Ensiling characteristic and nutritive value of Napier grass (*Pennisetum purpureum* Schumach) combined with or without leucaena (*Leucaena leucocephala* (Lam.) De Wit.) as influenced by starch or formic acid addition

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SUMMARY

About 12-week-old napier grass *Pennisetum purpureum* Schumach) and 10-month-old Leucaena (*Leucaena leucocephala* (Lam.) de Wit.) both from a naturalized field and chopped to about 3.5 cm were used. The grass and legume were combined in a grass:legume ratio of 7:3. There were five treatments viz., napier grass (T_1), leucaena (T_2), napier grass-leucaena (T_3), napier grass-leucaena with starch added (50 g starch/kg fresh mixed forage) (T_4) and napier grass-leucaena with formic acid added (2.3 ml per kg fresh mixed forage) (T_5). Each of the treatment sample was stuffed into a two-litre laboratory silo (1.4-1.5 kg sample) and stored for 42 days. Samples were taken at the time of silo filling and after ensiling and analyzed for total nitrogen (T-N), volatile basic nitrogen (VBN) as per cent of total N, neutral detergent fibre (NDF), acid detergent fibre (ADF), cellulose, acid detergent lignin (ADL) and *in vitro* dry matter digestibility (IVDMD). Napier grass (T_1) had significantly lower (P<0.01) T-N but higher cell wall components except for ADL compared to T_2. The IVDMD of T_1 was significantly higher (P<0.05) than that of T_2. Combination of napier grass with leucaena increased the T-N but reduced the fibres. Treatments T_4 and T_5 significantly differed (P<0.05) in T-N, cell wall components and IVDMD from each other. Treatment T_2 had a significantly higher (P<0.05) *p*H than the others. Lactic acid was signficantly developed in T_4. Only T_3 had some butyric acid. Treatment T_4 had the lowest VBN. NDF in all silages slightly decreased while ADF, cellulose and ADL in some cases slightly increased. IVDMD slightly decreased or remained unchanged on ensiling.

RÉSUMÉ

FLEISCHER, J. E., KAWAMOTO, Y., SHIMOJO, M. GOTO, I. & MASUDA, Y : *Caratéristique d' ensilage et la valeur nutritive de l'herbe Napier (*Pennisetum purpureum *Schumach) combiné avec ou sans leucaena (*Leucaena leucocephala *(Lam.) de W'it) comme influencé par la fécule addition d' acide formique.* L'herbe Napier (*Pennisetum purpureum* Schumach) à l'âge d' environ 12 semaines et leucaena (*Leucaena leucocephala* (Lam.) de Wit) à l'âge de 10 mois, tous les deux d'un terrain naturalisé et tranché à environ 3.5 cm étaient utilisées. La herbe et la légumineuse étaient combinées dans une proportion herbe : légumineuse de 7:3. Il y avaient cinq traitements à savoir:herbe napier (T_1) leucaena (T_2) herbe napier-leucaena (T_3), herbe napier-leucaena avec fécule ajoutée [50 g fécule/kg de fourrage frais mélangé (T_4)] et herbe napier-leucaena avec acide formique ajouté [2.3 ml per kg de fourrage frais mélangé (T_5)]. Chaque échantillon de traitement était fourré dans un silo laboratoire de deux litres (1.4-1.5 kg) d' échantillon) et mis en réserve pour 42 jours. Les échantillons étaient prélevés au moment de remplissage de silo et après l'ensilage et analysés pour l' azote total (T-N), azote basique volatil (VBN) comme pourcentage de N total, fibre détersive neutre (NDF), fibre détersive acide (ADF), cellulose, acide détersif de lignin (ADL) et *in-vitro* capacité digestive de matiére sèche (IVDMD). Herbe napier (T_1) avait T-N considérablement plus faible (P<0.01) mais plus forte en constituants de mur cellulosique à l'exception de ADL comparé à T_2 L' IVDMD de T_1 était considérablement plus fort (P<0.05) que celui de T_2. La combinaison de l' herbe napier avec leucaena augmentait le T-N mais diminuait les fibres. Les traitements T_4 et T_5 différaient considérablement (P<0.05) en T-N, en constituants de mur cellelosique et en IVDMD de l'un l'autre. Le traitement T_2 avait *p*H considérablement plus élèvé que les autre. L'acide lactique était développée considérablement en T_4. Seul le T_3 avait quelque acide butyrique. Le traitement T_4 avait le plus faible VBN. Le NDF dans tous les ensilages diminuait légèrement tandis que ADF, la cellulose et ADL dans certains cas augmentait légèrement. L'IVDMD diminuait légèrement ou restait inchangé à l'ensilage.

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Introduction

Napier grass is one tropical grass which has a very high dry matter yield potential (Vicente-Chandler *et al.*, 1974), yet not easily amenable to grazing (Mannetje, 1982). Consequently, effective use is made of this grass by making it into silage. The nutritive value of the silage produced depends on the orginal material (Kaiser, 1984). Invariably, the napier grass used in silage making is low in protein content and dry matter digestibility but these can be improved by including some browse or tree leaves. Fleischer & Tackie (1994) combining leucaena and sorghum in the ratio of 3:7 raised the crude protein content and the *in vitro* digestibility from 6 per cent and 47 per cent of sorghum to 23 per cent and 60 per cent in DM respectively in the mixtures. The inclusion of legumes, however, may pose ensiling problems since legumes are characterized by low non-structural carbohydrates and high buffering capacity (McDonald, 1981).

The objective of this work was, therefore, to ascertain what improvement can be achieved combining napier grass with leucaena and how best such material can be ensiled.

Materials and methods

The plant materials used were napier grass (*Pennisetum purpureum* Schumach) and leucaena (*Leucaena leucocephala* (Lam.) de Wit.) both obtained from a naturalized field near the University of the Ryukyus in Okinawa, Japan, while the laboratory analyses were carried out at the Laboratory of Feed Science and Animal Behaviour, Kyushu University, Fukuoka, Japan. The napier grass was about 12 weeks regrowth after cutting while the leucaena was about 10 months old and had a leaf: stem ratio of about 1:1.

Both napier grass and leucaena were chopped to about 3-5 cm length. The napier grass was divided into four batches, three of which were combined with leucaena in a grass: legume ratio of 7:3. Thus, there were five treatments viz., napier grass (T_1), leucaena (T_2) napier grass + leucaena (T_3), napier grass + leucaena + starch (T_4), napier grass + leucaena + formic acid (T_5). The starch was added at the rate of 50 g starch/kg fresh forage (Kaiser, 1984) while the formic acid was added at the rate of 2.3 ml/kg fresh forage according to Wilkins (1981). Each of the treatment groups was then stuffed into a 2-litre laboratory silo and sealed. Each silo contained about 1.4 - 1.5 kg of sample. The silos were opened after 42 days of ensiling. There were two replicates of each treatment. Some samples were taken at the time of silo stuffing for analysis.

At the time of opening the silos, the top and bottom 2-3 cm silages respectively were discarded and samples taken from the mid-portion. These were further chopped with scissors up to 2-5 mm lengths and used for analysis. 100 g of the sample was placed in 1-litre conical flask and distilled water added to the 1-litre mark. This was kept in a refrigerator for at least 12 h with occasional shaking. The extract was filtered using a No.41 Whatman filter paper. The *p*H of the filt rate was immediately determined using 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* dry matter digestibility (IVDMD) were determined with oven-dried (at 60 °C) samples according to the methods of

Goering & Van Soest (1970) and Goto & Minson (1977) respectively.

Results

Chemical composition and *in vitro* dry matter digestibility of forages before ensiling are shown in Table 1. There were significant differences ($P<0.05$) in all the parameters assessed. The dry matter (DM), total nitrogen (T-N) and acid detergent lignin (ADL) contents of leucaena were significantly higher ($P<0.05$) than those of napier grass. On the contrary, neutral detergent fibre (NDF), acid detergent fibre (ADF) and cellulose contents and IVDMD of leucaena were significantly lower ($P<0.05$) than those of napier grass. Combining leucaena with napier grass thus significantly increased ($P<0.05$) the DM, and T-N contents but decreased the NDF, ADF and cellulose content. The addition of formic acid slightly but not significantly decreased dry matter, T-N and ADL contents of T_3. The IVDMD of this treatment was decreased though not significantly ($P>0.05$) compared to T_3. The addition of starch to the combined grass-legume forage resulted in a significant decrease ($P<0.05$) in T-N, NDF, ADF, cellulose and ADL but slightly increased IVDMD, compared to T_3.

TABLE 1

Chemical Composition and IVDMD [1] of Forages before Ensiling

Treatment	*Chemical composition (per cent dry)*						
	Dry matter	*Total nitrogen*	*Neutral detergent fibre*	*Acid detergent fibre*	*Cellulose*	*Acid detergent lignin*	*IVDMD*
Napier grass (T_1)	24.14a[3]	1.76a	74.11a	42.78a	33.81a	7.17a	55.68a
Leucaena (T_2)	37.50b	3.50b	59.20b	35.77b	23.59b	12.31b	51.15b
Napier grass + Leucaena (T_3)	29.06c	2.76c	66.53c	41.93a	30.66a	10.05ab	54.88ab
Napier grass + Leucaena + Starch (T_4)	29.28c	2.20d	62.52b	35.37b	27.29ab	6.77a	57.40ac
Napier grass + Leucaena + Formic acid (T_5)	27.85ac	2.60c	65.49c	41.20a	31.15a	8.92a	52.13ab
SE[2]	4.891	0.651	5.562	3.553	3.945	2.257	2.572

1) IVDMD = *In vitro* dry matter digestibility
2) SE = Standard error
3) Figures in the same column with different letters are statistically significant ($P<0.05$).

The characteristics of silages are shown in Table 2. Except for leucaena whose DM content remained unchanged, there was a decrease in all the others (compare Tables 2 and 1), though the decreases were not significant ($P<0.05$). Significant differences ($P<0.05$) were observed among the *p*H of the silages. Leucaena silage had the highest *p*H and this was significantly different from all the others. The combined forage without additive (T_3) had a *p*H intermediate between that of napier grass and leucaena. However, adding starch (T_4) or formic acid (T_5) resulted in a reduction in *p*H compared to T_3 and these were also lower than that of napier grass (T_1). Though these reductions were not significant, the reduction due to addition of starch was greater than that due to addition of formic acid.

Lactic acid was the dominant organic acid produced in all the silages. Napier grass silage had a lower but non-significant ($P<0.05$) lactic acid content compared to the leucaena silage. Combining napier grass with leucaena resulted in increased lactic acid content compared to that of napier grass. Starch-added silage had the highest lactic acid content which was significantly different ($P<0.05$) from the others. Addition of formic acid, however,

TABLE 2

Silage Quality of Napier Grass Combined with or without Leucaena under Different Treatments

Treatment	Silage quality (% Dry matter)						
	Dry matter	pH	Lactic acid	Acetic acid	Butyric acid	Total nitrogen	(VBN %) T - N
Napier grass (T_1)	22.90a[3]	4.06a	1.42a	0.26a	-	1.61a	5.42ab
Leucaena (T_2)	37.83b	5.27b	1.95a	0.41b	-	3.36c	6.27ab
Napier grass + Leucaena (T_3)	26.87a	4.33a	1.65a	0.26a	0.12	2.59bc	6.75a
Napier grass + Leucaena + Starch (T_4)	28.20a	3.78a	2.77b	0.24a	-	2.16ab	4.83b
Napier grass + Leucaena + Formic acid (T_5)	26.11a	3.91a	1.34a	0.37ab	-	2.53bc	5.25ab
SE[2]	4.891	5.630	0.595	0.578	0.077	-	0.641

1) VBN per cent represents volatile basic nitrogen (VBN) production expressed as per cent of T-N.
2) SE = Standard error
3) Figures in the same column with different letters are statistically significant (P<0.05).

resulted in reduced lactic acid content.

The production of acetic acid was highest in the leucaena silage (T_2) and this was significantly different (P<0.05) from those of T_3 and T_4. Starch-added silage (T_4) had the lowest acetic acid content. Butyric acid was observed only in the combined napier grass-leucaena without additive silage.

Total nitrogen content decreased (compare Tables 1 and 2) in all treatments but the decreases were not significant (P<0.05). Napier grass silage had lower but non-significant (P<0.05) VBN content compared to leucaena silage. Combined grass-legume without additive silage had the highest VBN content but this was significantly different only from starch added silage. No significant differences (P<0.05) were observed among the others.

Cell wall components and IVDMD of the silages are shown in Table 3. The trends in the cell-

TABLE 3

Chemical Composition and in vitro *Dry Matter Digestibility of Silages (per cent dry matter)*

Treatment	Neutral detergent fibre	Acid detergent fibre	Cellulose	Acid detergent lignin	In vitro dry matter digestibility
Napier grass (T_1)	69.03a[2]	44.90a	36.36a	7.05a	55.11a
Leucaena (T_2)	56.92b	39.62ab	25.52b	14.17b	51.79ab
Napier grass + Leucaena (T_3)	59.87ab	41.44ab	30.85ab	9.54ab	51.56ab
Napier grass + Leucaena + Starch (T_4)	54.55b	34.59b	25.69b	7.80a	53.65ab
Napier grass + Leucaena + Formic acid (T_5)	62.48	41.12ab	29.58ab	10.37ab	50.01b
SE[1]	5.596	3.748	4.450	2.786	1.979

[1]) SE = Standard error
[2]) Figures in the same column with different letters are statistically significant (P<0.05).

wall components were similar to those observed before ensiling. However, by comparing with those in Table 1, it is observed that whereas NDF decreased slightly, the other cell-wall components either increased or were not affected. These changes were, however, not significant ($P<0.05$). The IVDMD of the silages were either slightly decreased or not affected by the ensiling process.

Discussion

The observed differences in the napier grass and leucaena are consistent with published literature on grasses and legumes (Wilson & Minson, 1980; Norton, 1982). However, the lower IVDMD of the leucaena compared to the napier was because it was more matured and had twice the lignin content. Furthermore, the leaf: stem ratio of the leucaena was 1:1. The addition of starch reduced the relative amount of cell-wall components further because starch is a non-structural carbohydrate in nature.

Napier grass is a good silage crop especially in the humid tropics because it contains adequate fermentable substrate (Skerman & Riveros, 1990). However, like most legumes, leucaena has low water soluble carbohydrates and high buffering capacity (Kaiser, 1984). Consequently its fermentation rate is very slow, taking a long time to reach stable *p*H (Alli, Baker & Garcia, 1983). Addition of formic acid immediately reduces the *p*H but it does also restrict the fermentation of the water soluble carbohydrates (Thomas & Thomas, 1985). On the contrary, starch as an additive provides the needed substrate for fermentation. This indeed offers a better opportunity to the peasant farmer than would formic acid, since the application of the latter poses its own technical problem apart from being expensive, whereas starch is technically safer to apply, easily available and cheap as a by-product of the cassava processing industry.

That the dominant acid produced was lactic acid appears contrary to that observed for some silages of tropical crops (Catchpoole & Henzel, 1971). Indeed, Vilela, Rodden & Oliveira (1983), ensiling elephant grass (napier grass) harvested at 9-10 weeks old, observed that the dominant acid was acetic acid. On the contrary, Woodward, Prine & Bates (1991), ensiling elephant grass (napier grass) harvested at 12 months, 9 and 3 months, 8, 4 and 2 months respectively observed that in all three cases, the dominant acid was lactic acid. It is not clear whether the age of the plant had any influence on the development of the acid but the material used in this experiment was about 12 weeks old.

The fact that butyric acid was observed only in the grass-legume without additive indicates that a very good ensiling condition was ensured and hence good quality silage was achievable.

The decrease in total nitrogen content on ensiling had been observed by other workers. Ooshima & McDonald (1978) has noted that in general only about 70 to 85 per cent of the nitrogen compounds in silages can be accounted for.

Contrary to many observations that tropical forage silages are characterized by high amount of volatile basic nitrogen (Catchpoole & Henzel, 1970; Kaiser, 1984), in the present study the amount of VBN was relatively small. In most lactate silages the VBN is less than 10 per cent of total nitrogen (Ooshima & McDonald, 1978) and such silages are usually classified as very good (Flynn, 1981; Thomas & Thomas, 1985). This is perhaps because a faster rate of acid development was achieved thus limiting the microbial breakdown of nitrogenous substances.

Decrease in NDF during ensiling has been reported in the literature. Kuntzel & Zimmer (1972) as quoted by Wilkins (1981) have indicated that structural carbohydrates also make a contribution to fermentation during ensiling.

Conclusion

The study has shown that napier grass can be successfully ensiled even after combining with leucaena to improve the protein levels and digestibility. The ensiling quality can be enhanced using starch as the additive. More work is however, needed to examine the animal's responses to this conserved feed. If such an exercise proves favourable it would really improve the productivity of ruminant livestock especially in the humid tropics.

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