Feed Profile of a Cut-and-Carry Feedlot Cattle Farming System in Sabah and Implications for Feedlot Feed Management

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ABSTRACT Little is known about feed profile of the cut-and-carry feedlot cattle farming system in Sabah. Thus, a study was conducted to perform metabolic energy budgeting at SPT 16 Tawau to assess the feed demand and supply of the said system. Available data were retrieved from 2008 to 2013, analysed and evaluated to identify the feed supply components of the system. The average herbage consumed in the system, expressed in proportion to the cut-and-carry paddocks, was 6.22 t DM ha^{-1} yr^{-1}. In herbage equivalent, the average concentrate consumed and feed loss as live weight loss energy were respectively 1.80 t DM ha^{-1} yr^{-1} and 0.59 t DM ha^{-1} yr^{-1}. It appears that the amount of herbage consumed is lower than the potential dry matter production of around 21.3 t DM ha^{-1} yr^{-1} based on the availability of light and rainfall for the region. The amount of concentrate consumed is relatively low, and this could be replaced with well-cultivated and high quality herbage to reduce overall feed cost. There is a need to reduce feed loss as live weight loss energy, so that a higher proportion of the herbage produced in the system could be retained as animal live weight. Based on the system feed conversion efficiency statistics, the Brahman animals tend to require more concentrate or high quality feeds compared to the Bali cattle, which could thrive more on herbage, or feed of lower nutritive value. However, the Droughtmaster cattle demanded a good balance of herbage and concentrate. Quite often the low level of animal production under the cut-and-carry feedlot farming system in Sabah has been associated with low feed production. Nevertheless the improvement of feed production alone cannot be considered as the only direct solution, as other factors, including improving system feed conversion efficiency are paramount for improving live weight gain in the whole system.

KEYWORDS: Cut-and-carry feedlot farming system; System feed conversion efficiency; Feed profile; Tropical pasture; Metabolic energy budgeting.

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TRANSACTIONS ON SCIENCE AND TECHNOLOGY

INTRODUCTION

The number and size of beef cattle farms in Sabah has not been accurately enumerated. Anecdotally, it is believed that there are 1,800 beef cattle farmers involved in beef production, practicing a variety of farming systems, which include cut-and-carry feedlot farming systems (CCFS) (13 of the 14 dairy cattle farms with a total size of 2,321 ha), grazing systems (GRZS) (a majority of government-initiated community farms and government demonstration farms aimed at promoting the development of the local beef industry as well as improving the economic well-being of rural landholders), traditional systems (villagers' ownership of around 5–10 animal herds and typically 4–5 ha in farm sizes), and oil palm integrated cattle farming systems (OPIFS).

The beef production systems in Sabah were described as having low productivity, often constrained by various factors including low calving rates, financial limitations, poor accessibility and support issues in remote areas, low levels of skill in cattle farming, and an unsystematic marketing of beef (Awang Salleh, 1991; Anon., 2008). The local beef production was estimated to be 537 tonnes in 2003 and 479 tonnes in 2012 as against a demand of approximately 9,959 tonnes and 10,314 tonnes in those years, respectively (Anon., 2014). Chew and Ibrahim (1992), and Anon. (2008) proposed the use of intensive cut-and-carry feedlot systems to alleviate the problem of low productivity in local beef production. Subsequently, these systems have been practiced alongside grazing on government demonstration farms, community farms under government initiatives and on dairy farms, which concurrently raise male calves for beef to enhance income. To date this intensive farming approach has not been properly analysed to demonstrate its effectiveness in the local beef production scenario. Analysis of such nature can only be properly executed with sufficient data on feed demand and supply, which is often lacking, inadequate or unreliable.

The present study is part of an earlier report on CCFS (Gobilik *et al*. 2017) to determine the feed profile of the system. Metabolic energy budgeting (MEB), a farm analytical tool widely utilized in New Zealand (Jagusch & Coop, 1971; Joyce, 1971; Nicol and Brookes, 2007; Webby & Bywater, 2007; Wheeler, 2015; Tayler *et al*., 2016), was used to capture the feed profile of a cut-and-carry feedlot cattle farming system on a government farm in Sabah. This study is extended to include further analyses on the very large data set and information captured during the course of MEB calculations. This includes a summary of farm performance statistics (system feed conversion efficiency, live weight loss energy, live weight gain), and their correlations, as well as pre-harvest herbage mass accumulation. Based on the analysis results, a feed management strategy to potentially improve the animal production system is discussed.

METHODOLOGY

Site and background of cut-and-carry feedlot farming system (CCFS)

This study was carried out in 2014 on a cut-and-carry feedlot cattle farming system at the Stesen Pembiakan Ternakan Batu 16 Tawau (SPT 16 Tawau), a farm situated in south eastern Sabah, in the coastal district of Tawau (Lat. 4.2892; Long. 118.0347). A description of the farm and the cut-and-carry feedlots in the system was mentioned in Gobilik *et al.* (2017). Briefly, the average annual rainfall on the farm was 1,837±322 mm (average over 2008–2013). The average monthly rainfall was 153±33 mm with August being the wettest month (237±131 mm) and February the driest (103±69 mm). Roughly, 70%–80% of the months of lower-than-average rainfall, however, had occurred in January, February, July and October. The air temperature was 28±3°C on average. The cattle reared in the system were entire male Brahman, Bali, Droughtmaster, a few entire male Bali crossbred (× Brahman sire), and a few entire male dairy crossbred (Friesian × Sahiwal). (The dairy animals, however, had all been sold or transferred out from SPT 16 Tawau by the end of 2009). The main herbage fed to the cattle were *Bracharia decumbens* Stapf and *Setaria sphacelata* 'Kazungula' (Schumacher) Stapf & C.E. Hubb. ex M.B. Moss; the latter was used only when the supply of the former was insufficient. The *B. decumbens* was planted on six cut-and-carry paddocks of over 22.26 ha. The herbage was harvested daily in the morning and after being left to wilt under roofed stall, fed *ad libitum* to the cattle in the afternoon (2–3 p.m.). Concentrate was made available to the animals at 2–3 kg head^{-1} day^{-1} in the morning (9–10 a.m.). Samples of the herbage and concentrate were sent to laboratory for nutritive analysis. For the herbage, the metabolisable energy content (ME) was 7.5–8.5 MJ kg DM^{-1} and crude protein (CP) was 9%–12% of dry matter for the herbage, and for the concentrate the ME and CP values were, respectively, 8.7–14.3 MJ kg DM^{-1} and 12%–16%, for the concentrate.

Collection of animal information

The collection and collation of animal data was similar to that described in Gobilik *et al*. (2017). Briefly, it involved historical information from the feedlots for the production period between January 2008 and December 2013. Information collected and collated included sire and dam, birth date, weaning date, transfers, sales, and deaths; live weight (LWT) readings at birth, pre-weaning, weaning, and post-weaning; and records of health treatment. The population dynamic in each feedlot was determined from the information gathered such as, weaning date, transfer-in and transfer-out, sales and deaths. Altogether, the data collection covered 485 head of animals and a collation of 5,981 monthly LWT records.

Pasture production assessment

Pasture production on the 22.26 ha cut-and-carry paddocks was assessed in July–October 2014. This was used as a basis to evaluate the feed consumption estimate from the metabolic energy requirement (MER) of the animals in the system. The first measurement was carried out 15 days before the herbage was harvested for the cattle in the feedlots. The sampling procedures were adapted from the technique described by Boswell (undated). Two cut-and-carry paddocks were selected and from the centre of each paddock, four sampling points were distributed at 50 m intervals towards North and South, and another six sampling points were distributed at 100 m intervals towards East, West, Northeast, Northwest, Southeast, and Southwest, respectively. At each sampling point, a pasture patch typical of the paddocks was selected and a 0.26-m^2 quadrat was placed on the patch. Herbage in the quadrat was harvested by hand with scissors to 7 cm above ground level for consistency with the normal harvesting residual height of the farm for *B. decumbens*. The main sample and components of the sorted sub-sample were weighed, dried at 60°C for 2 days and reweighed to obtain the herbage dry matter; this procedure was repeated until the samples attained a constant dry matter (DM) weight. The second measurement was carried out 2 days before the herbage was harvested for the cattle following the sampling procedures in the first measurement; however, the quadrats were placed adjacent to the previous sampling points. The dry weight data obtained were used to extrapolate an estimate of the annual herbage production per ha on the paddocks.

Monthly and annual feed demand and supply modelling and correlation between feed consumption and LWG

The MER of animals in the system over 2008–2013 was modelled following the methods described in Gobilik *et al*. (2017). Briefly, the modelling process involved entering the monthly LWT of every animal in Microsoft Excel® spreadsheet for the 2008–2013 production period, then calculating the MER of each animal based on the animal LWT, and summing the MER of each feedlot (Brahman, Bali, and Droughtmaster feedlots). (The MER of the small number of Bali crossbred and dairy animals were combined with that of Bali and Brahman cattle, respectively). The metabolic energy budgeting propounded by Nicol and Brookes (2007), SCA (Anon., 1990) and CSIRO (Anon., 2007) as described in Gobilik *et al*. (2017) was used for the MER calculation. The total MER of feedlot(s) was converted to herbage equivalent to obtain the total feed demand (herbage + concentrate consumed and translated into animal LWT) of the system or subsystems (Brahman, Bali Droughtmaster feedlots). From the total feed demand (of the system or subsystems), the total concentrate consumed (as herbage equivalent) was deducted to determine the total herbage consumed. The total feed demand (of the system or subsystems) was expressed in proportion to the cut-and-carry paddocks (22.26 ha) as t DM ha^{-1} per year or per month to assess its descriptive pattern. Correlation (Pearson's) analysis (at P = 0.05) was performed to assess the relationship between consumption of herbage and concentrate and liveweight gain (LWG) in the system. The data used for the correlation analysis were the average of 12 months data for each year (of the 6 years). Normal probability distribution of the data was tested using the Shapiro-Wilk Test; the test was carried out using Microsoft Excel®, following the methods described in *Real Statistics Using Excel* (www.real-statistics.com). The correlation analyses were performed using StatPlus:mac LE v5.9.50 (www.analystsoft.com/en/). For the use of correlation analyses in this study, in particular the issue over the strength of correlation analysis and sample size, the reader is referred to the relevant comment by Gobilik *et al*. (2017) on this matter.

System feed conversion efficiency (SFCE) and correlation between SFCE and feed consumption

The methods used to calculate the SFCE (expressed as kg DM kg LWG^{-1} per year or per month) were described in Gobilik *et al*. (2017). Correlation (Pearson's) analysis (at $P = 0.05$) was performed to assess the relationship between annual SFCE and consumption of herbage and concentrate in the system. The data used for the correlation analysis were the average of 12 months data for each year (of the 6 years). The correlation analysis was handled and performed as described above.

Herbage loss associated with LWT loss energy (ME_{LWL})

The methods used to calculate the ME_{LWL} and to convert it to pasture equivalent (expressed as kg DM ha^{-1} per year or per month) were described in Gobilik *et al*. (2017).

RESULTS AND DISCUSSION

Annual feed demand and supply

The total feed demand (expressed in proportion to the cut-and-carry paddocks: 22.26 ha) of the system averaged across years was 8.02 t DM ha^{-1} yr^{-1}, comprising 6.22 t DM ha^{-1} yr^{-1} herbage eaten and 1.80 t DM ha^{-1} yr^{-1} concentrate eaten as herbage equivalent (Figure 1). The highest feed demand across years occurred in 2012 at 9.03 t DM ha^{-1} yr^{-1} (7.42 t DM ha^{-1} yr^{-1} herbage + 1.61 t DM ha^{-1} yr^{-1} concentrate) and the lowest was in 2008 at 5.98 t DM ha^{-1} yr^{-1} (4.23 t DM ha^{-1} yr^{-1} herbage + 1.75 t DM ha^{-1} yr^{-1} concentrate). The consumption of concentrate decreased towards 2013 (Figure 1), as its use was reduced to control operational costs. The coefficients of variation (CV) of total feed demand, herbage consumption and concentrate consumption were 14%, 17% and 31%, respectively. The overall estimate of feed wastage was 167 kg DM ha^{-1} yr^{-1} for herbage (3% of the herbage offered) and 95 kg DM ha^{-1} yr^{-1} for concentrate (5% of the concentrate eaten as herbage equivalent). Based on the herbage assessment in July–October 2014, *B. decumbens* was found to produce 21.3 t DM ha^{-1} yr^{-1} of total green and 13.1 t DM ha^{-1} yr^{-1} of total leaf. *S. sphacelata* 'Kazungula' produced 10.9 t DM ha^{-1} yr^{-1} of total green and 6.7 t DM ha^{-1} yr^{-1} of total leaf. Elsewhere in Malaysia, DM production of *B. decumbens* and *S. sphacelata* 'Kazungula' has been reported to be, 19.7 and 21.0 t DM ha^{-1} yr^{-1}, respectively (Ng, 1972; Wong, 1980). When these values are compared against the values calculated above by MEB, it appears that herbage consumed and converted to animal LWT in the system is lower than the potential DM production of the herbage on the cut-and-carry paddocks or in other parts of Malaysia. This finding means there is a need to match annual herbage production with herbage consumption and conversion to animal LWG to improve beef production. It has been reported that the maximum potential animal production of a pastoral system is dependent on the maximum annual feed produced and its availability in that system (Valentine & Kemp, 2007), but ultimately this also depends on the amount of feed that can be ingested and converted to animal product (McMeekan, 1958). With reference to the high CV of concentrate consumption in the system, this is associated with the decision to reduce the use of this feed towards 2013. In terms of feed management, the latter decision is discouraged when Brahman and Droughtmaster animals are reared, because it was evident (as will be discussed below) that these breeds would require more feeding of concentrate to achieve high LWG.

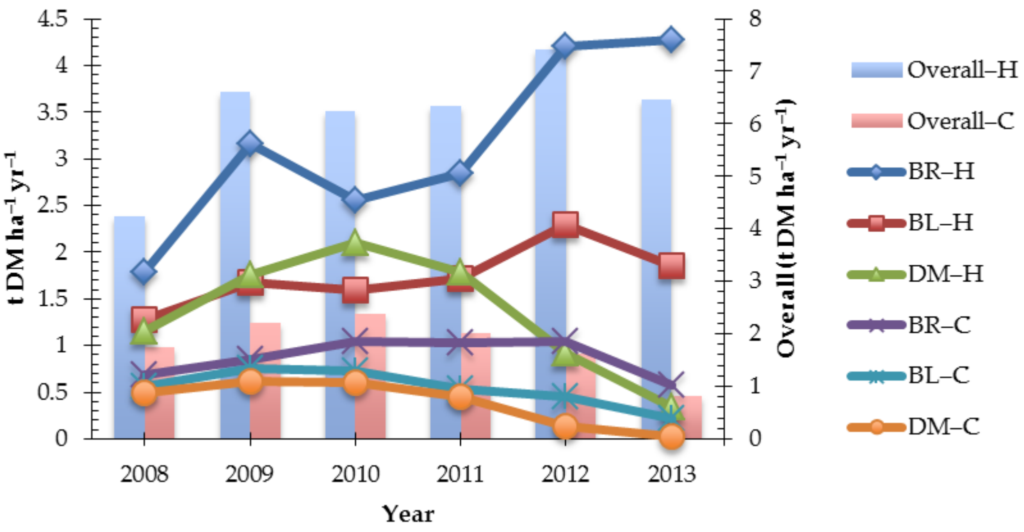

Figure 1. Annual feed demand of the system and subsystems. The marked drop of consumption in the Droughtmaster subsystem after 2011 was due to the phasing out of this breed whereby only a few bulls remained in 2012 and 2013. BR: Brahman. BL: Bali. DM: Droughtmaster. H: herbage consumed. C: concentrate consumed as herbage equivalent.

The probable reasons for the low herbage consumption and conversion to animal product of the system include: (a) low actual herbage production due to low soil nutrient levels, acidic soil conditions as well as invasion of non-sown species or weeds. The average quantum of nitrogen applied on the cut-and-carry paddocks (92 kg N ha^{-1} yr^{-1}) was lower than the recommended 112–224 kg N ha^{-1} yr^{-1} by Ng (1972) in Malaysia for optimum cultivation of *B. decumbens* pasture (Gobilik *et al.*, 2017). (Herbage can contain 2%–6% N. If the low value of 2% is taken, 100 kg N ha^{-1} yr^{-1} is enough N to grow 5000 kg herbage, so the estimate of herbage production by MEB is about expected considering the quantity of N supplied in the system). The level of phosphorus in the soils from the paddocks was found to be only 4.71±0.71 ppm (Gobilik *et al.*, 2017). In Thailand, even at 10.15 ppm of phosphorus in the soils, the dry matter production of *B. decumbens* was only 7.66 t ha^{-1} yr^{-1} (Pholsen, 2010). The uptake of these nutrients by the herbage would also be low, as at 5.2±0.3 (Gobilik *et al.*, 2017) the pH of the soils is lower than the ideal pH (5.8–6.3) for optimum plant nutrient uptake; (b) the proportion of non-sown species or weeds was 20%–30% for paddocks planted with *B. decumbens* and 60% for that with *S. sphacelata* 'Kazungula', meaning the actual herbage production on the paddocks was lower than the potential dry matter production of the two pasture species known from the pasture assessment carried out in July–October 2014; (c) the rejection of damp herbage by the cattle; drying was not effective enough to improve herbage consumption though the technique of drying has not being fully assessed. This problem is further compounded by the practice in the system of feeding the amount of herbage based only on experience, visual judgement of the animal appetite, and the assumption [or old conviction] that the feed requirement of the [ruminant] animals is 10% of LWT, and often the herbage offered was not weighed; and (d) the low herbage ME content which is rarely above 8.5 kg DM^{-1}. Experience in New Zealand on temperate pasture revealed that animals would not grow irrespective of the amount of the feed consumed if the ME of feeds was lower than or around 8 MJ kg DM^{-1} (Smeaton, 2003). The low herbage ME content in the system can possibly be mitigated through systematic fertiliser application (Gobilik *et al.*, 2017).

Monthly feed demand and supply

Monthly total feed demand of the system was 668.1 kg DM ha^{-1} (518.4 kg DM ha^{-1} herbage eaten + 149.7 kg DM ha^{-1} concentrate eaten as herbage equivalent). Monthly estimate of total feed waste was 21.8 kg DM ha^{-1}. Feed waste had little impact on the modelled average monthly herbage supply of the feedlots. Monthly total feed demand and herbage consumption varied little through the months of the year, with 4%–5% and 6%–7% CV, respectively (Figure 2). The CV of the monthly concentrate consumption (19%), however, was slightly greater than that of the herbage consumption.

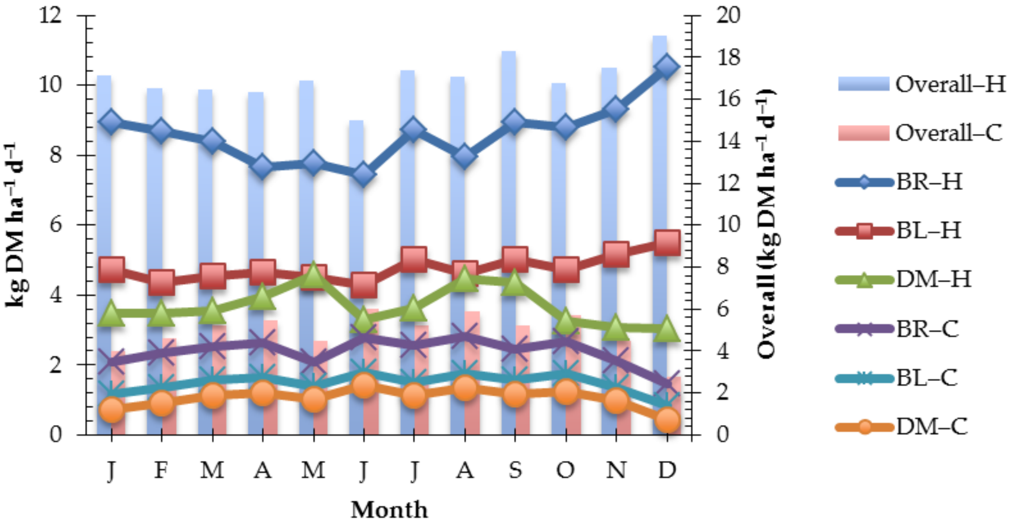

Figure 2. Monthly (average over 2008–2013) feed consumption of the system and subsystems. BR: Brahman. BL: Bali. DM: Droughtmaster. H: herbage consumed. C: concentrate consumed as herbage equivalent.

The small CV of the monthly total feed demand and herbage consumption indicates that there is no marked seasonality of total feed or herbage consumption or herbage supply in the system. An opposite scenario, however, will be expected during marked dry periods, such as during El niño–Southern Oscillation (ENSO), a phenomenon which occurs with a cycle of 3 to 5 years (Tangang, 1997). ENSO has been known to cause plant death in Sabah rainforests (Walsh & Newbery, 1999), and an ENSO event would markedly reduce herbage accumulation of pasture. The high CV of the monthly concentrate consumption arises from the low concentrate supply during December, January, and February, and May, which then results in low consumption of concentrate in those months (Figure 2). It was reported that in those months, availability of concentrate from suppliers was affected by constraints in purchasing the feed ingredients. During those months of low concentrate supply, feed demand of animals in the system was normally met with higher feeding of cut herbage (Figure 2); this indirectly reduces the CV of monthly total feed demand. As there was no indication of seasonality of herbage supply, feed demand was therefore not correspondingly tie to seasonal cycle of herbage production, unlike in temperate countries and in some parts of Indonesia where the dry and wet seasons are pronounced. Even so, it is paramount that flexible financial management and long-term plans to stock up sufficient feed concentrate are in place so as to reduce variation in supply and consumption in the system. Reducing this variation could at least maintain the LWT or improve the LWG of the Brahman and Droughtmaster animals. It was observed in this study (see below) that for these breeds, there is increase in LWG with increment of concentrate consumption, or feed of higher quality. It is also important to maintain the ME and CP of the concentrate to be at least 11.5 MJ kg DM^{-1} and 12%, respectively. Feed quality of PKC, one of the main components of the concentrate used at SPT 16 Tawau, has been reported to be highly variable (Alimon, 2004).

Correlation between feed consumption and LWG

The correlation between feed consumption (herbage and concentrate) and annual LWG was not significant for Brahman and Droughtmaster subsystems, but was significant for the Bali subsystem (Table 1). There was a trend towards increased LWG with increment of concentrate consumption for Brahman animals but with increment of herbage consumption for Bali and Droughtmaster animals. For the latter two breeds, there was a trend that LWG decreased with increment of concentrate consumption (LWG had negative correlation with concentrate consumption). These trends are similar to those of correlation between SFCE and feed consumption in the system; both trends will thus be discussed in the paragraphs below.

Table 1. Correlation between annual SFCE and LWG and herbage and concentrate consumed in the subsystems.

		Brahman		Bali		Droughtmaster	
		Herbage	Concentrate	Herbage	Concentrate	Herbage	Concentrate
SFCE	*r*	0.557	–0.511	–0.649	0.144	–0.636	–0.834
	P	0.273	0.320	0.186	0.789	0.452	0.279
LWG	*r*	–0.430	0.313	0.868	–0.468	0.846	–0.248
	P	0.411	0.557	0.039	0.367	0.266	0.779

* For SFCE, a higher numerical value denotes lower efficiency, and thus, a negative *r* (Pearson's correlation coefficient) indicates a positive relationship and conversely, a positive *r* indicates a negative relationship.

System feed conversion efficiency (SFCE)

As reported earlier (Gobilik *et al*., 2017), the average SFCE of the system across years (6 years) was 24±3 kg DM kg LWG^{-1}. The feed conversion efficiency of the subsystems was 21±3 kg DM kg LWG^{-1} for the Droughtmaster, 27±7 kg DM kg LWG^{-1} for the Brahman, and 29±3 kg DM kg LWG^{-1} for the Bali. It was suggested (Gobilik *et al*., 2017) that the difference between the subsystems in feed conversion efficiency was superficial and any of the three breeds could suitably be used for beef production under CCFS. The year with the highest SFCE was 2010 (20.4 kg DM kg LWG^{-1}), followed by 2009 (21.4 kg DM kg LWG^{-1}) and 2012 (22.8 kg DM kg LWG^{-1}) (Figure 3). The month with the highest SFCE was August (20.0 kg DM kg LWG^{-1}), followed by July (21.6 kg DM kg LWG^{-1}), April (22.1 kg DM kg LWG^{-1}) and May (22.7 kg DM kg LWG^{-1}) (Figure 3). The data obtained could not be compared with general knowledge on SFCE of tropical pastoral systems, because most study on feed conversion efficiency are at the animal level rather than at the system level. The high consumption of concentrate in 2010 and 2009 (Figure 1) could explain the high SFCE in those years. High quality feed contributes to high LWG for most cattle (and therefore to an increase in the ratio of energy allocated to LWG: energy allocated to body maintenance, both for Brahman and to some extent Droughtmaster cattle in this study. The SFCE in those years would have been better, if the Bali cattle were fed with less concentrate. As commented earlier, contrary to Brahman cattle, a high feeding of concentrate had negative effect on LWG of Bali cattle, and on the other hand, a high consumption of herbage had positive effect (Table 1). The response of Bali animals to herbage feeding could partially explain the high SFCE in 2012. In that year, there was a high consumption of herbage in the Bali subsystem (Figure 1), meaning the animals had higher LWG. However, exploration of optimisation of SFCE in future systems will involve wider considerations, most notably the ratio between MER and the total feed supplied. A high ratio of MER:feed supplied forces a larger proportion of the feed energy to be allocated by the system to unproductive animal body maintenance.

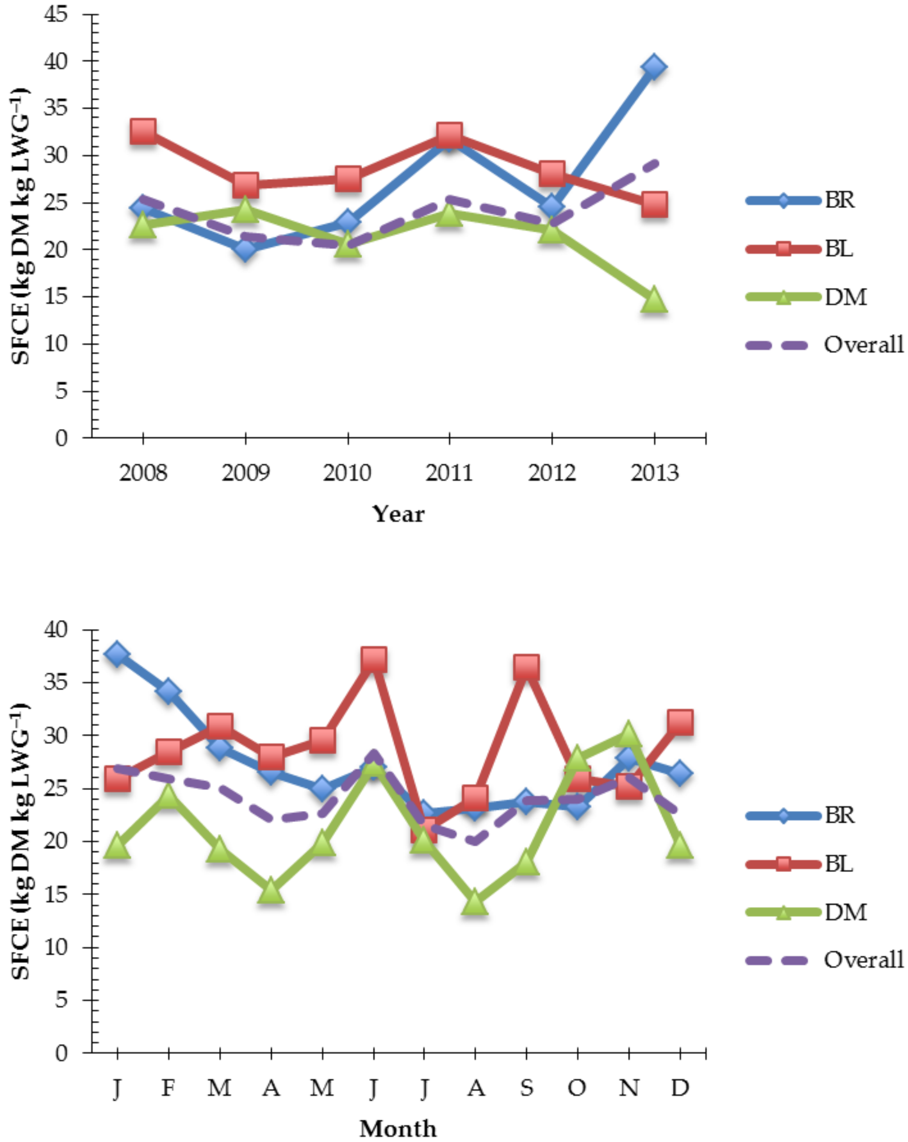

Figure 3. Annual and monthly (average over 2008–2013) feed conversion efficiency of the system and subsystems. BR: Brahman. BL: Bali. DM: Droughtmaster.

Correlation between SFCE and feed consumption

The correlation between annual SFCE and consumption of herbage and concentrate was not significant for the subsystems, although it would be interested to explore in future research to explore if the fluctuations in SFCE in Figure 3 can be explained by influence of herbage production variability month by month and the animal number in each month on the ratio of MER to total feed supply and the influence of that ratio on the system allocation of energy to body maintenance as mentioned above (Table 1). Overall, the correlation trends indicate the tendency that for the system to be productive, Brahman cattle have to be fed with more concentrate or high quality feed; Bali cattle with more herbage or in other words, low quality feed; whilst Droughtmaster cattle need a balanced amount of herbage and concentrate. As stated earlier, these trends conform to those of LWG and feed consumption correlation. The data are difficult to evaluate, as the trends are not formally tested and detailed reports on feeding experiments of cattle in Sabah are not yet available. It is acknowledged by farm staff members that it was difficult to meet the feed requirement of the

Brahman cattle and this supports the explanation SFCE might have been lower because of a higher ratio of MER: feed supplied in the Brahman system. Based on available farm records, the Brahman cattle were found to be descendant of pure breed animals brought in from Australia, and can grow to 700–800 kg LWT, which is considered a large animal. This could explain why the Brahman cattle grow better (high LWG and SFCE) when fed with high quality feed, such as concentrate. The Bali cattle, on the other hand, has been reported to have a low efficiency use of ME for LWG and thus unsuitable for high input–high output finishing systems; this breed suits better for low input–low output systems, such as those commonly owned by smallholder farmers (Quigley *et al.*, 2014). In other words, the high use of concentrate to improve LWG is not recommended for Bali animals. For the Droughtmaster cattle, the correlation result could not be explicitly explained due to limited data available.

The results of this system analyses could be utilised as a benchmark for a farm in Sabah with similar pasture production practice to explore and identify the ideal balance between feed demand and supply, which could be measured by kg ME or herbage fed per kg animal body weight per standard time period. In this study, where the system is still very much pasture-based (cut-and-carry), examples of low, near optimal and overstocked production system by year can be discreetly categorised, respectively as: 2008 (SFCE = 25.3 kg DM kg LWG^{-1}, without allowing for feed non-utilisation), 2010 (SFCE = 21.4 kg DM kg LWG^{-1}), and 2011 (SFCE = 25.3 kg DM kg LWG^{-1}). The average stocking rates for these three years calculated from the animal data collected were respectively, 767, 994 and 1,044 kg animal LWT ha^{-1}. These values then provide a first estimate of the optimal MER: feed supply ratio for a beef production system in Sabah. If the feed offered is taken as the average feed harvested of the system (8.02 t DM ha^{-1}) plus a 15% allowance for non-utilisation, then for the years of production values mentioned above, the comparative stocking rate (CSR) (kg animal LWT ha^{-1} per tonne total feed DM offered ha^{-1}: Penno, 1999; MacDonald *et al*., 2008) values are, respectively, 81, 105, and 111 kg LWT t DM^{-1}. Similarly in New Zealand, the CSR is now used mainly to account for imported feed in dairy farm systems, where milk solid ha^{-1} and operating profit are said to be at maximum when CSRs are respectively at 91 and 76 (MacDonald *et al*., 2008). The optimal range is now considered to be 75–80 kg LWT t DM^{-1} (DairyNZ, 2013). Further evaluation is needed to establish the optimal values of this index for this particular system in Sabah. A higher CSR for a cut-and-carry system seems logical because, for an animal in confinement, energy requirement for grazing activity is zero and thus a higher animal production can be supported by a hectare of cut-and-carry paddock than a grazing paddock and this may explain the higher CSR for the system in this study.

The key farm information for year 2010 for future comparison with other systems or for future use are as follows: 36 Brahman cattle (282.3 kg LWT hd^{-1}, 20.9 mo hd^{-1}), 25 Bali cattle (244.5 kg LWT hd^{-1}, 32.7 mo hd^{-1}) and 20 Droughtmaster cattle (293.0 kg LWT hd^{-1}, 28.4 mo hd^{-1}), and 1.60 t DM mo^{-1} of feed concentrate as herbage equivalent (this could simply be eliminated by increased herbage production and quality). These stock were carried on 22.26 ha, giving a stocking rate per ha for the above system of 994 kg animal LWT ha^{-1} as stated earlier. Land area for different animal numbers or weights or for different levels of herbage productivity could be adjusted on a pro rata basis, and can be maintained constant throughout the year because herbage supply is aseasonal. N application in 2010 (77 kg N ha^{-1} yr^{-1}) was slightly lower than the average (92 kg N ha^{-1} yr^{-1}), but from another perspective, this means that an efficient system can still be attained even at lower N addition, as long as other system configuration factors are aligned or coordinated correctly. The average cost of N application during 2009–2013 on the farm was RM0.61 kg N^{-1}, which means in 2010 the cost of N application was RM46 ha^{-1} yr^{-1} or RM9 ha^{-1} yr^{-1} cheaper than the average cost of N application. The advantage of this approach to farm operation is the system configurations recommended have been practically tested in the past and so would involve less risk for farmers implementing them, compared with a new system configuration devised from an untested combination of higher productivity and stocking rate.

Herbage loss associated with LWT loss energy (ME_{LWL})

The average ME_{LWL} (expressed in proportion to the 22.26 ha cut-and-carry paddocks) of the system averaged across years was 0.59 t DM ha^{-1} yr^{-1} as herbage equivalent (or 13.3 t DM yr^{-1} from 22.26 ha). The years of high ME_{LWL} were 2010 (0.8 t DM ha^{-1} yr^{-1}), 2012 (0.78 t DM ha^{-1} yr^{-1}), and 2011 (0.67 t DM ha^{-1} yr^{-1}). The difference between the subsystems in average annual ME_{LWL} was small at 0.01–0.11 t DM ha^{-1} yr^{-1}. The CV of the annual ME_{LWL} was 33%. The average monthly ME_{LWL} of the system was 49.3 kg DM ha^{-1} as herbage equivalent (or 1.1 t DM mo^{-1}). The monthly ME_{LWL} in February (59.0 kg DM ha^{-1} mo^{-1} as herbage equivalent), March (62.4 kg DM ha^{-1} mo^{-1}) and June (56.3 kg DM ha^{-1} mo^{-1}) were higher than the average across months. The CV of the monthly ME_{LWL} was 16%. The merit of assessing ME_{LWL} is that the data indicate the loss of investment in herbage and animal production that is unlikely to be known by simply measuring the dry matter of the feed waste in the system. A system with low feed waste but high ME_{LWL} is still unproductive. In the present study, the 13.3 t DM yr^{-1} herbage loss as ME_{LWL} should be a concern. To date, however, little has been studied on ME_{LWL} for CCFS or any other cattle pastoral system for comparison and benchmarking with the data obtained.

The CV implies that annual LWT and LWG were inconsistent to twice the extent of the monthly one. In other words, year-to-year feed and animal management in the system is weaker than that of month-to-month. This weakness has to be addressed to improve the performance of the system. Experience from more successful systems, such as those in New Zealand indicates that both short- and long-term feed and animal management strategies are important to maintain or improve farm productivity and profitability not only at the end of a production cycle but also for year-to-year production cycles (Gray *et al*., 2003; Gray *et al*., 2011). One strategy that can be used, which has been practiced unintentionally in the system at SPT 16 Tawau, is to take advantage of animal compensatory growth. There is a tendency in the system that the animals are offered greater amounts of concentrate when losing more weight, and thus, the annual SFCE is likely to improve during the time when annual ME_{LWL} is higher (Gobilik *et al*., 2017). When fed with high quality feed following weight loss, animals will improve in feed conversion efficiency (depending on the severity of weight loss), a phenomenon called compensatory growth (Wilson & Osbourn, 1960; Greenwood *et al*., 2005; Jennings, 2014). Compensatory growth and the relevant procedures to take advantage of this phenomenon, however, has to be further tested and developed for the system at SPT 16 Tawau.

The data show that LWT loss in the feedlots during 2010, 2011 and 2012, and during the months of February, March and June are higher. Another possible reason, other than low herbage production, herbage ME content, and concentrate use as discussed earlier, is the effect of weaning. An observation of the animal growth curves showed marked LWT loss within 2–3 months after the calves arrived in the feedlots. In an earlier report (Gobilik *et al*., 2017), the need to manage the welfare of newly arrived calves properly has already been highlighted as a way to improve animal LWG in the system.

CONCLUSION

Herbage consumed in the system is much lower than the potential herbage dry matter production based on light and rainfall for the environment in the region. Various factors contributed to this trend, including lower actual herbage production (due to low soil nutrient content, acidic soil as well as invasion of non-sown species or weeds) and thus resultant low herbage supply in the system; rejection of damp herbage especially during rainy season; lack of guidelines to match the amount of herbage offered with feed demand of the cattle on a daily basis; and low herbage ME and CP content. Herbage supply in the system, however, is aseasonal and thus, there is no requirement to match animal feed demand with seasonal cycle of herbage production. Even so, there is a need to have a flexible financial management and long-term plan to stock up concentrate to reduce variations in the monthly and annual supply and consumption in the system, which can produce negative effect on LWG of Brahman and Droughtmaster cattle. Moreover, concentrate use as herbage equivalent in the system is low and targeting improved pasture productivity and quality could reduce its use and cost. Because of its superior quality, concentrate is seen as a means to increase feed conversion efficiency for the Brahman and Droughtmaster animals, although its application for Bali animals is discouraged. It can be concluded that the first step to improving the production system should be to configure the system for optimal FCE. Subsequently, a pasture husbandry package that includes guidelines for nutrient application, pasture ME and CP enhancement, and timing and intensity of harvesting should be developed. Improvement of pasture production and quality are generally seen as a second step in Sabah, considering that this would involve high investment, which is beyond reach of average farmers with limited financial resources.

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