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PREFERENCE STUDY OF UNTREATED AND UREA-TREATED FONIO AND RICE STRAWS WITH SHEEP IN THE MOIST GUINEA SAVANNA ZONE

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Abstract

A preference study of fonio and rice straws was done for both untreated and urea-treated straws. Sixteen lambs were used to determine the preference. The experimental feeds were offered to the lambs for 10 days adaptation. Feed amounts consumed over specific times were measured during subsequent 3 days. Nitrogen content of untreated fonio straw was simimlar to that of untreated rice straw. Urea treatment of straws increased the nitrogen content but reduced intake. Untreated rice straw was the most preferred feed followed by untreated fonio straw and the urea-treated straws, in that order ($P < 0.05$). The consumption of experimental feeds interacted significantly ($P < 0.05$) with the time of collection of data. Large amounts of feed were eaten, however, the low protein intake would limit the growth of lambs.

Résumé

KARBO, N., AVORNYO, F., ADDO-KWAFO, A. & BRUCE, J.: *Etudes pour la préférence entre la paille de fonio et de riz non-traitée et traitée d'urée donné au mouton dans la zone humide de savane-guinénne.* Une étude pour la préférence entre les pailles de fonio et de riz était faite pour les pailles non-traitées et traitées d'urée. Seize agneaux étaient utilisés pour déterminer la préférence. Les fourrages expérimentaux étaient offerts aux agneaux pour dix jours d'adaptation. La quantité de fourrage consommée sur des temps spécifiques était mésurée pendant les trois jours suivants. Le contenu d'azote de la paille de fonio non-traitée était semblable à celui de paille de riz non-traitée. Le traitement d'urée des pailles augmentait le contenu d'azote mais réduisait la consommation. La paille de riz non-traitée était le fourrage le plus préféré suivi par la paille de fonio non-traitée et les pailles traitées d'urée, dans l'ordre logique ($P < 0.05$). La consommation de fourrages expérimentaux avait une interaction considérable ($P < 0.05$) avec le temps de collecte de données. Une grande quantité de fourrage était consommée. Toutefois, la moindre consommation de protéine pourrait limiter la croissance des agneaux.

Introduction

Fonio (*Digitaria exillis)* production as food for human consumption had received little attention in Ghana until recetly. In Mali, its price is three times the price of millet and twice the price of rice or millet flour (Spore, 1995). The nutritive value of fonio is speculated to be very good, but this information must be supported with scientific findings. The grain contains no lipids unlike some other cereals (Spore, 1995), and this fact confers on it certain advantages; however, its protein content is not readily available in the literature.

The ability to thrive in dry climatic conditions makes the fonio crop suitable for cultivation in areas where rainfall is unreliable and the soil is poor (Spore, 1995).

By-products of fonio crop such as the straw and the hulls may be fed to farm animals. There

is, therefore, the need to evaluate its suitability as feed for livestock.

Rediscovery of fonio in Ghana and its promotion by some Non-Governmental Organizations and other agencies have led to a series of studies such as the grain yield of the various cultivars, the by-products as feed for animals and the construction of a machine for processing the grain. The use of fonio decorticating machine has implications for increases in acreage cultivated, and large quantities of fonio straw generated for livestock. Some of the works done have been on the seed, herbage and other by-product yields of the different fonio cultivars at different stages of growth. There appears to be no documentation on the feeding of fonio herbage to livestock. The study examined the preference of urea-treated and untreated fonio straw compared with those of rice straw as feed for sheep.

Materials and methods

Climate of the study area

The study was conducted at the Animal Research Institute, Nyankpala, in the Northern Region of Ghana. It is located between latitude 9^0 25' and 41' N, and longitude 0^0 58' and 24' W, and has an altitude of 183 m above sea level. The vegetation is the moist Guinea savanna, and the annual rainfall is between 800 and 1500 mm. The daily temperature and humidity are 25-45 ^{0}C and 12 to 72 per cent, respectively.

Experimental animals

Sixteen Djallonke lambs were used in the experiment. Eight of them were grouped in one apartment of a sheep house and the remaining eight were also put in an adjoining apartment separated by a 1-m high wall. Selection of the group was such that there were three female and five male lambs in each house. Apart from this restriction, the animals were randomply allocated to the apartments. The mean weight (± s.d.) of the lambs in the first apartment was 11.9 kg (± 1.60 kg) while lambs in the second apartment weighed 10.9 kg ± 0.73 kg) on the average. The ages ranged from approximately 6 to 12 months for the first group and 5 to 9 months for the second group of lambs.

Housing

The animals were confined in a cement block house roofed with aluminium sheets. The floor area was 11.7 × 4.2 m^2 and the height was 2.0 m. The house was partitioned into two apartments. There were ventilation holes in the walls for free flow of air.

Urea treatment of straw

The inside of the two pits, measuring 2.40 m × 1.05 m × 0.45 m for one, and 1.65 m × 0.75 m × 0.15 m for the 2nd, were lined with polyethylene sheets. Enough free end of the polyethylene sheet was left to be used for covering the top of the straw. A layer of 50 kg rice straw was put into one pit and 50 kg of fonio straw was placed in the second pit. About 2 kg (4% w/w of straw) of fertilizer grade urea was dissolved in 25 l (50% w/w of straw) of water and sprinkled evenly on the straw in each pit (Alhassan & Aliyu, 1991). The layer of straw was then compressed and covered with the free end of the polyethylene sheets to keep it air-tight for 7 days after which it became ready for feeding.

Chemical analysis

Samples of the experimental feedstuffs were analyzed for dry matter, ash, crude protein, phosphorus, potassium, calcium, magnesium, copper, zinc and iron at the Savanna Agricultural Research Institute Chemical Laboratory. Crude protein was determined by the Kjeldah method and the minerals were determined by atomic absorption spectrophotometry.

Feeding

Prior to the study, the lambs were on free rtange with a little supplementation of untreated rice straw, whole cottonseed and *Cajanus cajan* leaves and pods. Feeds consumed at range included *Stylosanthes* sp., *Digitaria horizontalis,*

Pennisetum purpureum and *Brachiaria* sp. There was plenty of maize husk and stover that the animals consumed at leisure. The lambs had 10 days adaptation period as recommended by Topps (1993) during which they were confined and given all the experimental feeds together *ad libitum*.

Experimental procedure

The adopted method is typical of that used for a preference study (Topps, 1993; Karbo, Barnes & Rudat, 1996). Four feed troughs were constructed and two were placed in each apartment. The feed troughs were compartmentalized into eight sections. Each compartment had a volume of $30 \times 30 \times 30$ cm^3.

Four feed types were compared. They were untreated fonio straw, ureatreated fonio straw, untreated rice straw and urea-treated rice straw. The fonio straw was collected from the Savanna Agricultural Research Institute (SARI), Nyankpala experimental plots and from farmers' fields at Chereponi in the Saboba-Chereponi District of the Northern Region. It was a blend of the different cultivars. Bales of chopped rice straw were bought from the Animal Breeding Station at Pong-Tamale in the Northern Region, and used for the trial.

Approximately 500 g of the experimatal feed was placed in each compartment of the feed trough. Each experimental feed was duplicated (two replicates) in a feed trough. Hence, there were two lots of untreated fonio straw, two lots of treated fonio straw, two lots of untreated rice straw and two lots of treated rice straw in each feed trough. The experimental feeds were randomly put into the feed trough compartments before giving feeds to animals at 9 a.m. each day for 3 consecutive days. Therefore, 8 kg of feed was given to each group of eight growing lambs in a day. The amount of feed remaining in each compartment was noted after 1 h and 3 h on the 1st day, but 1 h, 3 h and 24 h on the next 2 days. The 24 h obeservation was included for more accurate detection of differences in the consumptions of the experimental feeds. Additional source of minerals was provided in the form of mineral blocks that were eaten by the lambs at free choice.

Statistical analysis

The General Linear Model procedure of Statistical Analytical System (SAS) was used (Hicks, 1993) to analyze the data, which were input in a computer SAS version 1998 programme. The unit of observation was the amount (g) of feed consumed. There were 256 observations altogether. Differences due to the following sources of variation were analyzed:

1. Four experimental feeds
2. Three times of data collection, namely 1h, 3 h and 24 h
3. Three days of experiment
4. Four feed troughs
5. Two apartments
6. Two replications of feed per feed trough.

The data was also analyzed for significant interactions between factors. Factors that were pooled to the error term and the data was re-analyzed. Differences that were significant were ranked with the Student-Newman-Keuls range test. The coefficient of preference (COP) was also calculated for each feed with the formula:

COP = amount consumed of the particular feed after 24 h/the average amount of all the feeds consumed after 24 h.

Results

The chemical composition of the experimental feeds is presented in Table 1. The crude protein (CP) content of untreated fonio straw was similar to that of untreated rice straw. Urea treatment at least doubled the CP contents of the untreated straws.

Significantly higher amounts of feed were consumed from a feed trough compartment with increasing time of data collection (Table 2). There were 16 lambs and 32 feed trough compartments, hence, the actual feed intakes by each lamb were 231.8 g, 396.4 g and 531.2 g at 1h, 3 h and 24h, respectively, which was twice the amount consumed in each feed trough compartment.

(Table 2).

The daily amounts of experimental feeds consumed by the 16 lambs were approximately 3.3 kg (3.2 kg DM) of untreated fonio straw, 0.5 kg (0.4 kg DM) of urea-treated fonio straw, 4.0 kg (3.7 kg DM) of untreated rice straw and 0.7 kg (0.7 kg DM) of urea-treated rice straw. These amount to 8.5 kg (8.0 kg DM) of the 16 kg (14.8 kg DM) of feed offered to the animals daily. Daily feed dry matter intake in terms of live weight was 4.4 per cent or 80.8 g DM/kg$W^{0.75}$ in terms of metabolic weight of lamb.

Daily protein intake was about 32.8 g/lamb or 65 g/kg DM of diet intake. The amounts of Ca and P consumed in the feeds were 1.5 and 0.6 g/lamb/day, respectively. The Zn content of the fonio straw appeared to be higher than that of the rice straw. Iron content was high while Cu was low for all straws.

Untreated rice straw was the most consumed feed followed by untreated fonio straw and then the urea-treated straws (Table 3). Consumption of untreated rice straw was significantly higher ($P < 0.05$) than each of the other experimental feeds at the time of data collection. Virtually all (0.99 decimal proportion) the untreated rice straw given to the lambs was eaten before the 24 h data collection. Untreated fonio straw was also eaten to a high extent (0.83 decimal proportion). Consumption of untreated fonio straw was significantly higher ($P < 0.05$) than the urea-treated straws at the 3 h andv 24 h readings. Even though intake of untreated fonio straw was higher at the 1 h reading when compared to the urea-treated straws only the difference between urea-treated rice straw and untreated fonio straw was statistically significant ($P < 0.05$). Intake of urea-treated rice straw was significantly lower ($P < 0.05$) than that of urea-treated fonio straw at the 1 h

TABLE 1
Chemical composition of the experimental feeds

Parameter	*Experimental feeds*			
	Untreated fonio straw	*Urea-treated fonio straw*	*Untreated rice straw*	*Urea-treated rice straw*
Dry matter (g/kg ADW)	950	870	950	940
Organic matter (g/kg DM)	930	780	820	840
Crude protein (g/kg DM)	50	110	60	140
Phosphorus (g/kg DM)	0.71	2.17	1.42	2.09
Potassium (g/kg DM)	15.45	18.29	22.87	20.71
Calcium (g/kg DM)	2.87	2.61	3.13	4.19
Magnesium (g/kg DM)	4.16	3.90	2.41	2.94
Copper (g/kg DM)	4.19	4.00	4.00	4.00
Zinc (g/kg DM)	23.15	24.20	17.18	11.58
Iron (g/kg DM)	1903	2200	3107	2370

TABLE 2
The average Amount (g) of feed consumed from a feed trough compartment at the various times of measurement

1 h	*3 h*	*24 h*
115.9^{c}	198.2^{b}	265.6^{a}
n = 96	n = 96	n = 64

Values with different superscript letters are significantly different at $P < 0.05$; mean square error = 7949.66; error degrees of freedom = 238; n = number of observations in each treatment total.

TABLE 3
Comparision of consumption (g of feed) of experimental feeds for the 1h, 3h and 24h feed intake data

Time	*Untreated fonio straw*	*Urea-treated fonio straw*	*Untreated rice straw*	*Urea-treated fonio straw*	*MSE; error df; n*
1 h	92.7[b]	61.5[b]	293.8[a]	15.6[c]	4960.483; 86; 24
3 h	242.7[b]	76.0[c]	406.3[a]	67.7[c]	10,510.9; 86; 24
24 h	417.2[b]	60.9[c]	495.3[a]	89.1[c]	9042.614; 55; 16
C.O.P.	1.57	0.23	1.86	0.34	

Values in the same row with different superscript letters are significantly different at $P < 0.05$;
MSE = mean square error, df = error degrees of freedom;
n = number of observations in each treatment total;
c. o. p. = coefficient of preference

reading but not at the 3 h and 24 h readings. Recorded intake of the urea-treated rice straw at 24 h was numerically higher than the corresponding value for the urea-treated fonio straw (Table 3). Only about 0.12 and 0.18 decimal proportions of the offered treated fonio straw and treated rice straw, respectively, were consumed in a day. Apparent anomaly was observed in the values for treated fonio straws in Table 3 as the 1h and 3 h values were higher than the 24 h value. The 1 h and 3 h values were the average for the 3 experimental days while the 24 h value was the average for the 2nd and 3rd experimental days, as 24 h measurement was not taken on the 1st experimental day. On the 1st day of experiment, 118.8 and 140.6 g of urea-treated fonio straw were consumed by 1h and 3 h, respectively. The intake values for urea-treated fonio straw on the 1st experimental day were higher than the average for the 3 days (Table 3).

Intake experimental feeds interacted significantly ($P < 0.05$) with time of data collection. This is seen as the change in the ranking of untreated fonio straw, urea-treated fonio straw and urea-treated rice straw at the different times of data collection (Table 3).

The coefficients of preference values were 1.86 for untreated rice straw, 1.57 for untreated fonio straw, 0.34 for urea-treated rice straw and 0.23 for urea-treated fonio straw (Table 3).

The amounts of feed consumed by lambs in apartment one did not differ significantly from the amounts consumed in apartment two. The mean 1 h feed consumption was highest on day one followed by day two and then day three, with the difference between day one and day three being statistically significant ($P < 0.05$). For the other times, the amounts of feeds consumed did not differ between days. Also the feed troughs that were used and the replications that were made did not consititute significant sources of variation in the data analyzed.

Discussion

The 10 days adaptation period probably was enough to help the lambs to become consistent in the order of prederence of the experimental feeds on the 3 days of experiment. However, group behaviour of animals might have influenced the experimental animals to aggregate in one area of

the feed troughs thereby consuming high amounts of experimental feeds present in the area. The absence of 24 h values in the 1st day's data has caused the 24 h value for urea-treated fonio straw to be lower than the 1h and 3 h values (Table 3). In a preference study, animals can be observed for up to 3 h or 24 h for preference (Avornyo, Karbo & Addo-Kwafo 2001; Karbo, Barne & Rudat, 1996; Topps, 1993). The switch from 1 h and 3h observations to 1 h, 3 h and 24 h was made to increase the level of accuracy in the determination of animal feed preference. On the 1st day, higher intakes of urea-treated fonio straw were recorded than on the 2nd and 3rd days. This caused the mean values of the 3 days for urea-treated fonio straw to be higher than the mean of the 2nd and 3rd day values.

Urea treatment of the straws increased the nitrogen content but reduced intake. The untreated straws were preferred to the treated straws. Virtually all the daily offer of the untreated rice straw was eaten. Familiarity with untreated rice straw may have been largely responsible for the preference given to it by the lambs. The instinct of animals to select feed that is palatable confirms earlier studies (Fianu, 1992; Karbo, Barnes & Rudat, 1996; Avornyo, Karbo & Addo-Kwafo, 2001). It is also a defence mechanism against ingestion of poisonous and other harmful matter. Animals from northern Nigeria when taken to southern Nigeria had preference for *Heteropogon* or *Sporobolus* but not *Panicum maximum,* which is the preferred feed for the animals native of southern Nigeria (Fianu, 1992). High consumption of untreated rice straw is a manifestation of the potential of untreated rice straw to be a basal diet for sheep in Ghana. Untreated rice straw should be introduced to sheep from infancy as is done with the sheep at the Animal Research Institute so that it may become a familiar feed for them.

Untreated fonio straw was also eaten to a considerable extent. However, its consumption appeared to be slow at the initial stages. Consumption of untreated fonio straw increased after 1 h of providing the feed. The animals appeared to give more attention to untreated fonio straw when less untreated rice straw was available. Fonio straw was a new feed that was being consciously introduced to the lambs. Presumably, because it was relatively unfamiliar, and this could affect its palatability (Fianu, 1992). Moreover, farmers from whom the fonio straw was obtained mentioned that the straw was not particularly relished by ruminants particularly if it had been beaten by rain. The ratoons after the grain has been harvested from the farm were the preferred fonio by-product by ruminants. Fungal growth due to dampness and odour, in addition to physical characteristica of the straw, may reduce its palatability. Intake of fonio straw may be improved if rain does nor beat it and also the soil does not contaminate it. Fonio may be harvested at pre-flowering stage and processed into hay to improve intake by sheep. Training of ruminants to develop appetite for fonio by-products is also crucial.

The urea-treated straws were damp and probably had the smell of ammonia. This may have contributed to the lambs eating them sparingly. Airing of urea-treated straw would reduce the dampness and the smell, and probably increase intake. Kearl (1982) mentioned that if urea constituted about 1 per cent of ration, dry matter intake (DMI) increased. However, if it constituted 2 per cent of ration DMI decreased. Animals will have to be traind from the period they begin to eat forage to consume urea-treated straws since their higher N content may be beneficial to the growth of lambs. Until consumption of urea-treated straw is appreciable it may not be advisable to include it as a basic component of a diet for ruminants otherwise they may suffer from starvation. Intake of urea-treated straw did not increase with time to the extent of the untreated fonio straw. However, there was a gradual increase in its consumption. Urea-treated straw was, therefore, not totally rejected. Their higher contents of N may have influenced the lambs to take occasional bites to supplement the

N obtained from the untreated straws. This may be a display of the instinct of the animal to meet its nutritional requirements for energy and protein. Some authors decribe the phenomenon as a nutritional wisdom of animals (Fianu, 1992).

Voluntary DMI is influenced by the kind of diet that is offered and the physiological stage of the animal. Daily DMI was high; 4.4 per cent of liveweight or 80.8 g DM/kg $W^{0.75}$. Ranjhan (1997) suggested DMI values between 3.9 and 4.5 percent of live weight for growing lambs and Kearl (1982) documented values ranging from 3.3 to 3.9 per cent for a 10-kg lamb. Studies with indigenous Indian and African lambs gave average intake values of 73.1 g DM/kg $W^{0.75}$ (Ranjhan, 1997) and 64.4 g DM/kg $W^{0.75}$ (Kearl, 1982), respectively. Livestock normally do not eat large amounts of sole roughage. Kearl (1982) found the DMI of straw by young ewe lambs to be 39.6 g/d/kg$W^{0.75}$. Dry matter intake of good quality forages could be more than that of poorer quality feed by about 50 per cent (Kearl, 1982). In this study, however, the lambs appeated to find untreated rice straw, in particular, to be very palatable.

The metabolizable energy (ME) content of the feeds was not determined in this study. However, rice straw has an ME value of 8.4 MJ/kg DM (Ranjhan, 1977). This value was adopted for the experimental feeds. The ME intake was, therefore, estimated to be 4.2 MJ/d. For a 10-kg lamb growing at100 g/d, the daily metabolizable energy intake (MEI) requirements were given as 4.2 MJ (Kearl, 1982) and 3.5 MJ (Ranjhan, 1997). Energy intake by the lambs was, therefore, high.

The daily protein intake was bout 32.8 g/lamb or 65 g/kg DM of diet intake. Even though the protein intake and per cent of DMC was low, the high amount of dry matter consumed has resulted in a protein intake value within the range of 26 to 49 g/d stated to be the requirement for a 10-kg lamb gaining at zero to 150 g/d, respectively (Kearl, 1982). The 32.8 g/d protein intake by the experimental lambs with an average weight of 11.4 kg is close to a value of 30 g/d given as the requirement for a 10-kg lamb gaining weight at 25 g/d. For a 10-kg lamb growing at 100 g/d, Ranjhan (1997) gave a higher protein requirement of 60.1 g/d. From the analysis, protein would be the factor limiting the growth of the lambs if they are raised on the experimental feeds, and would be expected to grow at 25 g/d or less. Supplementation of the feed with high protein feed may be needed for a better energy equal : protein balance for more efficient utilization of the feed for production.

The amounts of Ca and P consumed in the feed were lower than the recommended daily allowances for a 10-kg lamb, which were 2.2-2.5 g of Ca and 1.8-2.2 g of P (Kearl, 1982; Ranjhan, 1997). However, with the supply of the additional source of minerals, it was not likely that the diet of the lambs was deficient in Ca and P. Karbo, Barnes & Rudat (1996) and Karbo, Bruce & Alebikiya (1999) have observed that sheep consumed between 4 and 14 g/head/day of mineral lick that gave a supply of between 0.74 and 2.3 g of Ca and between 0.41 and 1.3 g/head/day of P.

Conclusion

Untreated rice straw was the most preferred feed followed by untreated fonio straw and the urea-treated straws, in that order. Untreated fonio straw may be used as a basic diet although possibly at a smaller amount than untreated rice straw. Animals may have to be trained to find urea-treated rice and fonio straws to be palatable before they are given in large amounts as a basic diet. Large amounts of feed were consumed; however, the low protein intake would limit the growth of the experimental lambs.

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References

ALHASSAN, W. S. & ALIYU, S. U. (1991) Studies on urea-treatment of maize straw: treatment method and potential for dry season feeding of cattle in Northern Nigeria. *Anim feed Sci Technol.* **33**, 289-295.

AVORNYIO, F. K., KARBO, N. & ADDO-KWAFO, A. (2001) An assessment of the preference of *Mucuna pruriens* var. *cochinchinesis, Mucuna pruriens* var. *utilis* and *Gliricidia sepium* by sheep at Nyankpala in the moist Guinea savanna agroecology. Accepted for publication in the *Bull. Anim. hth. Prod. Afr.*

FIANU, F. K. (1992) Preliminary observations on the feeding activities of West African Shorthorn cattle on simulated Grewia shrubs in natural grassland on the Accra Plains: II. Nutrient intake. In *Proc. of the 5th Annual Conference of the Ghana Society of Animal Production.* (ed. I. Adam, S. O. Apori, S. K. S. Awuma and I. Annor-Frimpong), pp. 29-39. University of Cape Coast, Cape Coast, Ghana. 19-22 August 1992.

HICKS, C. R. (1993) *Fundamental concepts in the design of experiments*. 4th edn. New York: Oxford University Press. 509 pp.

KARBO, N., BARNES, P. & RUDAT, H. (1996) Evaluation of browse forage preferability by sheep and goats in the northern Guinea savanna zone of Ghana. *Bull. Anim. hth. Prod. Afr.* **44**, 225-230.

KARBO, N., BRUCE, & ALEBIKIYA, M. (1999) Scientists and farmers evaluate a local salt lick block fed to indigenous rural sheep in Northern Region. In *The savanna farmer.* Newsletter of the Northern Ghana Leisa Working Group Vol. No. 1. October 1999 (ed. M. Alebikiya, A. B. Dery, D. Millar and K. van Veluw). The Northern Ghana LEISA Working Group (NGLWG) and The Association of Church Development Projects (ACDEP) in Northern ghana. pp. 22-23.

KEARL, L. C. (1982) *Nutrient requirements of ruminants in developing countries.* International Feedstuff Institute, Utah Agricultural Experiment Station, Utah State University, Lagan, Utah, 84322, USA. pp. 45-58.

RANJHAN, S. K. (1997). *Animal nutrition in the tropics.* 4th revised, edn. Vikas Publishing House PVT Ltd. pp. 557.

SPORE (1995) A small cereal with big promise. *Bi-monthly Bulletin. of the Technical Centre for Agricultural and Rural Cooperation (CTA).* No. 56 April, 1995. ACP-EEC Lome Convention CTA Post bus 380, 6700 AJ Wageningen, The Netherlands. p. 5.

TOPPS, J. H. (1993) Assessment of forage legumes as protein-rice supplement in ruminant production systems in Zimbabwe. In *Sustainable feed Production and Utilization for Smallholder Livestock Enterprises in Sub-Saharan Africa* Proc. of the Second African Feed Resources Network (AFRNET) Workshop held in Harare, Zimbabwe, 6-10 December 1993. (ed. J. Ndikumana and P. de Leeuw) pp. 69-72. AFRNET.

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