gwynne 1969; Tanner *et al.* 1990) which is one possible reason for the enhanced germination of *A. nilotica* seeds following acid treatment. It is also possible that the seed coat of *A. nilotica* is more resistant to acid degradation than those of other types of seeds.

Conclusion

This study showed that utilisation of *Acacia* and *Dichrostachys* pods by cattle is limited by a high proportion of seeds passing through the digestive system undigested. In order to optimise utilisation of the seeds, it is suggested that the pods could be collected and ground for cattle feeding, as most ingested seeds are not digested. Bush encroachment in areas grazed by livestock is a result of, among other factors, germination of *Acacia* seeds in the dung of the grazing animals. To reduce the high costs involved in bush clearance, dung voided by grazing animals could be collected during the dry season and distributed along the boundaries to form live fences or burnt as fuel. Further studies on *Acacia tortilis, Acacia nilotica, Faidherbia albida* and *Dichrostachys cinerea* are required to examine germination of seeds in dung and of uningested seeds left in the field at the start of the rainy season. The effects of damage to seeds on their nutritive value for livestock should be given attention.

Acknowledgements

The financial support of the Swedish Agency for Research Cooperation with Developing Countries (SAREC) is highly acknowledged. Sincere thanks are gratefully extended to Messrs Anthony Mbeho, Ally Bambaku, Rehema Kasiga and Helina Nhonya for maintaining the animals and data collection.

References

COE, M. and COE, C. (1987) Large herbivores, *Acacia* trees and bruchid beetles. *South African Journal of Science*, **83**, 624–635.

COLEY, P.D., BRYANT, J.P. and CHAPIN, F.S. (1985) Resource availability and plant anti-herbivore defense. *Science*, **230**, 895–899.

ERNST, W.H.O. (1992) Nutritional aspects in the development of *Bruchidulus sahlbergi* (Coleoptera Bruchidae) in seeds of *Acacia erioloba*. *Journal of Insect Physiology*, **38**, 831–838.

GWYNNE, M.D. (1969) The nutritive value of *Acacia* pods in relation to *Acacia* seed distribution by ungulates. *East African Wildlife Journal*, **7**, 176–178.

HALEVY, G. (1974) Effects of gazelle and seed beetles (Bruchidae) on germination and establishment of *Acacia* species. *Israeli Journal of Botany*, **23**, 120–126.

HASHIM, I.M. (1990) Germination of kadad (*Dichrostachys cinerea*) seed following pod digestion by goats, and various treatments. *Forest Ecology and Management*, **38**, 105–110.

JARMAN, P.J. (1976) Damage to *Acacia tortilis* seeds eaten by impala. *East African Wildlife Journal*, **14**, 223–225.

LAMPREY, H.F. (1967) Notes on the dispersal and germination of some tree seeds through the agency of mammals and birds. *East African Wildlife Journal*, **5**, 179–180.

LAMPREY, H.F., HALEVY, G. and MAKACHA, S. (1974) Interactions between *Acacia*, bruchid seed beetles and large herbivores. *East African Wildlife Journal*, **12**, 81–85.

MILLER, M.F. (1993) Is it advantageous for *Acacia* seeds to be eaten by ungulates? *Oikos*, **66**, 364–368.

MILLER, M.F. (1994) Large African herbivores, bruchid beetles and their interactions with *Acacia* seeds. *Oecologia*, **97**, 265–270.

MILLER, M. (1995) *Acacia* seed survival, seed germination and seedling growth following pod consumption by large herbivores and seed chewing by rodents. *African Journal of Ecology*, **33**, 194–210.

MWALYOSI, R.B.B. (1990) The dynamic ecology of *Acacia tortilis* woodland in Lake Manyara National Park, Tanzania. *African Journal of Ecology*, **28**, 189–199.

PELLEW, R.A.P. and SOUTHGATE, B.J. (1984) Parasitism of *Acacia tortilis* in the Serengeti. *African Journal of Ecology*, **22**, 73–75.

SENZOTA, R.B.M. (1984) Dry season food refuge of Thomson's gazelles in the Serengeti. *Oikos*, **42**, 411–412.

SHAYO, C.M. (1992) *Evaluation of water melons as a source of water, and water melon seeds and* Acacia *pods as a protein supplement for dairy cows in Central Tanzania.* M.Sc. Thesis. Swedish University of Agricultural Sciences, Uppsala, Sweden.

SHAYO, C.M., OGLE, B. and UDÉN, P. (1997) Comparison of water melon (*Citrullus vulgaris*)-seed meal, *Acacia tortilis* pods and sunflower-seed cake supplements in central Tanzania. 1. Nutritive value and influence on rumen environment. *Tropical Grasslands*, **31**, 124–129.

SPINAGE, C.A., RYAN, C. and SHEDD, M. (1980) Food selection by Grant's gazelle. *African Journal of Ecology*, **18**, 19–25.

STEEL, R.G.D. and TORRIE, J.H. (1980) *Principles and Procedures of Statistics. A biometrical approach.* 2nd Edn. (McGraw-Hill Book Company: New York).

TANNER, J.C., REED, J.D. and OWEN, E. (1990) The nutritive value of fruits (pods with seeds) from four *Acacia* spp. compared with extracted noug (*Goizotia abbyssinica*) meal as supplements to maize stover for Ethiopian highland sheep. *Animal Production*, **51**, 127–133.

ZODAPE, S.T. (1991) The improvement of germination of some forest species by acid scarification. *Indian Forester*, **117**, 61–66.

(Received for publication April 24, 1997; accepted February 3, 1998)