Formulating diets based on whole cassava tuber (*Manihot esculenta*) and gliricidia (*Gliricidia sepium*) increased feed intake, liveweight gain and income over feed cost of Ongole and Bali bulls fed low quality forage in Central Sulawesi, Indonesia

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Abstract

**Context.** Formulating rations with high energy and protein feeds such as cassava tuber and gliricidia, is an important strategy to increase liveweight gain (LWG) of bulls and improve profitability of smallholder farmers in Indonesia.

**Aims.** Two on-farm experiments were conducted to evaluate the effect of increasing the supplementation level of a mixture of cassava (*Manihot esculenta*) whole root tuber powder and fresh gliricidia (*Gliricidia sepium*) on feed intake and LWG of Ongole and Bali bulls given fresh corn stover and elephant grass, respectively.

**Methods.** Two experiments were conducted, each with five treatments: a basal diet of fresh corn stover (Experiment 1 for Ongole bulls) or elephant grass (Experiment 2 for Bali bulls) fed ad libitum or this diet supplemented with a combination of cassava tuber (whole root tuber including peel, sun-dried and ground) and fresh, chopped gliricidia (1:1) on estimated dry matter (DM) basis, at DM levels of 0.4, 0.8, 1.2 and 1.6% liveweight (LW)/day. Each experiment was run for 18 weeks, consisting of a two week adaptation and 16 week experimental period. Parameters measured included basal DM intake, supplement DM intake, total DM intake, total water intake, faecal pH, daily LWG, feed conversion ratio (FCR) and income over feed cost (IOFC).

**Key results.** Increasing supplement level linearly ($P < 0.05$) decreased basal diet intake, but linearly increased total DM intake and LWG ($P < 0.05$) in both breeds. Basal diet DM intake was reduced at the rate of 0.43 kg/kg of supplement DM consumed for both Ongole and Bali bulls. Water intake and faecal pH were not affected ($P > 0.05$) by increasing supplement intake. Inclusion of cassava tuber and gliricidia supplement up to 1.6% LW/day, increased total feed DM intake (up to 3.28 and 3.18% LW/day, for Ongole and Bali bulls, respectively) and LWG (maximum Ongole bulls 0.69 kg/day and Bali bulls 0.46 kg/day). Daily income over feed cost (IOFC) increased significantly ($P < 0.05$) in association with increased supplement intake in both Experiments 1 and 2. Using the derived model without supplementation, the value of IOFC was only IDR 7802/day and IDR 7687/day, for Experiments 1 and 2, respectively. The highest IOFC was achieved at a supplement intake of 1.6% LW/day with values of IDR 13 949/day and IDR 12 543/day for Experiments 1 and 2 respectively.

**Conclusions.** The addition of a cassava tuber and gliricidia mixture up to 1.6% LW/day increased LWG and profit for smallholders fattening bulls.

**Implications.** Formulating a ration with cassava tuber and gliricidia can be economically beneficial in cattle fattening systems in Indonesia.

**Keywords:** bull, cassava tuber, forage, gliricidia, smallholder farmers, supplementation, legume, liveweight gain, feeding strategy.

Received 15 May 2020, accepted 13 February 2021, published online 11 March 2021

Introduction

Small scale fattening bull enterprises are growing rapidly across Indonesia, in particular Central Sulawesi, due to the increasing demand for domestic beef and for income potential.

Most of the bulls are managed by smallholder farmers under traditional management systems with low input. The bulls are fed with locally available forages such as corn stover (CS) (*Zea mays*), elephant grass (EG) (*Pennisetum purpureum*) or...
native grass as a single feed in a cut and carry system. CS and EG have low metabolisable energy (ME) values (8.4 MJ ME/kg DM (Heuze et al. 2019) and 7.9 MJ ME/kg DM (Heuze et al. 2016b), respectively, and crude protein (CP) content (range 5–12%, Poppi et al. 2009; Heuze et al. 2016b, 2019; Rusdy 2016) and result in low liveweight gain (LWG) or even a loss in LWG with the potential to promote a high LWG and economic benefit to farmers. Gliricidia (Gliricidia sepium) is a widely distributed tropical tree legume containing high levels of CP (22.4% CP, Marsetyo et al. 2012). Gliricidia grows abundantly in Central Sulawesi where smallholders have free access to use as a living fence or cover for forages which had not been previously reported. Cassava tuber and gliricidia were prepared in equal proportions on a DM basis, and offered separately. The quantity of fresh feed offered was based on the DM content measured at the commencement of the experiment for the tabulated feed analysis data. Final feed DM content for each treatment was calculated as the sum of the quantity of fresh feed offered, and the quantity of feed feed offered as a supplement containing cassava tuber and gliricidia to bulls fed low-quality forages which had not been previously reported.

Materials and methods

Two separate on-farm experiments were conducted in parallel and aimed to evaluate the effect of increasing the level of supplementation of a cassava tuber and gliricidia mixture on ad libitum intake, LWG and other parameters in Ongole (Experiment 1) and Bali (Experiment 2) bulls fed low quality roughage basal diets.

Sites, animal and experimental design

Both on-farm experiments were conducted concurrently at two different villages over 18 weeks between January and May 2018. The Ongole bull experiment (Experiment 1) was carried out at village Bolu Pountu (00°00'58"–01′01″00′0S, 119°56′00″–119°58′00″E) Sigi subdistrict, Donggala region, Central Sulawesi, Indonesia and the Bali bull experiment (Experiment 2) was conducted at Malonas village (0°30′N to 2°20′S and 119°45′–121°45′E) Dampelas subdistrict, Donggala region, Central Sulawesi, Indonesia.

Fifty Ongole bulls, with a mean weight of 209 ± 4.7 (s.e.) kg and Bali bulls with a mean weight of 157 ± 3.7 kg, and both bull groups aged between 12 and 18 months, were used. The bulls were purchased from local markets around Palu, Sigi and Donggala regions, Central Sulawesi. All bulls were treated with Ivomec before the commencement of the experiment with the dose 1 mL per 50 kg LW to control internal and external parasites. This experiment was approved by the University of Queensland Animal Ethics committee (SAFS/516/17/INDONESIA/VILLAGE).

Each experiment consisted of 18 weeks: 2 weeks for adaptation and a 16 week experimental period. The design for each experiment was a completely randomised block design, with five treatments and 10 replicates (animals) per treatment. At the beginning of the experiment, animals were ranked and blocked on the basis of an unfasted liveweight. Animals were then allocated randomly to individual pens and treatment within each block. In Experiment 1, fresh CS was fed to Ongole bulls ad libitum. In Experiment 2, fresh EG was fed ad libitum to Bali bulls. Both experiments were supplemented with cassava tuber and gliricidia (CG, 1:1) at the following DM rates: 0.4% LW/day (CS + 0.4 CG or e.g. + 0.4 CG), 0.8% LW/day ((CS + 0.8 CG or e.g. + 0.9 CG), (1.2% LW/day (CG, CS + 1.2 CG or e.g. + 1.2 CG) and 1.6% LW/day (CS + 1.6CG or e.g. + 1.6 CG). Cassava tuber and gliricidia were prepared in equal proportions on a DM basis, and offered separately. The quantity of fresh feed offered was based on the DM content measured at the commencement of the experiment for the tabulated feed analysis data. Final feed DM content for calculations were measured from daily subsamples.

The fresh CS provided to Ongole bulls in Experiment 1 was purchased from local corn farmers and brought to the pen by the purchasers every day. For Bali bull farmers in Experiment 2, EG was grown on their own land and harvested daily. The EG was cut at ~50 days regrowth. At both sites, bulls were housed in a communal animal house and all feed was bulked, mixed and fed locally. Bull ownership and care was maintained by individual farmers but under the daily supervision of a graduate student who was responsible for all data collection and recording. The basal diets were fed in the fresh form, bulked and chopped using a mechanical chopper into lengths of 10 to 15 cm before feeding. The amount of feed offered weighed 10–15% more than feed consumed on the previous day. Fresh gliricidia was obtained for free and collected each afternoon from

Heuze et al. 2016; Wanapat and Kang 2015) and is available abundantly in Indonesia. Indonesia is the third largest producer of cassava in the world with ~1.0 million ha of cassava producing 23.9 million tonnes of gaplek (dried peeled cassava tuber) (Widaningsih 2016). Cassava tuber has potential as a supplement in cattle fattening systems as it is high in ME which could promote LWG, but is low in CP (12.4 MJ ME/kg DM) (Heuze et al. 2013) and is available in Indonesia. Cassava and gliricidia for cattle, but is also cultivated to provide a living fence or cover forages, and farmers buy cattle, fatten for a period and aim to sell at a profit. The sale weight is not set and farmers attempt to meet religious festivals or turnover animals quickly within 3–4 months. Animals preferably need to reach weights of 300 kg for Bali bulls and over 350 kg for Ongole bulls, but under current feeding regimes it takes between 6 and 10 months to reach a selling weight at a local market. Marsetyo and Pamungkas (2006) and Marsetyo (2012) reported that Bali cattle (across a range of locations in Indonesia and class of cattle), given native grass only, gained up to 200 g/day and with CS or EG gained 170–230 g/day. Mastika (2003), however, has shown that Bali cattle gained up to 850 g/day when given high-quality feed (EG + 4 kg concentrate (18% CP, 72% total digestible nutrient) and indicated the potential to increase growth rates of Bali bulls. Feeding strategies need to be developed within the existing constraints of the smallholder fattening system.

Formulating a ration with a high ME and CP content is an important strategy to boost the growth performance of bulls within these smallholder farms. Cassava (Manihot esculenta) root tubers have a high starch (85%) (Fakir et al. 2013) and ME content (12.4 MJ ME/kg DM) (Heuze et al. 2016) but very low in CP (1–3%) (Stupak et al. 2006; Ba et al. 2008; Wanapat et al. 2013; Wanapat and Kang 2015) and is available abundantly in Indonesia. The fresh CS provided to Ongole bulls in Experiment 1 was purchased from local corn farmers and brought to the pen by the purchasers every day. For Bali bull farmers in Experiment 2, EG was grown on their own land and harvested daily. The EG was cut at ~50 days regrowth. At both sites, bulls were housed in a communal animal house and all feed was bulked, mixed and fed locally. Bull ownership and care was maintained by individual farmers but under the daily supervision of a graduate student who was responsible for all data collection and recording. The basal diets were fed in the fresh form, bulked and chopped using a mechanical chopper into lengths of 10 to 15 cm before feeding. The amount of feed offered weighed 10–15% more than feed consumed on the previous day. Fresh gliricidia was obtained for free and collected each afternoon from

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surrounding areas for the subsequent morning feeding. Only leaf and young stem was fed to bulls. Cassava tubers were purchased from local traders. The whole root tubers (including peel) were then ground using a mechanical grinder and sundried for 2–3 days. Supplements were offered twice a day at 0730 and 1300 hours. CS or EG were given twice a day at 0900 and 1500 hours. All supplemented bulls received a mineral mix containing calcium 165 g, phosphorus 52 g, sodium 157 g, iron 2.5 mg, copper 2.5 mg, manganese 2 g, iodine 0.125 g, cobalt 0.05 g, zinc 5 g and selenium 0.01 g per kg that was included at a rate of 2% inclusion of the total ration (DM). For unsupplemented bulls, mineral was poured on the forage in the feed trough and hand mixed. For supplemented bulls, mineral was hand mixed with cassava tuber in the feed trough. Drinking water was offered ad libitum which was provided in a plastic bucket in each pen.

Sampling procedures and measurements
Feed intake for each bull was measured daily during the experimental period. Representative subsamples of feed offered were taken every day and dried in an oven at 60°C for 2–3 days to determine the DM content. Feed residues for each bull were bulked each week and a subsample taken to determine the DM content. ME intake was estimated by multiplying total DM intake and ME content of feed component. Liveweight was recorded fortnightly using electronic scales (Sonic A12-E) calibrated with standard weights at time of measurement and LWG was estimated by regression of liveweight against time of experiment. Feed conversion ratio (FCR) was calculated based on the average amount of feed consumed by a bull (kg/day) over the whole 16 week period divided by LWG of the bull (kg/day) to give a FCR unit kg feed DM/kg LWG. Daily total water intake was calculated from drinking water consumption plus the estimation of water intake from the feed (feed moisture). Imbibed water intake was recorded by measuring water offered and refused each day and adjusted for evaporation rates in the pens over the same time period on Weeks 3, 9 and 15. Evaporation rate was measured with buckets placed in pens with no cattle and measuring the loss of water over the week measured. The faecal pH of each bull was measured each day (total 7 days) during Weeks 3, 9 and 15 between 0730 and 0930 h in the morning by sampling fresh faeces from the floor. About 10 g of fresh faeces was taken from each bull and mixed well with deionised water at a ratio 1:1 (w/w) and pH determined with a portable pen type pH meter (unbranded) which was calibrated each day before use.

Chemical analyses
Dried samples of each feed were bulked for each week and ground to pass through a 1 mm screen. Feed samples were then analysed for organic matter according to AOAC (1990), while the CP content was determined using micro Kjeldhal. The content of ash-free neutral detergent fibre of the feed was measured according to the technique described by Van Soest et al. (1991). The concentration of hydrogen cyanide (HCN) of cassava tuber was measured at Jember University using a technique developed by Marlina (1996). Briefly, this is a modified picric paper method of Bradbury et al. (1999) and included a drop of chloroform to a cassava sample to allow for better hydrolysis of the cyanogenic glucosides to HCN.

Economic analysis
The economic analysis involved data such as the LWG value (IDR/bull.day), which was determined by the average daily gain (kg/day) multiplied by the average of the purchase and sale price per kilogram liveweight (IDR/kg) for each bull. Economic data also includes the cost of the feed and the amount of feed consumed by the bull. The cost of feeds purchased was recorded, and the cost of unpurchased feed was estimated using labour and transportation costs. These prices were then used to calculate income over feed cost (IOFC), which was determined using the method of Bailey et al. (2009), by measuring what remains of the income after subtracting the feed cost with sale price/kg liveweight of the bull on a per day basis.

Statistical analyses
Effect of dietary treatments on basal diet DM intake, total DM intake, LWG, water intake, faecal pH, FCR, LWG IDR value, feed cost and IOFC were performed using regression analyses in Minitab software version Minitab® 16.1 with a significance level set at 5%. No statistical comparison was made across the two experiments. Linear and quadratic terms were fitted and quadratic terms were removed when not significant.

Results
Feed composition
The chemical composition of the experimental feed ingredients is outlined in Table 1. The nutrient content of the CS was very similar to that of the elephant grass. Cassava tuber had a very low CP content. The concentration of HCN in the diets was 14.4 and 17.9 ppm for Experiments 1 and 2 respectively, which is categorised as low and safe for animals.

Animal parameters
All bulls receiving cassava tuber and gliricidia consumed their total allocation of the supplement. Both supplements were eaten in the same proportion (1:1) in Experiments 1 and 2. The effect of increasing intake of cassava tuber and gliricidia on basal and total intake is represented in Fig. 1 for both experiments. The average DM intake of the basal feed of unsupplemented bulls over the 16 weeks period was 2.35 and 2.29% LW/day for Ongole and Bali bulls, respectively. In both experiments, feeding the supplement was associated with a decrease in basal feed intake (substitution) and an increase in total feed intake. For both Experiments 1 and 2, basal feed DM intake declined linearly in association with increasing supplement DM intake with equations $y = 2.41 - 0.432x$, ($R^2 = 97.4\%$), and $y = 2.31 - 0.444x$ ($R^2 = 99.3\%$), respectively, where, $y$ is basal diet DM intake (% LW/day) and $x$ is supplement DM intake (% LW/day). Substitution was calculated from the slope of the linear regression of hay intake against supplement intake and was the reduction of basal diet DM intake (kg) per kg supplement DM intake. In both Experiments 1 and 2, basal diet intake was reduced at the
rate of 0.43 and 0.44 kg basal diet DM/kg of supplement consumed, respectively. In contrast, a linear increase was observed in total DM intake in association with increasing supplement DM intake for both experiments, with the equations, $y = 2.41 - 0.43x$ ($R^2 = 0.86; P < 0.01$) for Experiment 1 with Ongole bulls, and $y = 3.08 - 0.56x$ ($R^2 = 0.91; P < 0.01$) for Experiment 2 with Bali bulls.

Increasing the intake of cassava tuber and gliricidia had no significant effect on total water intake (imbibed water and water from feed) which averaged 15.9% LW/day for Experiment 1, and 14.7% LW/day for Experiment 2. Increasing the intake of supplement also had no significant effect on faecal pH which remained constant at 6.5 for both experiments.

The effect of increasing supplement intake on LWG of Ongole (Experiment 1) or Bali (Experiment 2) bulls is shown in Fig. 2. There was a similar pattern of the response of Ongole and Bali bulls to increasing intake of the cassava tuber and gliricidia mixture on LWG. In both experiments, increasing supplement intake was associated with a significant linear increase ($P < 0.01$) in bull LWG. Bulls supplemented at the 1.6% LW/day level of combination of cassava tuber and gliricidia had the highest daily LWG (Experiment 1 0.69 kg/day, Experiment 2 0.46 kg/day, Fig. 2). Average daily LWG of bulls fed only on fresh CS (Experiment 1) or EG (Experiment 2) over the duration of the experiment was 0.31 and 0.20 kg/day, respectively. Daily LWG of Ongole bulls...
tended to be higher than Bali bulls at a similar level of treatment. FCR showed a similar pattern in both experiments. In Experiment 1 and 2, FCR decreased significantly \((P < 0.01)\) by supplementation of a mix of cassava tuber and gliricidia (Fig. 3).

Table 2 shows daily LWG value (IDR/bull.day), daily feed cost and IOFC for Ongole and Bali bulls. Daily LWG value was calculated by multiplying the average of the purchase and sale price per kilogram liveweight (IDR/kg LW) with average daily LWG of each bull. The average price of bulls was Indonesian rupiah ( IDR) 48 000 and 50 000/kg liveweight for Ongole and Bali bulls, respectively. There was a linear increase in LWG IDR value \((P < 0.01)\) with increasing supplement intake for both experiments. In both experiments using the determined models, bulls supplemented at 1.6% LW/day had the highest LWG value (Experiment 1 Ongole bulls 31 160 IDR/bull.day; Experiment 2 Bali bulls 22 187 IDR/bull.day).

The daily feed cost of diet included the purchase of a basal diet for unsupplemented bulls, and basal diet plus a supplement for supplemented bulls. Feed such as EG and gliricidia were readily available locally and not purchased at the village level, but the value of labour or transport used to obtain the feed was calculated. The cost of fresh CS, cassava tuber and gliricidia at Sigi District was IDR 1135, 4267, and 1667 per kg DM, respectively, whereas EG, cassava tuber and gliricidia at Donggala district was IDR 638, 4367 and 1000 per kg DM, respectively. The daily total feed cost increased linearly \((P < 0.01)\) from 6366 to 17 210 IDR for Experiment 1 and 2446 to 9644 IDR for Experiment 2 in association with increasing supplement intake (Table 2). The IOFC linearly increased \((P < 0.01)\) with supplementation from 7802 to 13 949 IDR for Experiment 1 and 7687 to 12 543 IDR for Experiment 2.

Discussion
A supplementation strategy using two locally-available feed resources markedly increased intake and LWG of both Ongole and Bali bulls within a smallholder system. The combination of a high starch ingredient (whole cassava tuber) and a tree legume (gliricidia) provided a supplement mix of a high ME content and CP content (12.0 MJ ME/kg DM and 11.6% CP) (Table 1). The LWG response to level of cassava tuber/gliricidia supplement was linear up to the highest level used (1.6% LW/day) reaching 0.69 and 0.46 kg/day for Ongole and Bali bulls respectively. This demonstrates that successful feeding systems can be devised when the diet quality is

![Fig. 2. The effect of increasing dry matter intake of gliciridia and cassava tuber (1:1) supplement mix on liveweight gain of Ongole (Experiment 1) and Bali (Experiment 2) bulls. Points in brackets represent the mean value for 10 bulls. Ongole bulls closed circles, Bali bulls open circles.](image)

![Fig. 3. The effect of increasing dry matter intake of gliciridia and cassava tuber (1:1) supplement mix on feed conversion ratio of Ongole (Experiment 1) and Bali (Experiment 2) bulls. Points in brackets represent the mean value for 10 bulls. Ongole bulls closed circles, Bali bulls open circles.](image)

| Parameter                      | Equation                  | R²  | P-value |
|-------------------------------|---------------------------|-----|---------|
| **Experiment 1 Ongole bulls** |                           |     |         |
| LWG value (IDR/bull.day)      | \( y = 14168 + 10620x \) | 0.90| <0.01   |
| Total feed cost (IDR/bull.day)| \( y = 6366 + 6778x \)   | 0.80| <0.01   |
| IOFC (IDR/bull.day)           | \( y = 7802 + 3842x \)   | 0.41| <0.01   |
| **Experiment 2 Bali bulls**  |                           |     |         |
| LWG value (IDR/bull.day)      | \( y = 10133 + 7534x \)  | 0.69| <0.01   |
| Total feed cost (IDR/bull.day)| \( y = 2446 + 4499x \)   | 0.87| <0.01   |
| IOFC (IDR/bull.day)           | \( y = 7687 + 3035x \)   | 0.30| <0.01   |
increased particularly the ME content and CP% (Thang et al. 2010; Wanapat and Kang 2015).

There was a substitution effect associated with the level of supplement (Fig. 1), but total DM and ME intake increased linearly over the level of supplementation for both bull types. The substitution effect with a supplement causes reduced basal pasture intake and is a common response when a basal diet of grass is supplemented with a high-energy feed. This substitution effect of supplement for basal diet in these experiments was 0.43 and 0.44 (kg DM reduction in intake of basal forage/kg DM supplement consumed: kg DM/kg DM) for Experiments 1 and 2, respectively. The rate of substitution of the current study is lower than in the study of Ba et al. (2008) who reported that supplementation of cassava tuber at level at 0.3, 0.7, 1.3 and 2.0% LW/day, curvilinearly depressed rice straw intake of Lainsind cattle at the rate of 0.5–0.7 (kg DM/kg DM). Various authors (Doyle et al. 1988; Marsetyo 2004) have suggested that concentrates which were degraded rapidly in the rumen such as a high starch supplement, caused a greater substitution effect than a concentrate, which was slowly degraded in the rumen.

Ongole and Bali bulls consuming the basal diet of either CS or EG, demonstrated the lowest LWG (0.31 and 0.20 kg/day, respectively), across the two experiments and is in agreement with results of previous work (Marsetyo et al. 2012). Antari et al. (2016) reported that LWG of Ongole cattle given EG only was 0.18 kg/day. Both CS and EG are typical diets used by farmers under village management systems across Central Sulawesi. In Central Sulawesi, corn cobs are traditionally harvested at the milky dough stage for human consumption therefore the quality of the CS is comparable to tropical growing grass such as EG. Similarly, young Bali calves fed native grass or EG only gained 0.12 kg/day in East Java, 0.03 kg/day in Lombok, 0.02 kg/day in West Timor, 0.17 kg/day in Central Sulawesi (Poppi et al. 2009) and 0.16 kg/day in South-east Sulawesi (Saili et al. 2010).

Ongole and Bali bulls have higher potential LWG than recorded in this study. Moran (1985) and Haryanto and Pamungkas (2010) and Ndagiyono et al. (2019) showed LWG of 0.57–1.2 kg/day for Ongole bulls whereas Moran (1985), Mastika (2003) and Panjaitan et al. (2014) showed LWG of 0.61–0.85 kg/day for Bali bulls. The bulls in this study may have reached a higher LWG under a higher level of supplement but Retnaningrum et al. (2020) found that there was a maximum of 40% inclusion of cassava tuber in the total diet before intake and LWG declined. This level would be reached at ~2.6% LW/day supplement mix of cassava tuber and gliricidia (1.3% LW/day cassava tuber) if the total DM intake was 3.3% LW/day. It appears as if a much higher level of the supplement mix could be used by farmers.

Gliciridioa alone as a supplement gives an improved LWG response. A gliciridia supplement at a rate of 1% LW/day to Bali bulls fed either EG or fresh CS increased LWG from 0.17 to 0.28 kg/kg/day and from 0.23 to 0.31 kg/kg/day respectively (Marsetyo et al. 2012). The rationale for using a combination of gliciridia with cassava tuber was to increase the ME content and potentially higher LWG response of the supplement mix. In this study there was increase in LWG at a comparable level of supplement to Marsetyo et al. (2012) (increase of 0.19 kg/day vs 0.08 kg/day respectively). The experiments are not directly comparable but the desire to formulate a supplement mix of high ME and adequate CP content suggested the combination of cassava tuber and gliricidia. Cassava tuber with urea would similarly meet this requirement but there is a safety issue in feeding urea in mixtures in smallholder systems with potential for toxicity.

There was no negative effect of level of cassava tuber intake on total DM intake and LWG as has been observed previously (Ba et al. 2008; Cowley et al. 2020) but recognising that the highest level of supplement was less than that used by Ba et al. (2008) and Cowley et al. (2020). The upper level of cassava tuber inclusion was set by the need for safety in using cattle provided by farmers and to have relevance in the upper levels of expenditure by farmers. At all treatment levels, the supplement was readily accepted and consumed quickly within the hour. It would have been of interest to have used higher levels of supplement but this was not possible.

Cassava tubers are high in starch and almost completely digested (Tudor et al. 1985). High intakes of cassava tuber may reduce rumen pH, causing rumen dysfunction (Ba et al. 2008), which can depress fibre digestion and therefore basal diet intake (Orskov 1986). The upper level of cassava tuber was ~24% of the total diet for both feeding scenarios and this is well below the upper value of 40% cassava tuber inclusion, suggested by Retnaningrum et al. (2020), before depression in total food intake occurred. To slow the rate of starch consumption and minimise metabolic disorders related to rumen pH, the supplement was fed at least twice daily. Faecal pH was measured and it was in the normal range and not aligned with level of supplement. This suggests little escape of starch from the rumen and small intestine and fermentation within the hind tract. Limiting the cassava tuber supplementation to 0.8% LW and feeding several times per day, minimised possible starch intake issues as reflected by the experimental faecal pH values.

The cassava plant parts contain substantial amounts of cyanide in the form of cyanogenic glycosides, which are present in the cell vacuoles and when hydrolysed yield HCN. Drying and processing methods can substantially reduce HCN levels (Lukuyu et al. 2014). The concentrations of HCN in the cassava tuber in the current experiments were 14.5 (Experiment 1) and 17.9 mg/kg DM (Experiment 2) or estimated 3.5 (Experiment 1) and 4.3 mg HCN/kg DM (Experiment 2) in the total ration for the highest supplement level in the final ration consumed. These values were below the recommended safe level of HCN in the diet of 50 mg/kg DM (Bolhuis 1954).

Total water intake (from feed and imibed) was not significantly (P > 0.05) affected by increasing supplement intake, which ranged from 15.4 to 16.2% LW/day equivalent to 4.62–6.50 kg water/kg DM intake for Ongole bulls, and from 13.9 to 15.5% LW/day equivalent to 4.35–6.58 kg water/kg DM intake for Bali bulls. These water intakes of both breeds were in the range of water intake of cattle in previous studies. Freer et al. (2007) reported that water intake for weaned Bos indicus cattle was 4.5–6.0 kg water/kg DM intake. Antari et al. (2016) recorded total water intake of Ongole bulls was 0.4 kg/kg metabolic weight or 29% LW/day. With Bali bulls,
Dahanuddin et al. (2014) recorded total water intake of 14.0–15.2% LW/day. With smallholders, providing drinking water to the pen requires extra labour and the importance of water intake is often not recognised. The current results suggest that not much extra water needs to be provided if farmers are using fresh forages with high water content.

In the current study, for both Ongole and Bali bulls, inclusion of a supplement of cassava tuber and gliricidia was associated with an improvement in FCR, but there was no significant difference (P > 0.05) between each level of supplement. At zero supplementation the FCR value was 18.4 and 19.7 kg feed DM/kg LWG for Ongole and Bali bulls, respectively. At highest level of supplementation (1.6% LW/day) both Ongole and Bali bulls required less feed/kg LWG, with FCR value 12.6 and 13.0, respectively. These current FCR are within the range recorded in previous experiments. Antari et al. (2016) recorded that FCR of Ongole and Limousin Ongole bulls given EG was 24 and 16, respectively. Ngadiyono et al. (2019) reported that FCR of Ongole and Limousin Ongole (liveweight more than 300 kg) fed concentrate and King grass (70:30) was 11.7 and 14.2, respectively. Retnaningrum et al. (2020) recorded FCR in Limousin × Ongole bulls of 5.6 and a LWG of 1.35 kg/day in a feedlot ration based on cassava tuber, protein meal and fresh CS. This suggests that formulating diets and supplements to achieve high ME content and feeding them at high levels rather than simply the cheapest feed ingredients results in greater FCR and LWG, but whether profitable for farmers will depend on ingredient cost.

Daily feed cost for each bull was higher for Ongole bulls, which ranged from IDR 6366 to 17 210/day than for Bali bulls, which ranged from IDR 2446 to 9644/day (Table 2). On average, Bali bulls were smaller than Ongole bulls, therefore less feed was required. Moreover, the price of EG and gliricidia in the Bali bull area was cheaper than fresh CS and gliricidia in the Ongole bull area. In general, all local feed prices can be less as some smallholder farmers often involve family members to collect feed for free in both sites so opportunity costs are viewed differently. The daily feed price cost of this current study is within the range of feed costs of smallholder bull fattening operations in East Java (Ratnawati et al. 2015). The cost of gain was improved for both breeds with the best result at 1.6% LW/day level of supplement (Fig. 3; Tables 2, 3). The cost of gain can be compared with the sale price at the time of the experiment of IDR 48 000/kg for Ongole bulls, and IDR 50 000/kg for Bali bulls, liveweight sale price in Central Sulawesi.

Income over feed cost increased significantly (P < 0.05) in association with increasing supplement intake in Ongole bulls and Bali bulls (Tables 2,3). The highest IOFC was found in Ongole or Bali bulls supplemented at the highest level (1.6% LW/day) of supplement intake with total value of IDR 1 786 680 (or IDR 15 665/day) and IDR 1502250 (or IDR 13 302/day), respectively. The two concurrent experiments could not be compared statistically but the similarity in their results is remarkable (Fig. 3). This consistency between both experiments and both breeds implies the use of a combination of high ME feed and protein supplement from tree legumes would be very profitable for smallholder fattening systems across Indonesia. Responses may be even higher at higher levels of supplement.

Farmers need to plan for a fattening operation over ~3–4 months depending on the market and the need for cash flow. Table 3 outlines the total amount of individual

Table 3. Summary values over 16 weeks of feeding, of the effect of increasing whole cassava tuber powder and gliricidia supplementation (1:1) intake on the total dry matter (DM) intake of basal forage diet (elephant grass (EG) or corn stover (CS)), total feed cost (IDR), total cumulative liveweight gain (kg) and value of weight gain (IDR) for Ongole bulls fed fresh corn stover (Experiment 1) or Bali bulls fed elephant grass (Experiment 2).

| Parameters over 16 weeks | CS | CS +0.4CG | CS +0.8CG | CS +1.2CG | CS +1.6CG |
|--------------------------|----|-----------|-----------|-----------|-----------|
| **CS**                   |    |           |           |           |           |
| Corn stover intake (kg DM) | 631 | 634       | 568       | 534       | 499       |
| Gliricidia intake (kg DM) | 0   | 56        | 109       | 171       | 238       |
| Cassava intake (kg DM)    | 0   | 56        | 107       | 168       | 233       |
| Total feed cost (IDR)     | 716 | 1 051     | 1 282     | 1 608     | 1 957      |
| Total cumulative weight gain (kg) | 35 | 47       | 58        | 68         | 78        |
| Total cumulative weight value (IDR/bull) | 1 680 | 2 256 | 2 784 | 3 260 | 3 744 |
| Total income over food costs (IDR/bull) | 963 | 1 204 | 1 501 | 1 656 | 1 786 |

**Experiment 2:** Bali bulls

| Parameters over 16 weeks | EG | EG +0.4CG | EG +0.8CG | EG +1.2CG | EG +1.6CG |
|--------------------------|----|-----------|-----------|-----------|-----------|
| Elephant grass intake (kg DM) | 435 | 414 | 410 | 362 | 341 |
| Gliricidia intake (kg DM) | 0 | 38 | 80 | 118 | 164 |
| Cassava intake (kg DM) | 0 | 38 | 80 | 118 | 164 |
| Total feed cost (IDR) | 277 | 468 | 690 | 864 | 1 097 |
| Total cumulative weight (kg) | 23 | 31 | 39 | 44 | 52 |
| Total cumulative weight value (IDR/bull) | 1 150 | 1 550 | 1 950 | 2 200 | 2 600 |
| Total income over food costs (IDR/bull) | 872 | 1 081 | 1 259 | 1 335 | 1 502 |
feed ingredients required over 16 weeks and the total return (income over feed costs) for that period. A significant amount of feed needs to be budgeted and also to get the higher overall profit for a 16 week period there is a considerable outlay to buy feed and some farmers may not have that cash reserve nor be prepared to take the risk. There is an increase of 2.7–4 times the cost of a simple forage ration versus providing a supplement at 1.6% LW/day. Nevertheless, the increase in profit is ~1.8 times that of forage alone. In this region, the cost of cassava tuber is quite high, but if farmers were to grow their own cassava at an estimated cost of IDR agreed 1000/kg DM compared with the purchase price in the market of IDR for 4300/kg DM, the daily cost of gain and IOFC would be considerable improved over the current study. The cost of peeled cassava tuber (gaplek, Indonesian terminology) bought from traders is approximately IDR 3000/kg DM in East Java, much lower than in Central Sulawesi, which would result in an increase in IOFC for the whole 16 weeks of IDR 2 082 000 (Experiment 1) and 172 000 (Experiment 2) at the highest level of supplement compared with values in Table 3 (IDR 1 787 000 and 1 502 000 respectively). Gliricidia is grown widely across Indonesia and there is little cost in harvesting, however a labour cost has been included in these calculations although it is debatable if a smallholder takes this into account when looking at opportunity costs. This research highlights the opportunity for altering the systems of production and the likely benefits. The difficulty in establishing a particular recipe for a feeding regime in an animal production system is what to do if ingredients become unavailable or rise markedly in price. A least cost ration formulation system would be beneficial in addressing this whilst not compromising on final ration nutrient composition. It is important to formulate a ration which contains as high an ME content as possible given local ingredients, and ~10–12% CP.

Conclusions

Ongole and Bali bulls fed low-quality forages can increase their total feed intake, LWG and FCR through supplementation with a mixture of cassava tuber powder and gliricidia up to the level 1.6% LW/day with very similar and consistent results across both sites and breeds. Increased supplement intake was associated with an increase in daily feed cost but daily income over food costs almost doubled as a consequence of the much higher LWG. This was a more profitable strategy.

Conflict of interest

The authors declare no conflicts of interest.

Acknowledgements

We thank the Australian Centre for International Agricultural Research for funding this research. We also thank the farmers at Bolu Pountu and Malonas villages for providing pens, bulls and other facilities to support these experiments. Appreciation is also given to Ujang Kurniawan, staff at the Nutrition laboratory and students at Department of Animal Science, Tadulako University for their assistance in carrying out the experiments and feed analysis.

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Handling editor: Dean Thomas