**In vitro** gas production and **in vivo** nutrient digestibility and growth performance of Thai indigenous cattle fed fresh and conserved pangola grass

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**ABSTRACT**

Fresh and conserved pangola grass (*Digitaria eriantha* Steud., synonym *D. decumbens*) were compared in terms of **in vitro** gas production and **in vivo** nutrient digestibility, metabolisable energy (ME) concentration and average daily gain (ADG) of Thai indigenous cattle. The study was designed as a completely randomised design with Ruzi grass (*Brachiaria ruziziensis*) as a control and pangola grass in fresh, hay and silage forms at the same age at harvest (45 days regrowth) as treatments. As intended, the dry matter (DM) intake of forages supplemented with concentrate and a protein block was not different (*p* > .05) among treatments. All forms of pangola ranked higher in crude protein and ME concentrations than Ruzi grass. Pangola silage, to which 5% sugarcane molasses was added at ensiling to minimise the risk of bad fermentation, produced more gas **in vitro** after 96 hours of incubation and had greater (*p* < .05) **in vivo** DM, organic matter and crude protein apparent digestibility and ME concentrations and resulted in higher ADG of cattle. In conclusion, the form of pangola grass had a direct effect on digestibility, ME and ADG of Thai indigenous cattle. Pangola silage ranked higher than its fresh and hay forms as well as Ruzi grass which was the control. Pangola grass is a feasible alternative as forage source for cattle in tropical countries and can be recommended as a grass species for feeding especially during dry season.

**Introduction**

Ruminant livestock play a key role as an integral part of farming and rural life in tropical countries by providing food, family income and employment (Pezo & Devendra 2002). Most developing countries are located in the tropical area, including Thailand. White Lamphun and the mountain cattle are the most prominent native cattle breeds in northern Thailand. They are fertile animals, tolerant to poor feed quality and also towards internal and external parasites and adapt well to hot and humid climate (Rattanaronchart 1998). However, White Lamphun cattle are classified as an endangered-maintained breed with probably fewer than 1000 breeding females (Charoensook et al. 2013).

Feeding of cattle in the tropics is often difficult because of seasonal decline in feed supply, in both quality and quantity (Wanapat & Devendra 1992). The main cattle feed is grass, either from natural or cultivated pasture. The common problems that farmers face are cattle losing weight and lack of quality feed resources during dry season. Hay and silage making as reserve for feeding during periods of feed limitation is one possibility to overcome these problems. In Thailand, ensiling is one of the fodder conservation methods to avoid feed shortage in dry season and silage has been produced for many years by government research and field extension stations and distributed to farmers, mostly dairy farmers (Poathong & Phaikaew 2001).

Ruzi grass (*Brachiaria ruziziensis*) is one of the most important forage species cultivated in the tropics. For almost 30 years, Ruzi has been the grass most commonly sown on upland soils in Thailand because of...
the availability of relatively cheap seed (Hare et al. 2005) despite poor dry season forage production (Hare et al. 2009). Another commonly grown tropical grass is pangola grass (*Digitaria eriantha* Steud., synonym *D. decumbens*) (Cook et al. 2005). It is recommended for the poorly drained soils in Malaysia and the Philippines (Hacker 1992) and is utilised extensively for animal grazing, hay or silage making (Meeske et al. 1999). Pangola grass has already been used as animal feed for a long time (see review by Tikam et al. 2013) and has shown its potential as nutrient source for sheep in both fresh and preserved forms (Tikam et al. 2013). However, evaluation of pangola grass, grown under identical conditions at the same location, harvested at the same regrowth age and then utilised in fresh and conserved (hay, silage) forms in cattle has not yet been investigated. Therefore, the aim of this study was to evaluate *in vitro* gas production, and *in vivo* nutrient digestibility, metabolisable energy (ME) concentration and average daily gain (ADG) of Thai indigenous cattle fed fresh and conserved pangola grass and fresh Ruzi grass as a control.

**Materials and methods**

**Study site**

This study was carried out at the farm of Lampang Animal Nutrition Research and Development Centre, located in Lampang province, Thailand (latitude 18°16’N and longitude 98°32’E). The climate is tropical monsoon, with a wet season from May to October and a dry season from November to April. The experiment was conducted during the months of May to October 2009. The daily temperature (mean ± standard deviation) during the study was 27 ± 3.17°C and the daily relative humidity was 84 ± 16.3%.

**Forage management and harvest**

Pangola grass and Ruzi grass in different forms (fresh and conserved) were used for this experiment. Grasses were harvested from the same location at the same regrowth age at cutting (45 days) and were used to produce four forage treatments, namely Ruzi grass, fresh pangola, pangola hay and pangola silage. The 45 days of regrowth were chosen in accordance with Thai recommendations (Animal Nutrition Division 2002). The pangola grasses were planted in a rectangular plot of 12,800 m² (1.28 ha) in rows 50 cm apart with 50 cm spacing within rows. The area was sub-divided into three parts (3200 m² (0.32 ha) for fresh pangola, 3200 m² (0.32 ha) for silage production and 6400 m² (0.64 ha) for hay production). Ruzi grasses were planted in 4800 m² (0.48 ha). Pastures were fertilised with 500 kg/ha of N-P-K (15-15-15) compound fertiliser before the start of the planting. For pangola, stolons were used as planting material (1875 kg/ha) while Ruzi seeds were sown (125 kg/ha). Sprinkler irrigation for pastures was provided every 3 to 5 days during the first growing season and at rain delay or dry seasons. Weeding of pastures was removed 2 to 4 weeks after planting. For fresh pangola and Ruzi grasses, their fields were divided into different plots (45 plots each) already for the previous growth period such that their maturity could be controlled by cutting at different days in order to obtain fresh grass of 45 days regrowth duration and thus, similar quality, throughout the feeding and digestibility trial carried out in the following months. Grasses were harvested at approximately 5 to 10 cm above the ground. After harvesting, 125 kg of ammonium sulphate (46-0-0) per hectare were used. Grasses were cut early every morning and chopped before feeding. For pangola hay, fresh pangola was harvested and sun-dried on the field for 2 to 3 days to a dry matter (DM) concentration above 80%, then small square hay bales (0.9 m × 0.45 m × 0.35 m and weighing between 20 and 30 kg) were made and stored indoor. For pangola silage, grasses were chopped into pieces of 2 to 3 cm length, after which 5 kg sugarcane molasses per 100 kg fresh pangola were added. Molasses is the by-product of sugar production from sugarcane and contains 72.4% DM and 2.2% crude protein (CP) (Animal Nutrition Division 2004). The material was then homogenised and filled in 60 120-I plastic barrels (100 kg/barrel), compacted, sealed and ensiled for a minimum of 21 days. The barrels were opened one after the other during the feeding and digestibility trial where each was completely consumed within two days.

Ensiling of pangola is difficult to achieve without providing an additive, e.g. extra water-soluble carbohydrates which promote a strong lactic acid fermentation. The supplementation of a fermentable carbohydrate source like molasses is seen as a practical solution to the problem of delayed fermentation or malfermentation in tropical silages (Tjandraatmadja et al. 1994) and has successfully been used to produce pangola silages with both high sensory and fermentation quality (Tjandraatmadja et al. 1994; Tikam et al. 2015). It was assumed that the inclusion of molasses represents a standard type of pangola silage and therefore, this forage type was simply referred to as pangola silage hereafter.

Forages as well as the concentrate and the protein block used as supplement in the feeding trial were
sampled for chemical analyses four times (n = 4) before being fed to the animals during 111 days of the experiment. Afterwards, aliquots of the samples were taken to prepare a representative pooled sample for each treatment as well as for the concentrate and protein block. All laboratory analyses were carried out in triplicate.

Animals and experimental design

Sixteen native White Lamphun bulls at around 8 to 9 months of age with a body weight (BW) of 124 ± 16.9 kg (mean ± standard deviation) at the beginning of the experiment were housed individually in single compartments (2 m × 3 m, equipped with wooden fences at the sides allowing visual contact between animals and concrete floor) during the trials. Animals were randomly assigned to four treatment groups comprising of Ruzi grass (control), fresh pangola, pangola hay and pangola silage with four animals per treatment. Before starting the experiment, the cattle were drenched with Ivermectin 1% sterile solution (1 mL/50 kg BW) and vaccinated against foot and mouth disease. The experiment lasted for 111 days including adaptation and digestibility period (14 days for adaptation, 90 days for the feeding trial and 7 days for the digestibility period, in that order). The feeds were offered twice per day at 08:00 and 16:00 h in two equal portions. Each animal was fed a diet consisting of forage and a commercial concentrate (12% CP; ingredients; fish meal, soybean meal, peanut meal, rapeseed meal, maize meal, wheat bran and rice bran, cassava, Acacia leaves meal, copra meal, molasses, malt meal, barley meal, oil, calcium carbonate, salt, vitamin, mineral; Charoen Pokphand (CP) group, Bangkok, Thailand) at 2.0 and 0.5% (DM basis) of BW, respectively. Protein blocks (5 kg solidified mixture of 40% soybean, 35% sugarcane molasses, 13% cement, 8% urea, 2% salt and 2% dicalcium phosphate; Mikled et al. 2008) and fresh water were offered for ad libitum consumption separately in each compartment during the whole experimental period. Intake of the protein block was determined by dividing its total weight by the number of days the animals needed to consume it completely. The BW of the cattle were taken at the beginning, every two weeks and at the end of the feeding experiment. The amount of feed offered to the animals was adjusted according to these measurements. The digestibility trial was conducted in the last seven days of this study. Forages and feed refusals of each animal were collected and weighed fresh daily before the morning feeding, and dried in an oven at 60°C until constant weight was achieved. Faeces collected during the digestibility trial were weighed and recorded daily. Animals were kept on a clean, plane concrete floor such that a complete collection of faeces could be conducted. Five percent of the faeces voided daily were sampled and stored at −20°C and then pooled for each animal over the collection period.

Feed samples, feed refusals and faeces samples were oven-dried and then successively ground in mills with 3- and 1-mm sieves for use in chemical analyses. The DM concentration of samples was determined by oven-drying at 100°C for 24 h. For the pangola silage, a correction of DM (DMcorr) for losses of volatile compounds during drying was done according to Weißbach and Kuhla (1995) using the following equation:

\[ DM_{corr} (\%) = 2.08 + 0.975 \times DM (\%) \]

Crude protein (method ID 976.06), ash (method ID 942.05) and ether extract (hereafter denoted crude fat, method ID 920.39) analyses were carried out as described by AOAC (2000). Crude fibre, neutral detergent fibre (NDF) and acid detergent lignin (ADL) were determined according to the method of Van Soest et al. (1991). Acid detergent fibre expressed exclusive residual ash (ADFom) was analysed using method 6.5.2 of the German Handbook of Agricultural Experimental and Analytical Methods (VDLUFA 2012).

In vitro gas production measurement

In vitro gas production of forages was determined according to Menke and Steingass (1988). Three rumen-fistulated cross-bred (native × Holstein Friesian) dairy cows (BW 400 ± 15 kg) were used as rumen fluid donors. Animals were fed with fresh pangola for ad libitum consumption for 14 days before the rumen fluid was collected. About 300 ml rumen liquor were obtained from each animal before morning feeding. The rumen liquor was filtered through two layers of cheesecloth into a pre-warmed plastic bottle with punching out the air with carbon dioxide. The bottle was put in a pre-heated plastic box and was immediately transported to the laboratory. Preparation of incubation media, filling of syringes and all other procedures were done according to the protocol of Menke and Steingass (1988). For each forage treatment, three replicates (syringes) were used. The gas volume was recorded after 0, 3, 6, 8, 12, 24, 48, 72, 84 and 96 h of incubation.
Calculations and statistical analyses

Data of in vitro gas production were fitted to an exponential model given by McDonald (1981):

\[ y = B \left(1 - e^{-c(t-lag)}\right) \]

where ‘y’ is the cumulative volume of gas produced at time ‘t’ (h), ‘B’ the asymptotic gas volume, ‘c’ the rate constant and ‘lag’ is the time (h) between inoculation and commencement of gas production.

Gas production at 24 and 48h of incubation, together with the concentrations of chemical components, was used to predict concentrations of in vitro digestible organic matter (IVOMD24 and IVOMD48, respectively) of forages as follows:

IVOMD24 or IVOMD48 (%)
\[ = 15.38 + 0.8453 \times GP + 0.0595 \times CP + 0.0675 \times \text{ash} \]

where GP is in vitro gas production (mL/200 mg DM) at the respective incubation time, CP and ash are given as g/kg DM (Menke & Steingass 1988).

The ME values of forages based on GP and chemical composition were calculated using the following equation (GfE 2008): ME (MJ/kg DM) = 7.81 + 0.07559 × GP − 0.00384 × ash + 0.00565 × CP + 0.01898 × crude fat − 0.00831 × ADL where GP is in vitro gas production at 24h (mL/200 mg DM) and ash, CP, crude fat and ADL are expressed in g/kg DM.

The in vivo ME values of diets were calculated from in vivo digestibility values as follows (GfE 1995; all variables expressed per kg DM):

\[ \text{ME}_{\text{in vivo}} (\text{MJ}) = 0.0312 \times \text{digestible crude fat (g)} + 0.0136 \times \text{digestible crude fibre (g)} + 0.0147 \times (\text{digestible organic matter} - \text{digestible crude fat} - \text{digestible crude fibre}) \times \text{CP (g)} + 0.00234 \times \text{CP (g)} \]

This equation is based on in vivo digestibilities that were calibrated against a large number of measured ME values (92 diets) using respiration chambers.

Data were analysed using the MIXED procedure in SAS (Statistical Analyses System version 9.4). The model included the fixed effect of treatment, animal as random effect, and the residual error. Data are presented as least squares means with standard error of the means. Significance was declared at \( p \leq .05 \), and tendencies were considered at \( .05 < p \leq .10 \). Significant treatment effects were detected by the global F-test, pairwise comparisons were performed employing Tukey’s test.

Results and discussion

Chemical composition

The chemical compositions of the forages and the supplements (concentrate and protein block) are given in Table 1. Chemical characteristics of fresh pangola indicated a good forage quality when compared with previous reports (see review by Tikam et al. 2013) where CP measured in nine different studies ranged from 5.3 to 12.0% of DM. All forms of pangola ranked higher in CP concentrations than Ruzi grass. As CP concentration in pangola grass sharply declines with advancing maturity (Ventura et al. 1975), even higher values could be reached by an earlier age at cutting. As reported by Fanchone et al. (2012), fresh pangola harvested at 35 days of regrowth contained 12% CP in DM. Because diets based on poor quality tropical forages, crop residues or agro-industrial by-products which are typically fed in tropical countries are often low in CP (Leng 1990), using an early cutting age (<45 days) of pangola grass can be recommended, such that pangola can serve as a forage protein supplement to those diets. Concerning proximate constituents and fibre fractions, all forms of pangola were relatively similar. Therefore it is worth noting that conservation of pangola can be achieved with only few changes in feeding value.

In vitro gas production and nutrient digestibility

In vitro gas production and substrate degradability are commonly used to determine the nutritive value of forages (Blümmel et al. 1997; Getachew et al. 1998) and due to its ability to simulate the process of digestion in ruminant animals in a much better way than

Table 1. The chemical composition of the forages and the concentrate and protein block fed for supplementation.

| Item                  | Ruzi grass | Fresh pangola | Pangola hay | Pangola silage | SEM | Concentrate | Protein block |
|-----------------------|------------|---------------|-------------|---------------|-----|-------------|---------------|
| Dry matter, g/kg      | 236        | 229           | 836         | 231           | 10.0| 890         | 706           |
| Nutrient composition, g/kg DM |
| Organic matter       | 899        | 897           | 933         | 872           | 0.8 | 916         | 841           |
| Crude protein         | 81.9       | 93.5          | 94.5        | 97.7          | 0.20| 119         | 406           |
| Crude fat             | 25.9       | 26.8          | 21.4        | 27.6          | 0.09| 31.9        | 18.6          |
| Ash                   | 102        | 104           | 67.3        | 128           | 0.82| 84.3        | 159           |
| NDF                   | 688        | 695           | 723         | 695           | 0.52| 337         | –             |
| ADL                   | 363        | 379           | 394         | 374           | 0.42| –           | –             |
| ADL                   | 41.2       | 45.4          | 50.0        | 43.6          | 0.12| –           | –             |

SEM: standard error of the means; DM: dry matter; NDF: neutral detergent fibre; ADL: acid detergent lignin.
pure chemical methods, in vitro methods have been successfully used for prediction of IVOMD and ME concentration of ruminant diets. In this study, IVOMD24 values for the pangola forages ranged from 59.9 to 70.5% (Table 2) with lowest values for pangola hay. Losses of highly digestible leaf-rich material during harvest, drying and storage might be an explanation for that (McDonald et al. 2002). As in the in vivo measurements of OM digestibility, pangola silage showed the highest values for both IVOMD24 and IVOMD48. It shows the possibility of producing high quality conserved forms of pangola. The addition of molasses was successful in avoiding DM and nutrient losses caused by malfermentation. It even improved the digestibility and ME concentration by providing rapidly fermentable carbohydrates which often lack in poor-quality ruminant diets in tropical countries (Leng 1990).

The gas production curves are given in Figure 1 and the parameters of the exponential model are presented in Table 2. The parameters of the exponential model were affected by type of forage with biggest differences between pangola silage and Ruzi grass. There were differences in the asymptotic (B) gas production with greater values noted for pangola silage (60.6 mL) versus fresh pangola grass, pangola hay and Ruzi grasses (56.4, 54.2 and 51.3 mL, respectively). The rate constant (c) was higher (p < .05) for fresh pangola and pangola silage than for Ruzi grass and pangola hay.

Table 2. Cumulative gas produced at different times of incubation for forages and parameters of gas production estimated with the exponential model, in vitro organic matter digestibility and metabolisable energy.

| Item                   | Ruzi grass | Fresh pangola | Pangola hay | Pangola silage | SEM | p  |
|------------------------|------------|---------------|-------------|----------------|-----|----|
| Parameters of exponential model |            |               |             |                |     |    |
| B, mL/200 mg dry matter| 51.3<sup>d</sup> | 56.4<sup>b</sup> | 54.2<sup>c</sup> | 60.6<sup>a</sup> | 1.03 | .001|
| c, 1/h                 | 0.059<sup>b</sup> | 0.073<sup>a</sup> | 0.061<sup>b</sup> | 0.067<sup>ab</sup> | 0.001 | .011|
| Lag, h                 | 0.116<sup>a</sup> | -0.253<sup>b</sup> | -0.263<sup>b</sup> | -1.323<sup>c</sup> | 0.16 | .001|
| In vitro organic matter digestibility, % | 59.2 | 64.3 | 59.9 | 70.5 | 2.41 |
| IVOMD24                | 67.5       | 73.4          | 68.2        | 78.3           | 2.36 |
| IVOMD48                | 8.55       | 9.15          | 8.85        | 9.63           | 0.16 |
| ME, MJ/kg dry matter   | 8.55       | 9.15          | 8.85        | 9.63           | 0.16 |

SEM: standard error of the means; B: the asymptotic gas volume; c: the rate constant; Lag: the time between inoculation and commencement of gas production; IVOMD: in vitro organic matter digestibility; ME: metabolisable energy.

<sup>a–d</sup>Means with different letters within rows differ (p < .05).

Figure 1. In vitro gas production profiles of the forages. Gas production profiles have been fitted to curves using the equation $y = B (1 - e^{-ct} - \text{Lag})$; B, the asymptotic gas volume; c, the rate constant, Lag, the time between inoculation and commencement of gas production.
hay. The highest values of gas production parameters in pangola silage are at least partly caused by the addition of rapidly fermentable carbohydrate in molasses, and higher degradability of the insoluble fraction. Similar values for pangola silage to which molasses had been added before ensiling were observed in a previous study by Tikam et al. (2015). Juárez Reyes et al. (2009) who assessed the nutritive value of different tropical grasses reported higher (*p < .05*) *in vitro* gas production for pangola grass, and it was some 30% less in other grasses (Guinea, Bermuda and Tanzania grasses). They also reported greater (*p < .05*) gas production from the insoluble fraction in pangola grass versus Guinea and Bermuda grasses. The amount of gas produced after 24 h for pangola hay was much higher (40.7 mL/200 mg DM) than those presented by Thiputen and Sommart (2012) (20.7 mL/200 mg DM), which may also be caused by differences in maturity. It underlines the possibility of conserving pangola grass in high quality, especially when using grasses relatively early in regrowth.

**In vivo nutrient digestibility**

During the whole feeding trial, all diets were consumed without problems. One animal from the Ruzi grass treatment had to be taken out of the trial because of health disorders. This caused a slightly lower mean initial body weight of animals in the Ruzi grass group. All results regarding that treatment are based on the remaining three healthy animals while all *in vivo* data for the different forms of pangola were obtained from four animals per treatment.

With the combination of forage-based rations and supplemented concentrates and protein blocks, animal ingested diets with CP concentrations between 100 g/kg DM (Ruzi grass) and 114 g/kg DM (pangola silage, data not shown) which only allows moderate growth rates of growing cattle in tropical countries (McDowell 1985).

Data on *in vivo* digestibility and ME concentrations of the diets are given in Table 3. All diets based on fresh or preserved forms of pangola grass had higher (*p < .05*) nutrient digestibilities and also higher ME concentrations than the control diet which confirms results of the *in vitro* analyses. The OM digestibility is on a comparable level with data presented by Archimède et al. (2000; 64.5%) for pangola grasses with 42 days of age when offered for *ad libitum* consumption to Black-belly rams. The pangola silage diet had higher (*p < .05*) *in vivo* digestibilities of DM, CP and crude fat in comparison with the other forage diets. Higher concentrations of CP and also rapidly fermentable carbohydrates from the addition of molasses might have improved ruminal energy supply of microbes and the improvement in microbial activity resulted in greater DM and apparent CP digestibility. An improvement in digestibility for supplemented pangola silage was also observed by Tikam et al. (2015) when studying the *in vivo* digestibility of different pangola forms in sheep.

The pangola hay diet in this study had a lower (*p < .05*) OM digestibility (61.2%) than the other types of pangola but the same level as the fresh Ruzi grass (61.4%) which emphasises the high competitiveness of pangola. Even the conserved hay form with losses due to drying and transportation is comparable to fresh forms of other tropical grasses like Ruzi in this study or Napier grass as reported by Rahman et al. (2013; 59.5%) and Tikam et al. (2015; 60.6%). All forms of pangola ranked higher in NDF and ADF digestibility than fresh Ruzi grass.

However, previous studies have shown that in Thailand, the OM digestibility of pangola varied from 58.5-76.7% when fed as sole feed (Suzuki et al. 2008; Chobtang et al. 2012) or in forage-based diets (Suksathit et al. 2011). It is strongly affected by stage of maturity (Ventura et al. 1975) with decreases in digestibility with age following a curvilinear course (Archimède et al. 2000) which is mainly caused by lignification of cell walls. Besides reduction in digestibility also lowered intake was observed when feeding 42- and 56-day old pangola in comparison to grasses of younger regrowth (Archimède et al. 2000).

**Table 3. The *in vivo* nutrient digestibility (%) and concentration of metabolisable energy (ME) of the different diets (forages supplemented with concentrate and protein block).**

| Item             | Ruzi grass | Fresh pangola | Pangola hay | Pangola silage | SEM | p     |
|------------------|------------|---------------|-------------|----------------|-----|-------|
| Dry matter       | 59.5<sup>a</sup> | 60.9<sup>b</sup> | 63.1<sup>c</sup> | 65.0<sup>a</sup> | 0.242 | .001  |
| Organic matter   | 61.3<sup>c</sup> | 65.7<sup>b</sup> | 61.2<sup>c</sup> | 69.2<sup>a</sup> | 0.152 | .001  |
| Crude protein    | 50.5<sup>a</sup> | 55.8<sup>b</sup> | 56.3<sup>b</sup> | 58.0<sup>a</sup> | 0.102 | .001  |
| Crude fat        | 43.3<sup>b</sup> | 44.0<sup>b</sup> | 41.4<sup>b</sup> | 48.9<sup>a</sup> | 0.665 | .001  |
| Crude fibre      | 65.2<sup>a</sup> | 67.0<sup>a</sup> | 69.1<sup>a</sup> | 67.1<sup>a</sup> | 0.193 | .001  |
| NDF              | 70.7<sup>c</sup> | 73.2<sup>c</sup> | 74.9<sup>c</sup> | 73.7<sup>b</sup> | 0.149 | .001  |
| ADFom            | 56.8<sup>b</sup> | 58.6<sup>a</sup> | 60.6<sup>a</sup> | 58.7<sup>a</sup> | 0.350 | .001  |
| ME, MJ/kg dry matter | 8.25<sup>c</sup> | 8.85<sup>b</sup> | 8.40<sup>b</sup> | 9.22<sup>a</sup> | 0.067 | .001  |

SEM: standard error of the means; NDF: neutral detergent fibre; ADFom: acid detergent fibre expressed residual ash; ME: metabolisable energy.

<sup>a,b,c</sup>Means with different letters within rows differ (*p < .05*).
6.4 MJ/kg DM reported by Chaokaur et al. (2008) and Nitipot et al. (2009). It shows the high quality of the pangola forage used in this study in terms of feeding value for ruminants.

**Feeding trial**

The DM intake (DMI), BW gain and ADG are shown in Table 4. As intended, the DMI in this study was not significantly different among treatments (\(p > 0.05\)). The ADG of the White Lamphun native bulls were normal and in agreement with Mikled et al. (1991) who raised White Lamphun bulls under feedlot conditions and concentrate supplementation of 1.0 and 1.5% of BW with an ADG of 490 g. However, between treatments, there were differences in BW gain and ADG (\(p < 0.05\)), with cattle fed forms of pangola having higher (\(p < 0.05\)) values than the Ruzi treatment which can be explained by higher ME and CP concentrations. As summarised by Tikam et al. (2013) only few authors studied effects of pangola on growth of ruminants, and especially of cattle, which impedes comparison of the presented data. Highest ADG for Holstein steers fed pangola grass were observed by Hsieh (1990) using four tropical grasses (Pangola, Guinea, dwarf elephant and South African pigeon grass).

In the comparison of all treatments, the highest ADG and BW gain were achieved when feeding pangola silage. It shows the possibility of achieving moderate to high weight gains with indigenous cattle fed forage-based diets also during the dry season. By adding molasses, both a stable fermentation and conservation of the forage as well as increases in nutrient digestibility and ME concentration could be obtained. Higher digestibility and ruminal fermentation activities due to feeding pangola silage probably resulted in the observed increased BW gain and ADG. Feeding diets higher in CP and energy improved the feedlot performance of growing animals (Sultan et al. 1991). Also Preston and Leng (2009) reported that improved nutrition requires increasing the energy density of the diet, ensuring efficient rumen function and providing a complimentary source of bypass protein. The lower BW gain in the Ruzi, fresh pangola and pangola hay treatments in comparison with pangola silage indicate that supplementation with protein and energy source would potentially improve growth performance of growing bulls fed these forages. Also an adequate amount of fertiliser (nitrogen and sulphur) (Minson 1973; Rees et al. 1974) and use of an earlier stage of regrowth (Archimède et al. 2000) can help to improve DM and OM digestibility as well as voluntary intake of pangola grass in different forms. With a good forage management and supplementation of moderate amounts of concentrate pangola grass in both fresh and conserved forms can be used to achieve animal performances of indigenous cattle comparable or, like in the present study, even superior to Ruzi grass and can thus be recommended as a grass species for ruminant feeding especially during dry season in tropical countries.

**Conclusions**

Results from the present study showed that pangola grass is a feasible alternative as forage source for cattle in tropical countries. It could be well preserved as silage and hay. Pangola silage ensiled with molasses increased organic matter digestibility and thus, ME concentration, BW gain and ADG of Thai indigenous cattle fed forage-based diets and can thus be recommended as a grass species for feeding especially during dry season in tropical countries.

**Acknowledgements**

This study was financially supported by Institute of Animal Science, University of Bonn, Japan International Research Center for Agricultural Sciences (JIRCAS) and National...
Science and Technology Development Agency (Northern Network)-Thailand. Dr. Uchenna Young Anele is acknowledged for editing an earlier version of the manuscript.

**Disclosure statement**

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of this article.

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