Comparison of the fermentation quality and nutritive value of silage made from leucaena (*Leucaena leucocephala* (Lam.) De Wit.) and two tropical grasses

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ABSTRACT

About 10-month-old leucaena (*Leucaena leucocephala* (Lam.) De Wit.) grown in Japan and 52-day-old regrowth of guinea grass (*Panicum maximum* var. *maximum* cv. Gatton) and sorghum (*Sorghum bicolor* Moench cv. FS40IR), were chopped up to 3-5 cm lengths and ensiled in laboratory silos of 1.4-1.5 kg capacity. Samples were taken at 0, 1, 3, 5, 7 and 30 days of ensiling for laboratory determination of total nitrogen (T-N), volatile basic nitrogen expressed as per cent of T-N, *p*H, lactic acid, acetic acid, butyric acid, neutral detergent fibre (NDF), acid detergent fibre (ADF), cellulose, acid detergent lignin (ADL) and *in vitro* digestibility (IVD). There were significant differences ($P<0.05$) in the T-N and cell-wall components but not in IVD ($P>0.05$) among species. The final *p*H of the silages were 4.00, 3.94 and 5.27 for guinea grass, sorghum and leucaena respectively. Lactic acid was the dominant acid in all the silages. Significant differences ($P<0.05$) in lactic acid content were observed among the silages. No significant difference ($P>0.05$) was observed in acetic acid contents of the grass silages but these were significantly higher than that of the leucaena silage. Butyric acid was observed only in the grass silage. IVD of the silages after 30 days were 488.5, 519.6 and 515.5 g in kg DM of guinea grass, sorghum and leucaena respectively.

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RÉSUMÉ

FLEISCHER, J. E., KAWAMOTO, Y., SHIMOJO, M., GOTO, I & MASUDA, Y. : *Comparaison de la qualité de la fermentation et de la valeur nutritive entre le fourrage ensilé fait de leucaena (*Leucaena leucocephala *(Lam.) de Wit) et de deux autres herbes tropicales.* Leucaena (*Leucaena leucocephala* (Lam.) de Wit) à l' âge d' environ 10 mois cultivé au Japan et l'herbe guinéenne répoussée (*Panicum maximum* var. maximum cv. Gatton) à l' âge de 52 jours et sorgho (*Sorghum bicolor* Moench cv. FS40IR) étaient tranchés à 3-5 cm de longeurs et ensilés dans les silos laboratoires d'une capacité de 1.4-.5 kg. Les échantillons étaient prélevés à 0, 1, 3, 5, 7 et 30 jours d'ensilage pour la détermination laboratoire d'azote total (T-N), l' azote basique volatil exprimé en pourcentage de T-N, *p*H, acide lactique, acide acétique, acide butyrique, fibre détersive neutre (NDF), fibre détersive acide (ADF) cellulose, lignine d' acide détersive (ADL) et *in-vitro* capacité digestive (IVD). Il y avaient des différences significatives ($P<0.05$) dans le T-N et les constituants de mur cellulosique mais dans IVD ($P>0.05$) parmi les espéces. Les *p*H finals des fourrages ansilés étaient 4.00, 3,94 et 5.27 respectivement pour herbe guinéenne, sorgho et leucaena. Acide lactique était l' acide dominant dans tous les fourrages ensilés. Les différences significatives ($P<0.05$) en contenu d' acide lactique étaient observées parmi les fourrages ensilés. Aucune différence significative ($P>0.05$) n' était observée dans les contenus d'acide acétique des herbes ensilées mais celles-si étaient considérablement plus fortes que celui de leucaena ensilé. Acide butyrique était observé uniquement dans l' herbe ensilés. L' IVD des fourrages ensilés aprés 30 jours étaient 488.5, 519.6 et 515.5 g en kg DM respectivement de l'herbe guinéenne, sorgho et leucaena.

Introduction

Ruminant livestock production in many tropical countries is based on the natural grassland the productivity of which is seasonal (Fleischer, 1989). Thus, it is important that excess feed produced in favourable times should be preserved with a minimum loss of dry matter and nutrients in order to have a product of acceptable nutritive value for later use. This could be achieved by ensiling with a rapid reduction in *p*H to a value of 4.0-4.5 accompanied by a minimum production of volatile basic nitrogen (McDonald, 1981). The fermentation quality and the nutritive value of silage depends primarily on the parent material. The forages with high water soluble carbohydrate are more easily ensiled (Wilkinson *et al.*, 1983; Kaiser, 1984).

Tropical forages generally have low levels of water soluble carbohydrate (Catchpoole & Henzel, 1971). Thus, ensiling tropical forages has always been difficult. Even more difficult to ensile are tropical forage legumes, because apart from the low water soluble carbohydrate they also have a high buffering capacity (Kaiser, 1984). These notwithstanding, the fermentation characteristics of tropical forage silage should be understood before the ensiling process can be manipulated to achieve a desirable product. Loss of dry matter, mainly readily fermentable components, occur during the ensiling period. This may result in some changes in nutritive value.

Thus, the objective of this experiment was to study the fermentation characteristics of leucaena and two tropical grasses as well as the change in nutritive value during the ensiling period.

Materials and methods

Location

The plant materials used were obtained from the University of the Ryukyus in Okinawa, Japan, while the laboratory determinations were carried out at the Laboratory of Feed Science and Animal Behaviour, Kyushu University, Fukuoka, Japan.

Plant material

Leucaena (*Leucaena leucocephala* (Lam.) De Wit.) was collected from a naturalized field in Japan. The field had been frequently harvested. The leucaena was about 10 months old and about 3 m tall.

Guinea grass (*Panicum maximum* var. *maximum* cv. Gatton) and sorghum (*Sorghum bicolor* Moench cv. FS40IR) both 52 days regrowths were used. The grasses were seeded on 17 Apr 92 and were first cut on 12 Jun 92. At the time of seeding, a basal fertilizer of N-P_2O_5-K_2O at the rate of 150-100-100 kg/ha was applied. An additional nitrogen fertilizer at the rate of 150 kg/ha was applied immediately after the first cut. The grasses were cut for this experiment on 3 Aug 92.

Silage making

After harvesting, the plant materials were chopped to 3-5 cm lengths and stuffed into 2-litre capacity laboratory silos and sealed. Each silo contained 1.4-1.5 kg of sample. There were three silos per treatment. The silos were opened after 1, 3, 5, 7 and 30 days of ensiling.

Chemical analyses

At the time of opening the silos, the top and bottom 2-3 cm silage fractions respectively were discarded and samples were taken from the middle portion of the rest. These samples were further chopped up into 2-3 cm lengths and used for laboratory determinations. 100 g of the samples was placed in one-litre conical flask and distilled water was added to the one litre mark. This was then kept in a refrigerator at 4-5 °C for 12 h with occasional shaking. The extract was filtered through No.41 Whatman filter paper. The *p*H of the filtrate was immediately determined with a *p*H meter. The filtrate was used for the determination of organic acids and volatile basic nitrogen (VBN) (Morimoto, 1971).

Fresh samples were used for total nitrogen (T-N) determination (AOAC, 1990). Cell-wall components and *in vitro* digestibility matter (IVD) were determined with the oven-dried samples according to the methods of Goering & Van Soest (1970) and Goto & Minson (1977) respectively.

Results

The chemical composition and *in vitro* digestibility (IVD) of the forage material before ensiling are shown in Table 1. Significant differences

TABLE 1

Chemical Composition and in vitro *Digestibility of Forage Material before Ensiling (g kg^{1} DM)*

Forage material	*Dry matter*	*Nitrogen*	*NDF*	*ADF*	*Cellulose*	*ADL*	*IVD*
Guinea grass	266.4a	14.2a	728.4a	461.1a	361.6a	78.2a	576.7a
Sorghum	152.0b	15.7b	713.2a	417.3b	345.1b	58.9b	559.6a
Leucaena	378.5c	39.2c	597.3b	357.6c	235.9c	123.2c	567.5a
SE	113.34	0.01	6.13	1.20	68.31	32.99	7.96

($P<0.01$) were observed in the nitrogen and acid detergent fibre (ADF) contents of the three forages. Neutral detergent fibre (NDF) of guinea grass and sorghum were similar ($P>0.05$) but higher ($P<0.05$) than that of leucaena. No significant differences were found among forages of cellulose and acid detergent lignin (ADL). IVD of the forage material was, however, similar ($P>0.05$) to all three. Guinea grass had the lowest total nitrogen (T-N) but the highest fibre content. Leucaena, on the contrary, had the highest T-N and ADL contents but the lowest contents of NDF and ADF.

The *p*H and various organic acid contents of the silages are shown in Fig. 1. The *p*H of the silage significantly decreased ($P<0.01$) in all three silages with time. There were significant differences ($P<0.01$) among the three silages initially; however, no difference ($P>0.05$) was observed between guinea grass and sorghum silage which had *p*H 4.00 and 3.94 respectively after 30 days. Silage from the two grasses maintained a significantly ($P<0.05$) lower *p*H than that of the leucaena silage which had *p*H 5.40.

There was a significant increase ($P<0.01$) in the contents of various organic acids with time for all three silages. No butyric acid was observed in the leucaena silage. However, a small amount was produced in the grass silages and the level observed in guinea grass silage was higher than that of the sorghum silage (3.8 v. 2.8 g kg^{-1}). No significant difference ($P>0.05$) was observed in the acetic acid content between sorghum and guinea grass silages. However, the levels were higher ($P<0.05$) than that of leucaena silage. Acetic acid development was, however, slower than lactic acid in all the silages. Lactic acid production in sorghum silage was observed to be significantly higher ($P<0.05$) than in both guinea grass and leucaena silage.

Total nitrogen and VBN contents of the silages are shown in Fig. 2. Sorghum silage had slightly but not significantly

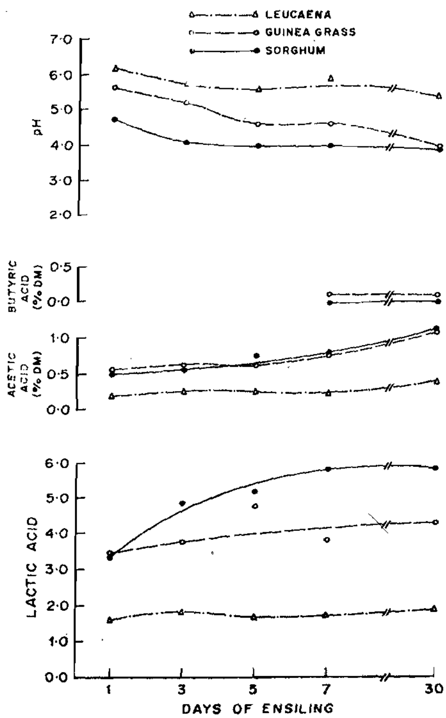

Fig. 1. Changes in *p*H and organic acids of leucaena, guinea grass, and two sorghum silages with time

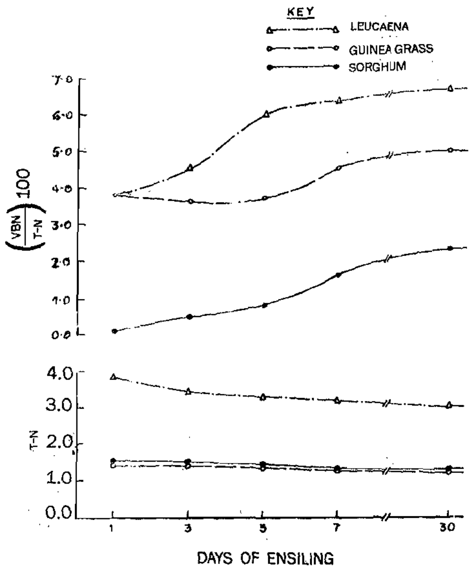

Fig. 2. Changes in total nitrogen and volatile nitrogen of leucaena, guinea grass and sorghum silages with time

(P>0.05) higher T-N content compared to the guinea grass silage and both were significantly (P<0.05) lower than that of leucaena silage. There was a decrease in T-N content in all the silages.

There was no significant difference (P>0.05) in VBN content of guinea grass and leucaena silages and both were significantly (P<0.05) higher than that of sorghum silage initially. However, with advancing ensiling period, VBN content of all silages significantly increased (P<0.01). The rate of increase in early stage of ensiling was higher for leucaena.

Table 2 shows the changes in dry matter and cell-wall components of the silages with time. No significant changes in dry matter content (P>0.05) were observed in the silages with time, except for leucaena silage showing a reduction between the first and third days.

No significant change (P>0.05) in NDF content was observed with time except for the leucaena silage showing changes between the first and third days and again between the fifth and seventh days. Sorghum silage had NDF content similar to that of guinea grass silage and these were higher (P<0.05) than that of leucaena silage. Similarly, there was no significant change (P>0.05) in ADF content with time. ADF content of guinea grass silage was similar to that of sorghum silage which also was higher but non-significant (P>0.05) compared to that of leucaena silage. The differences between the ADF contents of guinea grass and leucaena silage were significant (P<0.01). There was a small increase (P<0.05) in the cellulose content of sorghum and guinea grass silage but not with leucaena silage. In general, cellulose content of guinea grass and sorghum silages were similar but higher than that of leucaena silage. No significant change in ADL was found for all silages with time.

Table 3 shows the IVD of the silages. There was generally a significant decrease (P<0.05) in IVD in all silages with time. The decrease in IVD was more rapid in guinea grass silage and slowest in leucaena silage. There were also significant differences (P>0.05) observed between guinea grass silage and the others on the 30th day.

Discussion

The variations observed in the chemical constituents of the grasses and legumes are consistent with published results (Norton, 1982). However, the difference between the guinea grass and sorghum indicates that though the two were grown over the same period they were at different physiologically developmental states at the time of harvest. These notwithstanding, all the different forage species had similar *in vitro* digestibility.

The organic acid production in the grass silages was relatively fast such that by the 7th day of ensiling a stable pH was already produced. On the contrary, development of lactic acid in the leucaena silage was very little such that even by the 13th day of ensiling, pH was still high. Indeed, Alli, Baker & Garcia (1983) reported that the fermentability rate of leucaena was slow. The difference in the fermentability rate of the grass and legume when ensiled may be due to the higher content of water

TABLE 2

Dry Matter Content and Cell-wall Components of Silages as influenced by Ensiling Period

Characteristic	*Days of ensiling*	*Guinea grass*	*Sorghum*	*Leucaena*
Dry matter	1	267.6	148.2	374.9
	3	268.2	150.8	354.1
	5	262.9	150.9	358.3
	7	265.7	145.1	358.9
	30	267.4	155.1	358.3
			SE=12.10	
Neutral detergent fibre	1	754.3	713.2	600.0
	3	756.5	721.3	571.2
	5	753.1	717.7	574.7
	7	753.2	723.1	588.4
	30	762.3	726.8	582.7
			SE=46.98	
Acid detergent fibre	1	489.3	453.5	415.3
	3	488.9	455.6	391.9
	5	488.7	448.7	403.8
	7	481.2	462.2	395.0
	30	520.5	480.7	424.6
			SE=3.19	
Cellulose	1	393.9	385.6	240.4
	3	396.7	376.8	241.0
	5	393.9	383.1	251.1
	7	393.8	395.1	248.8
	30	411.2	396.2	244.9
			SE=1.87	
Acid detergent lignin	1	78.1	58.9	146.6
	3	79.6	55.0	141.2
	5	74.1	55.2	154.4
	7	79.6	52.2	147.9
	30	79.7	65.4	150.2
			SE=1.50	

soluble carbohydrates in the grass (Kaiser, 1984), aggravated by the very high buffering capacity of the legume (McDonald, 1981; Kaiser, 1984). Consequent upon these changes, the *p*H of the legume silage remained relatively high. Unlike most tropical forages which on ensiling have high *p*H (Miller, 1969; Catchpoole & Henzel, 1971), the grass silage in this experiment had a comparatively low *p*H and may be considered good even by temperate grass silage standards (Flynn, 1981).

Alli, Baker & Garcia (1983) observed a decrease in T-N content of leucaena silage even though in the same experiment no such observation was made of alfalfa silage. The reason for this observation is, perhaps, that there were losses of some VBN when the silo was opened and also during sample preparation.

Increase in VBN on ensiling is due primarily to proteolysis by plant enzymes (McDonald, 1981) and also by butyric acid bacteria (Kaiser, 1984). The VBN levels obtained for silages in the experiment reported here were relatively low compared to some of the published results even for leucaena (Catchpoole & Henzel, 1971; Kaiser, 1984) and hence may be considered very good silages (Flynn, 1981; Fujita, 1984; Thomas & Thomas, 1985).

Fermentation of water soluble carbohydrates and production of VBN during ensiling causes a relative increase in structural carbohydrate component, viz., NDF, ADF and cellulose, hence the observed increase in these chemical components

TABLE 3

In vitro *Digestibility of Silages as influenced by Ensiling Period*

Days of ensiling	*Forage type*		
	Guinea grass	*Sorghum* *SE = 1.866, n=5*	*Leucaena*
1	55.28a	55.96a	54.60a
3	54.90a	54.93a	54.84a
5	51.97b	52.13b	54.66a
7	51.94b	51.83b	53.91a
30	48.85c	51.96b	51.55b

on ensiling. Even though Kuntzel & Zimmer (1972) as quoted by Wilkins (1981) have indicated that structural carbohydrates may contribute to the fermentation quality of silage this was not observed in this experiment.

The decrease in IVD with time such as observed in the present experiment is very well documented (Brown & Rodcliffe, 1970; Dermarquilly & Jarrige, 1970), and it is due largely to some potentially digestible portion, protein and water soluble carbohydrates, which were fermented and the volatile characteristic of the resultant products. On the contrary, variation in the fermentability rate as well as degree of solubility of the residual structural carbohydrate component may explain the difference in IVD of the three silages with time.

Conclusion

The experiment discussed here has shown that when ensiled in a properly-sealed silo, guinea grass and sorghum ferment very fast reaching a stable *p*H value by the 7th day. On the contrary, leucaena silage ferments very slowly and hence the decrease in *p*H is not rapid.

T-N content decreased but VBN (expressed as g kg^{-1} of T-N) increased. IVD decreased with time in all silages and the decrease was faster in guinea grass silage than in leucaena silage.

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REFERENCES

Alli, I., Baker, B. E. & Garcia, G. (1983) The ensiling of chopped whole-plant leucaena. In *Proc. Vth Wld Conf. Anim. Prod.* Vol. **2**, pp. 621-622.

AOAC (1990) *Official methods of analysis* 15th ed. Washington, DC: AOAC.

Brown, D. C. & Rodcliffe, J. C. (1970) A new method of preparing ground silage for the determination of chemical composition and *in vitro* digestibility. In *Proc. 11th Int. Grassl. Congr., Suffers Paradise, Australia*, pp. 750-754.

Catchpoole, V. R. & Henzel, E. F. (1971) Silage and silage making from tropical herbage species. *Herb. Abstr.* **41**, 213-221.

Dermarquilly, C. & Jarrige, R. (1970) The effect of forage conservation on digestibility and voluntary intake. In *Proc. 11th int. Grassl. Congr., Suffers Paradise, Australia*, pp. 733-737.

Fleischer, J. E. (1989) Feed resource availability and the future of livestock in the ECOWAS. *W. Afr. econ. J.* **6**, 101-110.

Flynn, A. V. (1981) Factors affecting the feeding value of silages. In *Recent development in ruminant nutrition* (ed. W. Haresign and D.J.A. Cole), pp. 265-273. London: Butterworths.

Fujita, H. (1984) Recent problems of the nutritive value of grass silage. *Jap. J. Zootech. Sci.* **55**, 903-910.

Goering, H. K. & Van Soest, P. J. (1970) *Forage fibre analyses*, Agriculture Handbook (USDA), Jacket No. 379, pp. 1-20.

Goto, I. & Minson, D. J. (1977) Prediction of the dry matter digestibility of tropical grasses using a pepsin-cellulase assay. *Anim. Feed Sci. Technol.* **2**, 247-253.

Kaiser, A. G. (1984) The influence of silage fermentation on animal production. In *Silage in the 80's*. Proceedings of a National Workshop, Armidale, New South Wales, Australia, 8-9 August, 1984 (ed. T.J. Kempton, A.G. Kaiser and T.E. Trigg), pp. 106-136.

McDonald, P. (1981) *The Biochemistry of silage*. Chichester: John Wiley and Sons.

Miller, T. B. (1969) Forage conservation in the tropics. *J. Br. Grassl. Soc.* **24**, 158-162.

Morimoto, H. (1971) *"Dobutsu Eiyo Shiken Ho"*, Yokendo, pp. 319-323 (in Japanese).

Norton, B. W. (1982) Differences in species in forage quality. In *Nutritional limits to animal production from pastures* (ed. J.B. Hacker), pp 89-110. Farnham Royal, UK: Commonwealth Agricultural Bureaux.

Thomas, C. & Thomas, P. C. (1985) Factors affecting the nutritive value of grass silages. In *Recent development in ruminant nutrition* (ed. W. Haresign and D.J.A. Cole), pp. 274-307. London: Butterworths.

Wilkins, R. J. (1981) The nutritive value of silages. In *Recent development in ruminant nutrition* (ed. W. Haresign and D.J.A. Cole), pp. 268-282. London: Butterworths.