Correlations between Feed Conversion Efficiency, Rainfall, Nitrogen (N) Application, and Mobilised Body Energy (ME_{LWL}) of a Cut-and-Carry Feedlot Cattle Farming System at SPT 16 Tawau, Sabah and Implications for Feedlot Nutrient Management

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ABSTRACT: Little is known about factors influencing pastoral systems in cattle production in Sabah. Metabolic energy budgeting (MEB) was introduced to assess feed conversion efficiency (FCE) of a cut-and-carry feedlot cattle farming system at SPT Tawau, Sabah and its correlations with rainfall, Nitrogen (N) application, and mobilised body energy (ME_{LWL}) were assessed. The results indicated that there is a trend that high farm rainfall, N application, and ME_{LWL} will improve FCE. The relationship, however, is complex where all three variables as well as the farm management procedures may act in synergy. High N application during low rainfall, for example, will not lead to high FCE, but when rainfall increases, the benefit of the N added will be apparent. High ME_{LWL} will lead to low FCE, but with nutrient correction (with supplement), the production cycle that has high ME_{LWL} may yield a better overall FCE. It is recommended that more research be done to establish farm management guidelines with better perspectives on N application, farm rainfall and pasture harvesting, as well as the understanding of the energetics and the role of dietary supplements on the recovery of body weight for improving beef production of the cut-and-carry feedlot cattle farming system in Sabah.

KEYWORDS: Cut-and-carry feedlot cattle; Feed conversion efficiency; Rainfall; N fertiliser; Metabolic energy budgeting.

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INTRODUCTION

Beef cattle pastoral systems used in Sabah have never been formally described, but they have many similarities with those in Peninsular Malaysia where systems have been classified into traditional, draught, crop integrated, and feedlot systems (Liang, 1996). Grazing systems are also used quite extensively in Sabah. In 2003, there were 42,380 cattle reported in Sabah, and the beef demand was 9,959 tonnes (Anon., 2014). In 2012, the population was 55,530 head, and the beef demand was 10,314 tonnes. Sabah has seen a declining trend in beef production over the years. The average beef production of over 537 tonnes in 2003 has decreased to around 479 tonnes in 2012 (Anon., 2014). Awang Salleh (1991) reported that production systems were constrained by many factors including low calving rate, financial constraints to development of grazing land, access and support issues in remote areas, limited skills in cattle farming, and an unsystematic marketing of beef. Most cattle farms are also small with average sizes of between 4 to 5 hectares. Despite cattle production facing numerous aforementioned problems, little or no work has been done to elucidate current systems. The lack of systematic collection and analysis of data on farm operations, performance and factors relating to production systems has further hampered efforts to improve productivity in cattle farming in Sabah.

In the present study, metabolic energy budgeting (MEB) was used to investigate correlations in the data obtained from available farm variables. The aim was to investigate the correlations between feed conversion efficiency (FCE) of cut-and-carry feedlot cattle farming system and farm rainfall, nitrogen (N) application, as well as mobilised body energy (ME_{LWL}: energy recovered by the animal from mobilisation of body tissue), and to suggest improvements to farming systems.

METHODOLOGY

Site and background of cut-and-carry feedlots

The Stesen Pembiakan Ternakan Batu 16 Tawau (SPT 16 Tawau) situated in the Southeastern Sabah, in the coastal district of Tawau (Lat. 4.2892; Long. 118.0347) was selected for the study. This farm has been operating since the 1970s and practises both extensive grazing and cut-and-carry feedlot pastoral systems; only the latter system was covered in this study. Information for the period of production between January 2008 and December 2013 was collated. Three of the four feedlots on the farm were used to raise entire male Brahman, Bali, and Droughtmaster beef cattle, and one was used to raise a small number of entire male dairy crossbred cattle (Friesian × Sahiwal). A few Bali crossbred (× Brahman sire) were farmed together with the Bali animals. The management of the feedlots underwent some changes during 2008–2013 when the dairy and the Droughtmaster cattle were phased out. At the end of 2013, only two feedlots were active, viz. the Brahman and Bali feedlots.

Similar types of herbage and concentrate were used as feeds for the cattle. The main herbage used was *Bracharia decumbens*. However, *Setaria sphacelata* 'Kazungula', which are mainly planted on grazing paddocks adjacent to the feedlots, was also used when the supply of *B. decumbens* was insufficient. The *B. decumbens* was planted on six cut-and-carry paddocks of over 22.26 ha. The herbage (ME: 7.5–8.5 MJ kg DM^{-1}; CP: 9%–12% of dry matter) was harvested daily in the morning and fed *ad libitum* to the cattle in the afternoon (2–3 p.m.). Concentrate feed (ME: 8.7–14.3 MJ kg DM^{-1}; CP: 12%–16% of dry matter) was made available to the animals at 2–3 kg hd^{-1} d^{-1} in the morning (9–10 a.m.). The composition of the feed concentrate was (by weight): palm kernel cake (65%), milled corn (21%), milled soybean (11%), and fishmeal (3%). The characteristics of the soil samples collected from the paddocks (in August–September 2014) were analysed and described as follows: pH 5.2±0.3; Total N, 0.22±0.00%; available P, 4.71±0.71 ppm; K, 0.21±0.03 meq%; Ca, 11.82±4.06 meq%; and Mg, 5.75±0.80 meq%.

Rainfall and nitrogen (N) application data

Data on rainfall and nitrogen application were scrutinized from available farm records. The average annual rainfall on the farm from 2008 to 2013 was 1,837±200 mm. The average monthly rainfall was 154 mm, and generally, there was no marked seasonality of rainfall, except August appeared wetter and February drier than other months. Over 2008 to 2013, lower-than-average rainfall (i.e., <154 mm) was more likely (71%–86%) to occur in January, February, July, and October. The environmental temperature of the area was almost constant throughout the year at 28±3ºC.

The average N application on the cut-and-carry paddocks was 92 kg ha^{-1} yr^{-1}. The highest application of 135 kg ha^{-1} yr^{-1} was done in 2012 and the lowest was 48 kg ha^{-1} yr^{-1} in the following year (2013). The amount of N applied was normally determined based on the amount of N required to improve the soil nutrient content/level. Nevertheless, the actual amounts were at times adjusted according to the availability of urea and sulphate of ammonia (SOA) at the farm.

Metabolic energy requirement modelling

Data from the record cards of each animal in the feedlots were collated for modelling of the metabolic energy requirement of the system. Information of animals that were recorded and extracted for analysis included the following: sire and dam, date of birth, date of weaning, transfers, sales, and deaths; liveweight (LWT) readings at birth, pre-weaning, weaning, and post-weaning; and records of health treatment. The LWT data were obtained using a digital scale (TRU–TESTTM HD800) and normally recorded once a month, or once in two or three months, depending on availability of farm labour. For the purpose of this study, where monthly liveweight records were not available, the average of the previous and following months was enumerated. Altogether a total of 5,981 monthly LWT records of 485 heads of animal were assessed. Five of the cattle were Brahman cows kept in feedlots at different times for a relatively short period (<3 months), and 20 were the crossbred dairy cattle.

The first step in the modelling process involved entering the monthly liveweight of every animal in the feedlots from January 2008 to December 2013 in Microsoft Excel® spreadsheet. The second step involved calculating the metabolic energy requirements of each animal based on the liveweights (Eq. 1), and thereof the resultant or total energy requirement of each feedlot (Brahman, Bali, and Droughtmaster feedlots). The total energy requirement of the whole cut and carry feedlot system is then deduced by adding the total sum of each feedlot. The modelling was performed using the Microsoft Excel® software. The results obtained and the data for feed demand associated with the amounts of concentrate feed given to the cattle were then converted to herbage equivalents. The difference between feed demand and concentrate fed was therefore approximately the amount of herbage fed to the cattle. The feed demand and supply (monthly or annual) were expressed relative to the total area of the cut-and-carry paddocks in kg DM ha^{-1} yr^{-1}. Metabolic energy requirements of each animal were calculated for body maintenance (Eq. 2) and liveweight gain (Eq. 3). The energy equations propounded by Nicol and Brookes (2007), SCA (Anon., 1990) and CSIRO (Anon., 2007) were used as follows (formulated following Microsoft Excel® functions):

$$\mathbf{ME_{TOTAL} = ME_{BASALMETABOLISM} + ME_{GAIN}} \quad (1)$$

(i) Energy requirement for body maintenance

$$M_{BASALMETABOLISM} = (Species*sex*0.28*EXP(–0.03*Age)*LWT\hat{}0.75)/k_m \quad (2)$$

(ii) Energy requirement for liveweight gain in addition to $M_{BASALMETABOLISM}$

$$ME_{GAIN} = 1.1*((0.92*LWG)*((6.7+(((920*LWG)/(4*(SRW\hat{}0.75)))–1))+(20.3–(((920*LWG)/(4*(SRW\hat{}0.75)))–1))/(1+EXP(–6*((LWT/SRW)-0.4)))))/k_g \quad (3)$$

Species is 1.2 for *Bos indicus* and 1.3 for *B. indicus* × *B. taurus*; sex is 1.0 for females and castrates and 1.15 for entire males; age is in years; LWT is liveweight; LWG is liveweight gain; SRW is standard reference weight; and k_m (i.e., efficiency of use of ME for maintenance) is M/D*0.02+0.5, and k_g (i.e., efficiency of use of ME for weight gain) is M/D*0.042+0.006. M/D is feed ME content (MJ ME kg DM^{-1}).

Feed conversion efficiency modelling (FCE)

The information on feed demand and animal liveweight gain was extracted from the analyses on metabolic energy budgeting for every animal on each grazing unit from Jan 2008 until Dec 2013. This was then used to evaluate the monthly and the annual FCE of each grazing unit. FCE was calculated based on the total feed demand (monthly or annually) divided by the total liveweight gain for the same period. This calculation allows for the evaluation of factors that may affect the system performance.

Implications of liveweight loss energy on FCE

In a cut-and-carry feedlot system, it is also of interest to account for the feed implications of animal weight loss, which is a feed saving at the time of weight loss, but a feed cost at another time when the weight is regained, effectively creating a transfer of feed in time. The energy associated with weight loss is termed here 'mobilised body energy' (ME_{LWL}) and expressed as herbage equivalent. Feed saving from ME_{LWL} when animals lose liveweight was explicitly identified in the metabolic energy budgeting as a potential system efficiency factor and used to quantify the monthly and annual ME_{LWL} of each grazing unit. CSIRO (2007) stated that "the energy value of 1 kg liveweight loss by non-lactating animals of any particular live weight should be taken to be the same as the energy content 1 kg liveweight gain made at the same live weight by animals of the same breed and sex" and "the energy provided to animals from catabolism of their tissues may be calculated by means similar to those used to calculate the energy content of gains". Thus, the equations used for ME_{LWL} as derived by Nicol and Brookes (2007), SCA (Anon., 1990) and CSIRO (Anon., 2007) were:

$$ME_{LWL} = 1.1*((0.92*LWG)*((6.7+(((920*LWG)/(4*(SRW^{\wedge}0.75)))-1))+(20.3-(((920*LWG)/(4*(SRW^{\wedge}0.75)))-1))/(1+EXP(-6*((LWT/SRW)-0.4)))))/k_g \quad (4)$$

The conversion of ME_{LWL} to dietary energy (for non-lactating animals, since most animals in the system were entire males) was carried out in two steps. The equations used for the conversion as derived by Nicol and Brookes (2007) were:

$$ME_{LWLRNL} = ME_{LWL}*0.80 \quad (5)$$

$$ME_{LWL} \text{ as dietary ME spared} = ME_{LWLRNL}/k_m \quad (6)$$

LWL is liveweight loss and ME_{LWLRNL} is energy recovered by non-lactating animals from liveweight loss (from mobilisation of body tissue).

Correlation analysis

Correlations (Pearson's) between FCE and N application (to the cut-and-carry paddocks) and farm rainfall, between FCE and ME_{LWL}, and between N application and farm rainfall were calculated in which for the monthly correlation (n = 12), data used to represent each month were the average of 6 years of data or 5 years for correlation with N fertiliser, as there was no record for one year. For the annual correlation (n = 6), data used were the average of 12 months data for each year (of the 6 years or 5 years for correlation with N fertiliser). Normal probability distribution of the data was tested using 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/).

RESULT AND DISCUSSION

The average FCE of the system across years (6 years) was 24±3 kg DM kg LWG^{-1}. The FCE of the sub-systems 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. The above results indicated that there is no marked difference between sub-systems. The Droughtmaster feedlot exhibited a better FCE than the other feedlots, but the difference in FCE between the feedlots was observed to be superficial, if the productions for 2012 and 2013 were excluded from the comparison. The better FCEs in those years could have been due to the decision of the farm to phase out the breed thereby allowing the few remaining Droughtmaster bulls in 2012 and 2013 left to have had better access to feed and thus increased growth. This finding suggests that any of the three breeds could suitably be used for beef production under the cut-and-carry feedlot system.

In describing the results of the correlation analysis, it should be noted that a higher numerical value for FCE denotes lower efficiency, which means a negative r indicates a positive relationship (between FCE and farm rainfall, N application, and ME_{LWL}) and conversely a positive r indicates a negative relationship. In addition, in this study, the Shapiro-Wilk Test did not indicate that the data deviated from a normal distribution (P >0.05). For the system, the correlation between monthly FCE and rainfall (on the farm) was moderate but was not significant (r = –0.569, P = 0.053). It is interesting to note that the P value of the r for the monthly correlation was almost 0.05. The correlation between annual FCE and farm rainfall was weak and not significant (r = –0.057, P = 0.915). In both cases, the r were negative, indicating there is a positive effect of high monthly or annual rainfall on FCE (high rainfall may lead to high FCE; Figure 1).

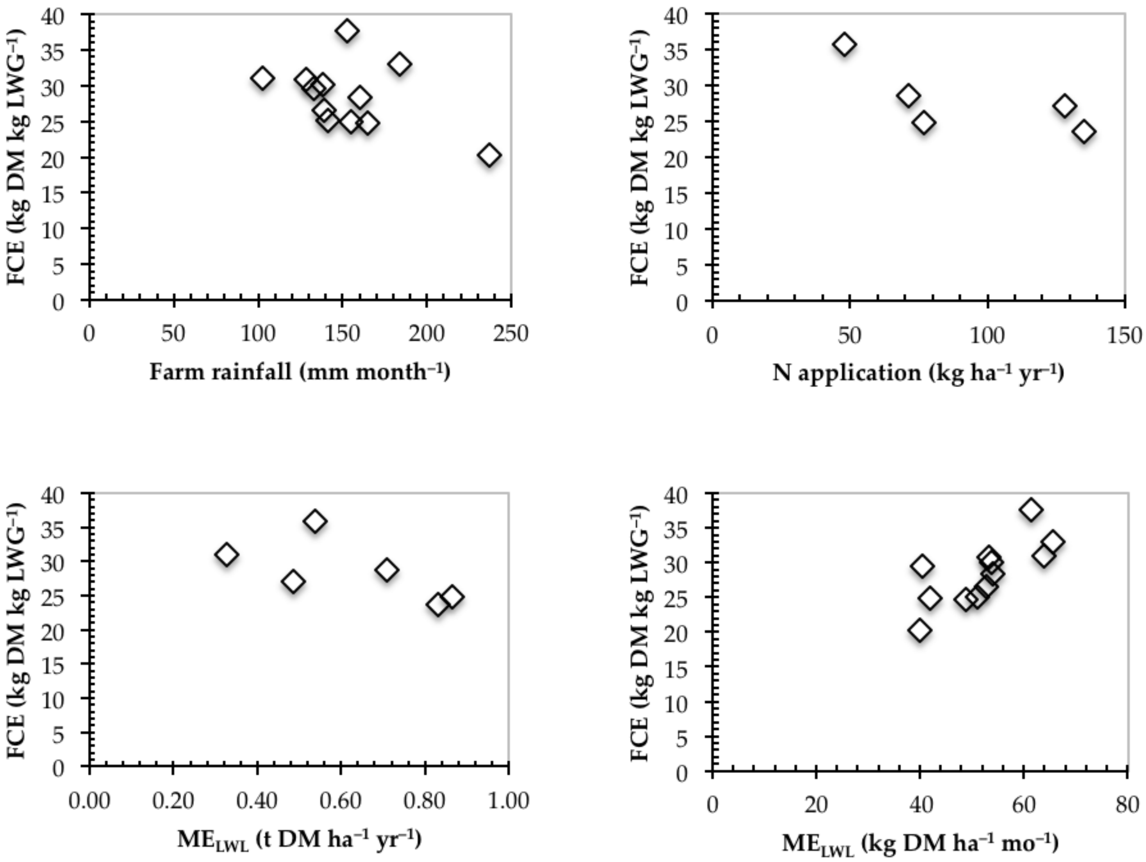

Figure 1. Relationship between FCE and farm rainfall, N application, and ME_{LWL} of cut-and-carry feedlot cattle farming system at SPT 16 Tawau.

The correlation between monthly FCE and N application (on the cut-and-carry paddocks) was moderate and significant (r = 0.659, P = 0.020). The r was positive, meaning high monthly application of N does not lead to better FCE. The annual correlation was strong, but was not significant (r = –

0.864, P = 0.059). This time, the r was negative, which means higher annual N application will lead to a better FCE (Figure 1). Again, it is also interesting to note that the P value of the r for the annual correlation was not markedly higher than 0.05.

It was noted that the correlation between monthly N application and farm rainfall was weak and not significant (r = –0.078, P = 0.809). The annual correlation was also not significant (r = –0.342, P = 0.573). The r was negative in both cases, indicating that the application of N was carried out during dry period (low rainfall on the farm). This result implies that the effect of the higher monthly N application on FCE is delayed until the wet period. This also explains why the monthly FCE and N application stated above had negative relationship.

With reference to the correlation between FCE, farm rainfall, and N application, FCE is expected to increase in relation to any increments of the latter two factors. During high rainfall and N application, and given that soil nutrient leaching remains fairly low, there will be corresponding increase in forage production hence more fodder available. Growth of cattle would therefore be enhanced. N application close to harvesting also improves crude protein content of grass (Minson, 1967), and this is an advantage, as protein particularly the volatile fatty acids (VFA) is an important nutrient for ruminant. The merits of N application in relation to monthly rainfall towards the end of the herbage regrowth cycle, however, need to be further investigated particularly in terms of dry matter production and nutritive value of herbage. N requirement of the pasture would normally be higher than the amounts applied during higher rain pour. In fact, the average quantum of N applied on the cut-and-carry paddocks in SPT Tawau (92 kg ha^{-1} yr^{-1}) is still lower than the recommended 112–224 kg ha^{-1} yr^{-1} by Ng (1972) in Malaysia for the cultivation of *B. decumbens* pasture. Moreover, the effect of fertiliser on herbage nutritive value could be indirect (Lambert & Litherland, 2000). Tropical grass pasture fertilised with SOA, for example, has higher metabolisable energy and crude protein content compared to unfertilised pasture, but this was later found to be due to the increase in legume yield in the pasture after the SOA application (Manning & Kesby, 2008). Another drawback that has been noticed at the farm was the rejection and lesser consumption of damp herbage by animals, hence the need for effective drying prior to feeding, irrespective of the pasture being fertilised close to harvesting.

For the correlation analysis between FCE and ME_{LWL}, the monthly correlation was moderate and significant (r = 0.643, P = 0.024). This result indicates a lower efficiency, whereby larger monthly ME_{LWL} will lead to lower monthly FCE (i.e., larger numerical value; Figure 1). The inter-annual correlation was also moderate but not significant (r = –0.589, P = 0.218), but this time it was a positive correlation (r was negative). There is thus a tendency that FCE is better during the year when the ME_{LWL} is higher (Figure 1). In addition, the correlation between monthly FCE and feed concentrate consumption was weak and not significant (r = –0.043, P = 0.894); and the annual correlation was moderately strong but was also not significant (r = –0.735, P = 0.096). The r was negative in both cases, meaning there is a positive effect of feed concentrate on FCE whereby higher levels of concentrate feeding will lead to high FCE. The latter explains why FCE was high during the year when ME_{LWL} was high. In this system (SPT 16 Tawau feedlots), greater amounts of concentrate were offered when animals were losing weight.

A possible factor in the improved performance following weight loss is compensatory growth. Compensatory growth could improve FCE of animal, depending on the severity of the weight loss (Wilson & Osbourn, 1960; Greenwood *et al*., 2005; Jennings, 2014). However, because this phenomenon was not formally tested in the data analysis, a study should be carried out to ascertain the dynamics of recovery as a result of body weight loss and the role of dietary supplementation in feedlot systems in Sabah. Another factor possibly contributing to the improved performance following weight loss is the practice (on the farm) of feeding Bovitas (Bovita-8), a protein supplement and appetite stimulant to animals with marked weight loss.

FCE is better when animals are growing faster so more efficient future systems will come from understanding how factors like N, rainfall, and the relationship between number of animals and feed supply combined together within the system to determine animal growth rate, and similarly, from understanding how compensatory growth works in feedlot systems. There is also argument, however, that since exploitation of compensatory growth will usually involve the use of good quality feed (Jennings, 2014), the cost of such feed and the market price of beef will have to be considered too. An additional step suggested to avoid marked average daily gain loss and the need of expensive nutrient correction to stimulate growth is a proper feed management for the newly arrived calves in the feedlots (see Rivera *et al*., 2005).

In this study, it is noted that the number of years included was only six. In correlation analysis, there is an issue over the strength of the correlation and sample size, and this may have been the reason for some of the correlations just attaining <0.05 P values. Larger sampling may yield better and improved results. While this limitation must be acknowledged as a probable cause of biasness in the interpretation of the results and the accompanying suggestions, this study is nevertheless very important in providing the relational landscape of cattle production in Sabah. In farm system analysis, finding and analysing a large number of farms of similar attribute and management regime is often difficult especially in Sabah where the beef industry is still small.

CONCLUSION

This study showed that the application of N has to be well planned in accordance with (farm) rainfall and pasture harvesting to improve the FCE of the cut-and-carry feedlot cattle farming system. Compensatory growth could have contributed to the improved FCE of the system, although this phenomenon needs to be formally tested. More research on feeding, dietary energy requirement and nutrient management for cattle need to be established to develop relevant farm management guidelines for cattle farming in Sabah.

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