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The level of tree legumes required to meet the maintenance energy requirements of Ongole (*Bos indicus*) cows fed rice straw in Indonesia

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Abstract. Improving the productivity and profitability of smallholder cattle enterprises in Indonesia requires greater and more efficient utilisation of underutilised feed resources such as rice straw. The experiment tested the hypothesis that an Ongole cow with low energy requirements can maintain weight (W) on a rice straw-based diet with the addition of a small amount of tree legumes. Thirty-two Ongole cross (*Bos indicus*) cows were allocated to one of four treatments in a randomised block design with eight cows per treatment. Cows were offered untreated rice straw *ad libitum* with four levels of tree legumes (0, 11, 21, and 42 g DM/kg $W^{0.75}$.day) for 20 weeks. Feed intake was determined daily and liveweight was measured every second week. There was no difference in total feed intake between the treatment groups ($P > 0.05$). Intake of tree legumes was higher when more was offered ($P < 0.05$), but cows did not consume all of the legumes offered to them. The inclusion of tree legumes in the diet had no effect on organic matter digestibility, ME content of the diet, liveweight gain or estimated energy balance of the cows ($P > 0.05$). Rice straw alone contained insufficient ME and rumen-degradable N to meet the maintenance requirements of the cows. From the regression relating liveweight change and ME intake for all cows across all diets, the inclusion of tree legumes in the diet at ~12 g DM/kg $W^{0.75}$.day or 2.8 g DM/kg W.day was enough to meet the energy requirements for maintenance of Ongole cows fed rice straw *ad libitum*.

Additional keywords: gliricidia, leucaena.

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Introduction

Domestic beef supply in Indonesia is currently unable to meet local demand for beef products. The major concentration of cattle in Indonesia is in East Java, with 3.4 million head in 2009 contributing 21% of national beef production (Ditjennak 2009). These cattle are mostly Ongole crosses (*Bos indicus*) and are kept by smallholder farmers. Farmers typically manage one to two cows plus their offspring in an intensive cut-and-carry system (Hanifah *et al*. 2010). Increasing beef supply in Indonesia will require an increase in the number of breeding cows, improvement in the reproductive performance of these cows, and increased productivity of smallholder fattening operations. The high rural population and intensity of land use for food crops mean there are limited opportunities to increase the feed available for livestock. Increasing cattle numbers and improving the productivity and profitability of smallholder cattle enterprises will therefore require greater and more efficient utilisation of underutilised feed resources such as rice straw and crop by-products.

Rice straw is currently underutilised in Indonesia. Rice straw contains low levels of crude protein (CP) (5% DM), high neutral detergent fibre (75% DM), high ash (20% DM) and has poor organic matter digestibility (OMD, 51%) (Bakrie 1996; Dahlanuddin *et al*. 2003). Rice straw alone is not sufficient for maintenance (McLennan *et al*. 1981; Suriyajantratong and Wilaipon 1985). However, it is cheap, readily available, and can be stored for long periods of time to meet periods of feed shortages or reduce daily labour requirements for cutting feed for cattle.

Previous research has focussed on improving the feeding value of rice straw through treatment with additives such as urea, ammonia and enzymes, but these treatments have not been widely adopted by smallholder farmers because they are considered costly, labour intensive, technically difficult or dangerous (Doyle *et al*. 1986; Van Soest 2006). The use of supplements to increase the energy and protein content of rice straw-based diets has also been investigated. Supplements need to be cost effective, easily accessible, and practical to be adopted by farmers (Owen and Jayasuriya 1989). Concentrates, urea and molasses are of limited use to Indonesian smallholder farmers because they are expensive (Doyle *et al*. 1986). Tree legumes are a viable alternative; they provide green feed throughout the year, including in the dry season when use of rice straw is likely to be highest, they contain high levels of CP (25–30% DM, Lowry *et al.* 1992), and can be planted as living fences around animal houses where they can be harvested with little labour cost. Feeding tree legumes as a supplement to untreated rice straw has been shown to increase total feed intake, energy intake and OMD, and decrease rumen retention times in cattle (Moran *et al.* 1983; Doyle *et al.* 1986; Seresinhe and Pathirana 2008). In results from work reported by Doyle *et al.* (1986), the inclusion of gliricidia in the diet at 10 and 24% reduced weight loss in bulls in Sri Lanka. Gliricidia at 50% of the diet was sufficient for bulls to gain 10 g/day.

Most research to date has been focussed on the feeding value of rice straw for animals with high nutrient requirements, such as dairy cows and growing steers (for example, Schiere *et al.* 1989; Wanapat *et al.* 2011). A more efficient system would be to feed untreated rice straw as a maintenance feed for cows with low energy requirements, for example, cows that are not pregnant or lactating, or cows in the early stages of pregnancy. Tree legumes (e.g. *Gliricidia sepium* or *Leucaena leucocephala*) could be used to meet any shortfall in protein and energy requirements, but the majority of high quality forages and by-products would be redirected towards cows in late pregnancy (7–9 months' gestation), lactating cows, weaned calves and fattening cattle. The hypothesis tested in this experiment was that it is possible for an Ongole cow in Indonesia with low energy requirements (<7 months pregnant, non-pregnant or non-lactating) to maintain weight on a rice straw-based diet with the addition of a small amount of tree legumes.

Materials and methods

All procedures were reviewed and approved by the University of Queensland Animal Ethics Committee in accordance with the Australian code of practice for the care and use of animals for scientific purposes.

Animals and experimental design

Thirty-two multiparous, dry Ongole cross (*Bos indicus*) cows [318 ± 12 kg (s.e.m.) liveweight; body condition score (BCS) 2.6 ± 0.1 out of 5] were allocated to one of four treatments in a randomised block design. Cows were first assigned to one of eight blocks based on liveweight, and one cow from each block was then randomly assigned to each treatment diet. Cows were housed in individual pens at the Beef Cattle Research Institute, Grati, East Java, Indonesia, and had free access to fresh drinking water at all times. The experiment consisted of a 2-week adaptation period where cows were introduced to the pens and experimental diets, followed by a 20-week experimental period.

Diets and feeding

All cows were offered untreated rice straw *ad libitum.* The amount of rice straw offered each day was calculated as 110% of the previous week's average daily intake. Cows in each treatment group were offered different levels of fresh tree legumes as a supplement on a metabolic weight ($W^{0.75}$) basis: (A) no tree legumes, (B) 11 g DM/kg $W^{0.75}$.day, (C) 21 g DM/kg $W^{0.75}$.day, (D) 42 g DM/kg $W^{0.75}$.day. The tree legumes used were *Gliricidia sepium* and *Leucaena leucocephala*, and were offered in equal portions on a DM basis at the designated treatment levels. Composition of the forages offered to the cows is shown in Table 1. The amount of tree legumes offered to cows was calculated (based on designated treatment levels) every second week after the cows were weighed to account for any changes in liveweight.

The cows were fed at 0800 hours each morning and feed remaining from the previous day was collected, separated and weighed. The feed troughs were not big enough to contain the entire daily ration and rice straw and tree legumes were added to the trough every hour until the entire ration was offered, at ~1500 hours. Rice straw and tree legume stems were not chopped in order to simulate the conditions of feeding in the villages.

Feed for the cows was prepared 1 day in advance. Rice straw was grown in irrigated rice paddies and dried standing in the field. Straw was purchased from local traders and delivered to the research station once a week. Fresh tree legumes were purchased from traders and delivered every second day.

Sampling procedures and measurements

Feed intake was measured daily for the duration of the experiment. Subsamples of feed offered were collected each day as the feed was weighed and dried at 60°C for 48 h to determine DM. Dried samples of each feed were bulked for each week and ground to pass through a 1-mm screen in a Retsch GmBH 5657 HAAN mill. OM was determined by combusting samples at 600°C for 3 h in a NEY M-525 Series II furnace (AOAC 1984). Total N was analysed using the Kjeldahl technique (AOAC 1984). Ash-free neutral detergent fibre and ash-free acid detergent fibre were measured according to the technique described by Goering and Van Soest (1970). Amylase is not used in this method and is not necessary for samples low in starch (Cherney *et al.* 1989). Residues of each feed type for each cow were bulked each week and a subsample taken to determine DM and OM as described above.

Digestibility of the diets was determined by total faeces collection on three separate occasions, during weeks 5, 12 and 20 of the experimental period. Faeces were collected from each animal over 24 h for 7 days. Daily faecal output for each animal was weighed, mixed and a 10% subsample collected and stored at −20°C. At the end of the week, subsamples were thawed and bulked for each animal. Subsamples of the bulked samples were dried at 60°C for 72 h to determine DM content. The dried samples were ground and OM was determined using the same protocol as for the feed samples.

Table 1. Chemical composition of forages offered to cows (mean ± s.e.)

	Rice straw	Gliricidia	Leucaena
DM (g/kg)	678 ± 26	257 ± 7	330 ± 11
Organic matter (g/kg DM)	762 ± 3	913 ± 3	926 ± 2
Crude protein (g/kg DM)	64 ± 3	206 ± 4	244 ± 5
Neutral detergent fibre (g/kg DM)[A]	611 ± 11	457 ± 13	446 ± 27
Acid detergent fibre (g/kg DM)[A]	395 ± 24	348 ± 19	333 ± 17

[A]Ash-free fibre fractions.

Water intake of individual animals through drinking was measured during the digestibility periods. Water was offered in plastic buckets and the weight of water consumed was recorded. Water consumption was corrected for evaporation. Total water intake was calculated as water from drinking plus water from feed intake.

Liveweight and BCS (1–5 scale) of all cows were measured every second week before feeding. Some animals were found to be pregnant during the experiment and their liveweight was corrected for pregnancy using the equations of Silvey and Haydock (1978). Average stage of pregnancy of cows at the start of the experiment was 67 ± 8 days. No cows gave birth during the experiment.

Calculations and statistical analyses

Equations from CSIRO (2007) were used to estimate the ME content of the diets (M/D, MJ/kg DM) and the ME required for maintenance (ME_m, MJ/day);

$$M/D = 0.172\ OMD - 1.99\,(\%)$$

$ME_m = 1.2 \times 1 \times 1\,[0.28\ W^{0.75}\exp(-0.03\ A)]/k_m$, where W is liveweight, A is age (with a maximum value of 6), and k_m is the net efficiency of use of ME for maintenance.

$$K_m = 0.02\ M/D + 0.5$$

Energy balance was calculated as ME intake – ME_m. Simple linear regression of ME intake (based on CSIRO equations) on daily weight gain was used to estimate the ME_m observed in the experiment (GENSTAT 13th edition, VSN International, Hemel Hempstead, UK). This regression method was also used to estimate the amount of tree legumes required for maintenance.

The Large Ruminant Nutrition System (LRNS) version 1.0.17, based on the Cornell Net Carbohydrate and Protein System 5.0.40 (Fox *et al*. 2004), was also used to calculate the ME content of the diets and ME_m. Ruminal N balance was estimated using the LRNS.

Differences in parameters measured between the treatments were analysed using one-way ANOVA with blocking and pairwise comparisons in GENSTAT. Treatment and block were considered fixed and random effects. Pregnancy status (pregnant or not pregnant) was used a covariate, but did not have an effect on any of the parameters analysed ($P > 0.05$). Results presented are means of each treatment group.

Results

Feed and water intake

There was no difference in average total feed intake between the four treatment groups ($P > 0.05$; Table 2), and average intake of all animals during the experiment was 78 g DM/kg $W^{0.75}$.day. There was a time effect on average total weekly intake ($P < 0.05$). Low total intake occurred in weeks with low rice straw intake. Low rice straw intake was associated primarily with low DM of the rice straw offered, which varied from 28 to 95%.

Intake of tree legumes was higher when more was offered ($P < 0.05$), and was accompanied by an increase in CP intake (Table 2). Cows in all groups did not consume all of the legumes offered to them, with cows in groups B, C and D consuming 85, 67 and 51%, respectively. At the start of the experiment cows showed a preference for leucaena over gliricidia, and leucaena accounted for 79% of tree legume intake in the first week. This preference decreased during the experiment ($P < 0.05$), and in week 20 leucaena accounted for 43% of tree legume intake. Intake of rice straw decreased as tree legume intake increased, but was only significantly different between cows offered no tree legumes and the highest supplement level (Table 2).

There was no significant difference in water intake from drinking only between groups (0.24 kg/kg $W^{0.75}$.day). However, total water intake (water from drinking and feed) was significantly higher in cows consuming the two highest levels of tree legumes compared with cows offered rice straw only (Table 2).

Energy and ruminal N balance

The inclusion of tree legumes in the diet had no effect ($P > 0.05$) on OMD, ME content of the diet, liveweight gain, BCS or estimated energy balance of the cows (Table 2). The OMD of the high legume diets (C and D) decreased between the second and third measurements of digestibility. However, in all three

Table 2. Mean feed and water intake, digestibility, ME content, liveweight gain and energy balance of mature Ongole cows fed rice straw and increasing amounts of tree legumes

Means within rows followed by different letters are significantly different at $P = 0.05$

	A	B	C	D	s.e.
Total feed intake (g DM/kg $W^{0.75}$.day)	73.7	78.5	78.7	80.6	5.06
Tree legume intake (g DM/kg $W^{0.75}$.day)	0a	9.20b	14.0c	21.9d	1.25
Rice straw intake (g DM/kg $W^{0.75}$.day)	73.4	69.3ab	64.7ab	58.7b	4.88
Crude protein intake (g DM/kg $W^{0.75}$.day)	4.8a	6.5b	7.3b	8.6c	0.44
Total water intake (kg/kg $W^{0.75}$.day)	0.25a	0.29ab	0.31b	0.33b	0.01
Organic matter digestibility (g/kg)	531	531	546	559	11.3
ME content (MJ/kg DM)[A]	6.98	6.98	7.25	7.46	0.20
Liveweight gain (kg/day)	–0.12	–0.16	–0.01	–0.06	0.10
Estimated ME maintenance (MJ/kg $W^{0.75}$.day)[A]	0.44	0.45	0.44	0.43	0.004
Estimated ME intake (MJ/kg $W^{0.75}$.day)	0.51	0.54	0.57	0.60	0.04

[A]ME content and estimated ME_m were calculated using the equations in CSIRO (2007).

periods of measurement, increasing the level of legumes in the diet did not increase the OMD. Regression of daily weight gain and ME intake for all cows in the experiment predicted maintenance requirements of 0.57 MJ/kg $W^{0.75}$.day. The average value for ME_m predicted by the LRNS model was 0.56 MJ/kg $W^{0.75}$.day. The ME content of diets A, B, C and D calculated by the LRNS model were 7.1, 7.3, 7.4 and 7.5 MJ/kg DM. Tree legume intake required for maintenance was estimated to be 12 g DM/kg $W^{0.75}$.day or 2.8 g DM/kg W.day when fed with *ad libitum* rice straw.

Ruminal N balance as calculated by the LRNS model was negative for all groups, accounting for 88, 95, 97 and 98% of requirements for groups A, B, C and D, respectively.

Effect of pregnancy

There was no effect of pregnancy status (pregnant or not pregnant) on any of the parameters analysed ($P > 0.05$).

Discussion

Our results demonstrate that it is possible for an Ongole cow in Indonesia with low energy requirements (not lactating, not pregnant or early stages of pregnancy) to maintain weight on a rice straw-based diet with the addition of a small amount of green feed, ~12 g DM/kg $W^{0.75}$.day (2.8 g DM/kg W.day). Higher levels of tree legumes are required to increase the feeding value of a mixed diet, predominantly based on rice straw, to the extent where animals would gain weight, and this highlights the appropriateness of using rice straw as a maintenance feed for cows with low energy requirements rather than growing cattle or other classes of animal with high energy demands.

The ME_m of Ongole cows in the experiment was estimated to be 0.57 MJ/kg $W^{0.75}$.day. This was similar to the value estimated using the LRNS model (0.56 MJ/kg $W^{0.75}$.day), but higher than the average value calculated using the CSIRO equation for maintenance, 0.44 MJ/kg $W^{0.75}$.day (CSIRO 2007). The difference in ME content of the diets estimated using the CSIRO and LRNS equations is not large enough to account for the difference in ME_m. Both equations account for breed, weight, age, sex, physiological state and efficiency of energy use. However, the CSIRO equation may not fully account for the energy expended by the animals standing in their pens, changing position, consuming unchopped roughage feed, coping with high environmental temperatures or catabolising body fat and protein during weight loss (CSIRO 2007). The stage of pregnancy of the cows is unlikely to account for the difference in ME_m. The same inputs were used in both the LRNS and CSIRO equations. In addition, the energy requirements for pregnancy only increase during the third trimester.

Our value is also higher than the value published by Chizzotti *et al*. (2008), of 0.47 MJ/kg $W^{0.75}$.day for genotypically similar Nellore cattle in Brazil. This paper used data from 16 published studies to calculate ME_m for bulls, steers and heifers, as well as a group mean. Diets fed in these experiments were of higher quality than that used in our feeding experiment. For example, in the studies by Tedeschi *et al*. (2002), cattle were fed forage diets based on corn or sorghum silage, containing on average 13% CP, 5% ash and 50% neutral detergent fibre. These diets would have had a higher ME content and efficiency of use of ME for maintenance, resulting in lower ME_m.

In a study by Jenkins and Ferrell (2007), nine breeds of *Bos taurus* beef cows were fed an alfalfa hay-based diet at four different levels (56, 76, 93 and 111 g DM/kg $W^{0.75}$.day) until they reached bodyweight equilibrium. This was when the weight of individual cows did not change over 8 consecutive weeks. Cows were mature (6–10 years) and not pregnant or lactating. At the lowest level of intake, average weight of cows at bodyweight equilibrium was 529 kg and ME_m was 0.58 MJ/kg $W^{0.75}$.day. At the highest feeding level, average bodyweight and ME_m were 701 kg and 0.69 MJ/kg $W^{0.75}$.day, respectively. Although it was not reported, it is assumed that the difference in weight of cows at bodyweight equilibrium reflects a difference in BCS. This work clearly demonstrates the influence of cow weight and condition score on ME_m. Cows in our experiment had an average starting weight of 318 kg and were in BCS 2.6 on a 1–5 scale. To increase the reproductive success of Ongole cattle in villages cows will need to have a BCS of 3 or higher (Montiel and Ahuja 2005). Based on the work of Jenkins and Ferrell (2007), Ongole cows in BCS 3 will have a higher ME_m than the value obtained in our experiment. This will require higher levels of tree legumes to maintain weight; however, cows may not consume enough tree legumes under the feeding regime tested in this experiment. Other supplements which might be useful are rice bran and cassava by-products such as onggok (cassava bagasse), which have higher ME content and digestibility than tree legumes. The level of rice bran or cassava by-product which is required is not known.

The consumption of rice straw alone was not enough for cows to maintain weight as the diet was deficient in rumen-degradable N (RDN) and energy content. All levels of tree legume supplement practically met the RDN requirements (lowest was 95% of RDN requirement) and this is a simple, safe and cost-effective way to supply RDN within these systems. Although the addition of tree legumes to the diet tended to increase the total feed intake ($P = 0.6$), energy intake ($P = 0.2$) and OMD ($P = 0.1$), these effects were not significant (Table 2). This is in contrast to the results of Suriyajantratong and Wilaipon (1985), who reported increases in feed intake and liveweight gain in native steers in Thailand (breed unknown) fed rice straw *ad libitum* with increasing amounts of the forage legume, *Stylosanthes hamate* cv. Verano. Consumption of rice straw without legumes was 74 g DM/kg $W^{0.75}$.day, the same as the value obtained in our experiment (Table 2). Legume supplements were consumed at 11, 23 and 31 g DM/kg $W^{0.75}$.day, with total feed intakes of 88, 101 and 107 g DM/kg $W^{0.75}$.day, respectively. Unlike the results of our experiment, legumes were not substituted for rice straw, accounting for the increase in total feed intake and subsequent liveweight gain. In Suriyajantratong and Wilaipon's (1985) experiment, rice straw was fed during the day and then removed at 4 p.m. before the legume was offered, so cattle were never offered a choice between the two. In our experiment, rice straw and tree legumes were always offered at the same time.

Alayon *et al*. (1998) conducted a similar experiment where they fed sheep increasing levels of gliricidia as a supplement to poor quality stargrass hay (*Cynodon nlemfuensis*). Dried gliricidia was mixed in pellets with ground hay, molasses and salt at 0, 10, 20 and 30%, which is similar to the levels of tree legumes consumed in our experiment (0, 12, 18 and 27%). The inclusion of gliricidia increased the ME content of the diet by 0, 5 and 12% compared with 0, 4 and 7% in our experiment. They reported an increase in total feed intake and OM digestibility at the two highest levels of gliricidia in the pellets. Although our results showed a trend in this direction, this was not significant. The effect of grinding and pelleting the diets would have increased the potential intake of the feed, and may account for the different results measured in the two experiments.

Across all treatments, none of the cows ate all of the gliricidia and leucaena offered to them, which was unexpected. This also occurred in experiments by Smith *et al*. (1995) where they fed gliricidia to sheep and goats at 5, 10 and 15 g/kg W.day. Intake of gliricidia averaged 90, 81 and 71% at the three increasing levels of supplement offered. It appears unlikely that Ongole cows will consume enough tree legumes to improve digestibility, ME intake and daily liveweight gain unless rice straw intake is restricted. The preference for leucaena over gliricidia at the start of the experiment was likely due to the low palatability of gliricidia. Although gliricidia has a high nutritive value, its acceptance to livestock as a feed varies (Simons and Stewart 1994). For example, Quigley *et al*. (2009) reported low acceptance of gliricidia by Bali cattle in Lombok, Indonesia, but found no problems in central Sulawesi. Anecdotal evidence suggests cultivars and cutting frequency may affect the palatability of gliricidia. Smith *et al*. (1995) found that sheep and goats preferred fresh (2 h post-harvest) and wilted (26 h post-harvest) gliricidia compared with sun-dried gliricidia. Lana *et al*. (1989) reported that Bali cattle (*Bos sondaicus*) preferred older gliricidia leaves to younger leaves. Secondary compounds in gliricida leaves may be more concentrated in dried and young leaves, accounting for relative preference by livestock. The higher preference of cattle for gliricidia compared with leucaena at the end of our experiment suggests that previous exposure plays a large role in acceptability of gliricidia as a forage to cattle.

Average water intake from drinking was 0.24 kg/kg $W^{0.75}$.day, which equates to ~18 L/day for a 320-kg cow or 2.9 L/kg DM intake. This provides guidelines for the amount of water which is needed by Ongole cows in Indonesia. Water intake is often inadequate in these systems as water is usually collected in a village well or waterway and carried to the cows.

Conclusion

Untreated rice straw can be used as a maintenance diet for Ongole cows with low energy requirements when supplemented with tree legumes at 12 g DM/kg $W^{0.75}$.day or 2.8 g DM/kg W.day. Much higher levels of tree legumes are required for cattle to gain weight, making this feeding strategy difficult for cows in late pregnancy, lactating cows, cows with a need to increase BCS and growing cattle.

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