Trop Anim Health Prod (2016) 48:741–746
DOI 10.1007/s11250-016-1019-4

REGULAR ARTICLES

Change in growth performance of crossbred (Ankole × Jersey) dairy heifers fed on forage grass diets supplemented with commercial concentrates

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Received: 28 July 2015 / Accepted: 11 February 2016 / Published online: 18 February 2016
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Abstract Rearing heifers for dairy cow replacement is a challenge in smallholder dairy farms in the tropics due to feed shortage. The objective of this study was to evaluate *Brachiaria* hybrid cultivar Mulato II as a forage resource for improving growth performance of dairy heifers under cut-and-carry feeding system in Rwanda. Sixteen crossbred (Ankole × Jersey) heifers (mean weight 203 ± 35 kg) were randomly allocated to two dietary treatments viz: Mulato II with 2 kg/day of commercial concentrates (MCC) and Napier grass (*Pennisetum purpureum*) with the same supplement (NCC), for a period of 12 weeks. Mineral lick and water were provided ad libitum. Daily feed intake and fortnightly live weight were measured. Average daily gains and feed conversion ratio (FCR) were calculated. Results showed that absolute daily dry matter intake (g DMI/day) and relative intake (g/kg of metabolic body weight—$BW^{0.75}$) were higher in heifers fed on MCC than in heifers fed on NCC ($P < 0.001$). FCR was lower ($P < 0.001$) in MCC than NCC diets. Final body weight (FBW) and body weight gain (BWG) did not differ between the two groups of heifers ($P > 0.05$). Average daily weight gain (ADWG) also not differed significantly ($P > 0.05$). Based on numerical body weight changes and nutritive values, Mulato II showed potential to be integrated into local cut-and-carry feeding systems for better heifer rearing to facilitate dairy cow replacement.

Keywords Dry matter and nutrient intake · Feed conversion ratio · Brachiaria grass · Napier grass

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Introduction

Population growth and shrinking of grazing land have compelled farmers to shift from extensive to intensive dairy system in order to optimise milk yield per cow (Lukuyu et al. 2012). In spite of the additional stress on limited feed resources, especially during the dry season, farmers retain female calves to replace culled cows (Mohd Nor et al. 2015). In tropical areas of Asia, Africa, and South American highlands, farmers lose replacement dairy stock due to limited knowledge on calf and heifer rearing. Approximately 35 % of the losses can be restored using adequate feeding (Moran 2011). In these areas, Napier grass (*Pennisetum purpureum*) is the most abundant single, year-round feed resource in smallholder dairy farms (Rahman et al. 2015; Mutimura et al. 2013). However, total dependence of farmers on Napier grass is risky because of Napier stunt disease that poses threats to the production of this grass throughout the East African region (Asudi et al. 2015). Developing disease resistant cultivars has been identified as one possible approach to address the problem (Kawube et al. 2014). However, there is need to consider alternative fodder species to complement the search for disease resistance in the global germplasm collection and local landraces.

Brachiaria species are indigenous grasses to Africa, which have been selected for productivity and tolerance to abiotic and biotic stresses in Latin America (Miles et al. 2004).

Brachairia hybrid cultivar (cv.) Mulato II was introduced, evaluated, and selected by farmers in Rwanda (Mutimura and Everson 2012). However, its superiority over Napier grass in terms of animal productivity in stall-fed cattle has not been examined. Data on animal growth performance from different *Brachiaria* grass species is limited to grazing trials (Gracindo et al. 2014). The objective of this study was to evaluate the relative intake and growth performance of crossbred dairy heifers fed on *Brachiaria* hybrid cv. Mulato II compared with Napier grass under a cut-and-carry forage feeding system in Rwanda.

Materials and methods

Location

The feeding trial was conducted at Songa research station of Rwanda Agriculture Board (RAB). The station is located in the mid-altitude zone (1471 m.a.s.l) of Rwanda, and it lies between 29° 48′ E, 2° 25′ S. The average annual rainfall is 1087 mm and relative humidity of 77 % with an average temperature of 20.1 °C per year.

Management of animals

Sixteen (Ankole × Jersey) crossbred heifers (605 ± 11 days of age and 203 ± 35 kg live weight) were selected and divided into two groups of eight animals. The animals from each group were ear tagged, randomly assigned to one of the two dietary treatments. Animals were put in individual pens in a house built for cows in the station and partitioned for stall feeding. ALBENDOZOLE (10 mL/10 kg body weight) and acaricide (Norotraz 12.5 % effective concentration (EC), 2 mL/1 L of water; twice/week) were used to control endo and ecto-parasites, respectively. Individual pens were cleaned every morning.

Feeds and feeding

The dietary treatments were two different roughages: *Brachiaria* grass (*Brachairia* hybrid cv. Mulato II) or Napier grass (*Pennisetum purpureum*) fed as basal diets. All animals received commercial concentrate supplements (2 kg/day) which was composed of maize (55 %), soybean (10 %), rice bran (10 %), palm cakes (20 %), bone powders (1.5 %), salt (0.5 %), and molasses (3 %). Water and mineral blocks were provided ad libitum. The basal feeds (grasses) were harvested (15 cm above ground) from the station plots where they were planted without fertiliser application. The soil type of the plots is sandy clay with nitrogen and carbon content of 0.2 ± 0.4 % and 1.2 ± 0.5 %, respectively. The harvested herbages were chopped (10 cm length) using forage chopper (Mild steel, 7 HP of power, electric motor/diesel engine, BrazAfric Ltd) before feeding. Basal diets were given at ad libitum based on individual body weights. After an adaptation period of 14 days, daily feed offers and refusals, respectively, were weighed, recorded, and sampled at 9:00 h and 15:00 h for a period of 12 weeks (from 21st February to 21st May 2014). Fortnightly, individual animals were measured to the nearest 100 g using mechanical weigh bridge (PORTEE 1000 kg, 2 × 1 m, B.C, 188021, RAPPORT).

Daily feed dry matter (DM), organic matter (OM), crude protein (CP), metabolisable energy (ME), calcium (Ca), and phosphorus (P) intake were calculated as the difference between feed offer and refusal corrected for the respective contents in the original samples (Balehegn et al. 2014). Feed conversion ratio (FCR) was calculated as the slope of the linear regressions of cumulative nutrient (DM, OM, and CP) intakes on growth rates. Daily ME requirement for growing heifers was calculated based on Eqs. 1, 2, 3, 4, and 5 (AFRC 1993). Growth rates (g/day) were estimated as the slope of the linear regressions of weekly body weights on days of feeding.

$$ME_m \ (MJ/\text{day}) = (F + A)/k_m \quad (1)$$

where ME_m is the metabolisable energy for maintenance; F is the fasting metabolism; A is the activity allowance, and K_m is the efficiencies of utilization of metabolisable energy for maintenance which is 0.665 for a heifer (AFRC 1993).

$$F \ (MJ/\text{day}) = C_1\left\{0.53(W/1.08)^{0.67}\right\} \quad (2)$$

where W is the body weight and C_1 is the Constant which takes 1 for other cattle except bull.

$$A \ (MJ/\text{day}) = 0.0071W \quad (3)$$

$$EV_g \ (MJ/\text{kg } WG) = \frac{C_2(4.1 + 0.0332W - 0.000009W^2)}{(1 - C_3 \times 0.1475\Delta W)} \quad (4)$$

where EV_g is the energy values for growth; WG is the weight gain; C_2 is the corrects for body size and sex, for heifer at early mature, it is 1.3; $C_3 = 1$ when it is a plane nutrition; ΔW is the body weight change.

Energy retained in animal's body per day (E_g) was calculated as follows:

$$E_g \ (MJ/\text{day}) = \Delta W \times EV_g \quad (5)$$

Chemical composition of feeds used

Samples of feed offered and refusal were collected daily. Samples of every week were mixed and two samples were taken and analysed for chemical composition. The official protocol was used to the determine DM, Ash, and OM (AOAC 1990; method ID 9420.5) and CP (AOAC 2006; method ID 984.13). Macro and micronutrients were determined using Atomic Absorption and Flame Emission Spectrophotometer (PerkinElmer, Inc., Precisely, A. Analyst 200).

Data analysis

Chemical compositions of feeds over 12 weeks were analysed using general linear model (GLM) procedures of the Statistical Analysis System (SAS 2010). Means were compared using PDIFF option of SAS. Data from experiments on feed intake and live weight gain were subjected to analysis of variance (ANOVA) in a completely randomised design using GLM procedures of the Statistical Analysis System (SAS 2010) based on the following model (Eq. 6):

$$Y_{ijk} = \mu + H_i + F_j + e_{ijk} \quad (6)$$

where Y_{ijk} is the variable dependent; μ is the boverall mean; H_i is the animal effect; F_j is the effect of feed; and e_{ijk} is the residual error.

Initial body weight of heifers was used as a covariate in analysis of the effect of diets on body weight gain. Individual and group animal differences between means were separated using least significance difference (LSD) at $P<0.05$ level of significance.

Results

Feed composition

Chemical composition of the feeds used in this experiment is presented in Table 1. Ash contents of the roughages were significantly higher than the contents in concentrates ($P<0.05$). *Brachiaria* hybrid cv. Mulato II had less ash content than Napier grass ($P<0.05$). Commercial concentrates had more OM and CP than roughages ($P<0.05$). OM and CP in Napier grass were lower than those of Mulato II ($P<0.05$). The roughages and concentrates did not differ in Ca contents ($P>0.05$) but the roughages had lower contents of P than the concentrates ($P<0.05$; Table 1).

Intake

Absolute (kg or g/day) and relative (kg or g/kg metabolic body weight, $BW^{0.75}$) daily intake of DM, OM, CP, and Ca were significantly ($P<0.01$; Table 2) higher in animals fed Mulato II supplemented with CC (MCC) than Napier grass supplemented with concentrates (NCC) as basal diets. However, P intake was higher in NCC than in MCC diets.

Body weight gain and feed conversion ratio

Results from live weight gain (LWG) and feed conversion ratio (FCR) are shown in Table 3. The final body weight (FBW) and average body weight gain (ABWG) were similar

Table 1 Chemical composition of feed used in the experiment

Parameters	Feed types			
	Commercial concentrates	Mulato II	Napier grass (Control)	Mineral block
DM (g/kg)	910^{a}	320^{b}	270^{c}	–
Ash (g/kg DM)	72 ± 4^{c}	110 ± 32^{b}	147 ± 20^{a}	–
CP (g/kg DM)	172 ± 9^{a}	131 ± 17^{b}	85 ± 12^{c}	–
OM (g/kg DM)	928 ± 4^{a}	890 ± 32^{b}	854 ± 20^{c}	–
Ca (g/kg DM)	5 ± 1^{a}	5 ± 1^{a}	5 ± 1^{a}	39
P (g/kg DM)	8^{a}	2 ± 1^{b}	2^{b}	43
ME (MJ/kg DM)	13.1	8.1	7.2	–
Mg (g/kg DM)	–	–	–	4
K (g/kg DM)	–	–	–	2
Na (g/kg DM)	–	–	–	187
Fe (mg/kg DM)	–	–	–	6
Zn (mg/kg DM)	–	–	–	4
Cu (mg/kg DM)	–	–	–	0.01
S (mg/kg DM)	–	–	–	0.3

Means in the same row with the same lowercase letter are not significantly different at $P<0.05$

DM dry matter, *CP* crude protein, *OM* organic matter, *ME* metabolisable energy

Table 2 Effect of roughage on intake of feeds and its nutrients by crossbred heifers

Intakes	Treatments			
	NCC	MCC	SEM	*P* value
Absolute intake:				
DMI (kg/day)	4.3[b]	5.4[a]	0.03	<0.0001
OMI (kg/day)	3.8[b]	4.9[a]	0.03	<0.0001
CPI (kg/day)	0.5[b]	0.8[a]	–	<0.0001
ME intake (MJ/day)	41.8[b]	52.9[a]	0.23	<0.0001
Ca intake (g/day)	21.5[b]	27[a]	–	<0.0001
P intake (g/day)	19.5[b]	21.7[a]	–	<0.0001
Relative intake:				
DMI (g/kg $BW^{0.75}$)	76[b]	82[a]	–	<0.0001
OMI (g/kg $BW^{0.75}$)	67.3[b]	74.1[a]	–	<0.0001
CPI (g/kg $BW^{0.75}$)	9.2[b]	11.8[a]	0.05	<0.0001
Ca intake in the diet (g/kg $BW^{0.75}$)	0.38[b]	0.41[a]	0.002	<0.0001
P intake in the diet (g/kg $BW^{0.75}$)	0.34[a]	0.33[b]	0.001	0.0094

Means in the same row with the same lowercase letter are not significantly different at $P < 0.05$

SEM standard errors of the mean, *DMI* dry matter intake, *CP* crude protein intake, *OM* organic matter intake, *ME* metabolisable energy, $BW^{0.75}$ metabolic body weight

($P > 0.05$) between the two roughages. Although there was no significance difference ($P > 0.05$) between dietary groups, average daily weight gain (ADWG) of heifers fed on MCC diet was numerically higher than those fed on NCC diet. Feed conversion ratio (FCR) for DM, OM, and CP was significantly different ($P < 0.001$) between MCC and NCC diet. This suggests that high numerical body weight gain observed in MCC diet was due to higher FCR.

Table 3 Bod weight gain and feed conversion ratio of crossbred dairy heifers fed on MCC in comparison to NCC diet

	Treatments			*P* value
	NCC	MCC	SEM	
Body weight gain:				
IBW (kg)	190[a]	215[a]	12	0.16
FBW (kg) after 12 weeks	218[a]	266[a]	16.5	0.06
ABWG (kg) after 12 weeks	28[a]	50[a]	8	0.06
ADWG (g/day)	375[a]	580[a]	127.4	0.32
Feed conversion ratio (FCR; kg/kg BW gain):				
FCR of DM	11.5[a]	9.3[b]	0.06	<0.0001
FCR of CP	1.4[a]	1.3[b]	0.01	<0.0001
FCR of OM	10.2[a]	8.4[b]	0.06	<0.0001

Means in the row with the same lowercase letter are not significantly different at $P < 0.05$

SEM standard errors of the mean, *IBW* initial body weight

Discussion

Dry matter intake (DMI) and contents of nutrients in feeds are major factors determining feed quality and animal productivity (McDonald et al. 2011). In the present study, we found that Mulato II was better than Napier grass as a potential source of protein and energy. Although diets offered to crossbred dairy heifers differed in CP and OM, no variation in P and Ca was observed. Higher values of OM and CP in Mulato II than in Napier grass were reported in previous studies (Mutimura et al. 2015). DM and nutrient intakes were higher in MCC diet than in NCC diet. In this respect, Mulato II had comparative advantage in DM intake than Napier grass because of its leafiness and thinner stems than Napier grass (Maass et al. 2015). Therefore, the animals could eat more Mulato II than Napier grass. Also, high DMI in MCC diet might have influenced by high CP content in the diet. This observation is in agreement with Malisetty et al. (2014) who reported that DMI increases with the increase of CP content in a diet. Morais et al. (2014) also reported that when quality of supplement and supplementation frequency remain the same, the difference in weight gains of an animal will be based on the quality of roughage. As the two groups of crossbred dairy heifers had received the same amount of the commercial concentrates, the major factor which influenced differences in DMI might have been the quality of roughages where MCC had higher CP and MO content than NCC (Table 1).

High-crude protein CP intake was observed in MCC diet, and this diet had high CP. This suggests that CP content in feed influenced its intake. This agrees with Singh et al. (2015) who reported increase of CP intake when CP was increased in a feed. CP intake of 0.8 kg/day was slightly higher than results reported on CP intake from corn meal supplemented with jatropha and fed on Holstein heifers (da Silva et al. 2015). However, our results were higher than those reported in a feeding trial when Tho-tho male cattle were fed on tree leaves based ration (Das et al. 2011). Relative DM and nutrient

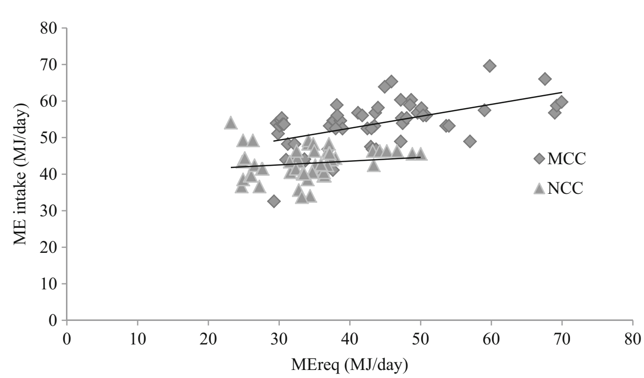

Fig. 1 Relationship between metabolisable energy (ME) intake and metabolisable energy requirement (MEreq) for the two groups of growing heifers (MCC—$Y = 0.33x + 40$, $R^2 = 0.30$; NCC—$Y = 0.11x + 39$, $R^2 = 0.03$)

intakes were higher in MCC than in NCC diet (Table 2). Similar findings were reported by Ngim et al. (2011) and suggested that grass with high relative intake should be integrated in livestock feeding system. Generally, the trend showed that diet with high nutrient content had higher intake of these nutrients; however, this trend was different for minerals. This is because both diets had similar P content but higher P intake was observed in NCC diet. Although the explanation of this observation seems complicated, however, previous studies have reported similar trend where Ca and P intakes did not correlate with their concentration in a diet (Sinha et al. 2011).

Body weight changes from the two groups were not statistically different, but numerically average daily weight gain (ADWG) of heifers fed on MCC exceeded those fed on NCC. Ngim et al. (2011) reported similar results on cattle fed on Mulato II as the basal feed in comparison with other grass in Thailand. In addition, differences in CP, OM, and ME intakes between the two dietary groups are attributable to increased ADWG in MCC diet. ME intake was much higher than requirement for MCC heifers compared to NCC heifers. A positive weak correlation between ME intake and ME requirements was observed in MCC whereas there was no correlation in NCC diet (Fig. 1). This means that high ME consumed was not translated into superior growth performance in heifers fed on NCC diet. However, our results on ADWG of heifers fed on MCC were slightly higher than those reported on crossbred (Friesian × Boran) heifers (532 g/day) and on Bhadawari buffalo heifers (330 g/day) fed on hay and wheat straw supplemented with commercial concentrates, respectively (Singh et al. 2015; Gojjam et al. 2011). Furthermore, FCR values were different between the two dietary groups of heifers. FCR showed that for the heifer to gain 1 kg of live weight per day it should eat 9.3 and 11.5 kg of DM in MCC and NCC diets, respectively. Similar value for FCR (9.5 kg of DM/kg ADWG) was reported when steers were grazing on smooth bromegrass (Lardner et al. 2015).

FCR data showed that diet with low CP and ME had poor FCR. A similar observation was reported when cows were fed on low and high level of protein (Fiems et al. 2015; Wang et al. 2014). It has been also reported that good FCR value was influenced by environment, feed type, and high energy intake (Singh et al. 2015; Fiaz et al. 2012). This suggest that diets should be selected based on their quantity and quality.

Daily body weight gain of heifers fed on MCC diet showed no statistically significant difference but numerically exceeded those fed on NCC diet. Considering DM and nutrient intakes as well as the quality attributes of Mulato II, this forage grass can be integrated into cut-and-carry feeding system in smallholder farms to feed heifers predestined for dairy mature cow replacement.

Acknowledgments Authors are grateful to financial support from Swedish International Development Agency (Sida) under "Climate smart *Brachiaria* grass to improve livestock production in East Africa" funded project through Biosciences for eastern and central Africa under International Livestock Research Institute (BecA-ILRI), Nairobi, Kenya.

Compliance with ethical standards

Conflict of interest Authors declare that they have no conflict of interest.

References

AFRC (Agricultural and Food Research Council), 1993. Energy and protein requirements of ruminants. A manual prepared by AFRC advisory Technical committee on responses to nutrients. CAB International, Wallingford, UK, 159 p.

AOAC, 1990. Association of official Analytical chemists. Official methods of analysis. 15th edition. A.O.A.C. Arlington Virginia, USA.

AOAC (Association of Official Analytical Chemists), 2006. Total nitrogen, Official Methods of analysis, 984.13, 18th edition. Association of official analytical chemists, Washington, DC.

Asudi, G.O., van den Berg, J., Midega, C.A.O., Pittchar, J., Pickett, J.A. and Khan, Z.R., 2015. Napier grass stunt disease in East Africa: Farmers' perspectives on disease management. Crop Protection, 71, 116–124.

Balehegn, M., Eik, L.O. and Tesfay, Y., 2014. Replacing commercial concentrate by *Ficus thonningii* improved productivity of goats in Ethiopia. Tropical Animal Health and Production, 46, 889–894.

da Silva, L.D., Pereira, O.G., Valadares Filho, S.C., Ribeiro, K.G., Valadares, R.F.D., Silva, T.C. and Santos, S.A., 2015. Intake, digestibility, and nitrogen efficiency in Holstein heifers fed treated jatropha (Jatropha curcas L.) kernel cake. Livestock Science, 178, 100–107.

Das, K.C., Haque, N., Baruah, K.K., Rajkhowa, C. and Mondal, M., 2011. Comparative nutrient utilization, growth, and rumen enzyme profile of mithun (*Bos frontalis*) and Tho-tho cattle (*Bos indicus*) fed on tree-leaves-based ration. Tropical Animal Health and Production, 43, 209–214.

Fiaz, M., Abdullah, M., Javed, K., Babar, M.E., M. Nasir, Pasha, T.N. and Jabbar, M.A., 2012. Effect of varying dietary energy levels during the last trimester of pregnancy on subsequent first lactation performance in Sahiwal heifers. Tropical Animal Health and Production, 44, 975–981.

Fiems, L.O., De Boever, J.L., Ampe, B., Vanacker, J.M., De Campeneere, S. and Sonck, B., 2015. Effect of energy restriction and dietary protein level during the re-alimentation period on feed efficiency in double-muscled Belgian Blue cows. Livestock Science, 174, 46–52.

Gojjam, Y., Tolera, A. and Mesfin, R., 2011. Management options to accelerate growth rate and reduce age at first calving in Friesian–Boran crossbred heifers. Tropical Animal Health and Production, 43, 393–399.

Gracindo, C.V., de Castro, M.B., Louvandini, H., Riet-Correa, F. and Barbosa-Ferreira, M., 2014. Performance of sheep grazing in pastures of *Brachiaria decumbens*, *Brachiaria brizantha*, *Panicum maximum* and *Andropogon gayanus* with different protodioscin concentrations. Tropical Animal Health and Production, 46, 733–737.

Kawube, G., Alicai, T., Otim, M., Mukwaya, A., Kabirizi, J. and Talwana, H., 2014. Resistance of Napier grass clones to Napier grass stunt disease. African Crop Science Journal, 22, 3, 229–235.

Lardner, H.A., Damiran, D. and McKinnon, J.J., 2015. Evaluation of 3 bromegrass species as pasture: Herbage nutritive value, estimated grass dry matter intake and steer performance. Livestock Science, 175, 77–82.

Lukuyu, B., Gachuiri, C., Lukuyu, M., Lusweti, C. and Mwendia, S., 2012. Feeding dairy cattle in East Africa. In: Lukuyu, B. and C. Gachuiri (eds), East Africa Dairy Development Project, Nairobi, Kenya, 95 p.

Maass, B.L., Midega, C.A.O., Mutimura, M., Rahetlah, V.B., Salgado, P., Kabirizi, J.M., Khan, Z.R., Ghimire, S.R. and Rao, I.M., 2015. Homecoming of Brachiaria: Improved hybrids prove useful for African animal agriculture. East African Agricultural and Forestry Journal, 1, 7–78.

Malisetty, V., Yerradoddi, R.R., Devanaboina, N., Mallam, M. and Mitta, P., 2014. Effect of feeding sorghum straw based complete rations with different roughage to concentrate ratio on dry matter intake, nutrient utilization, and nitrogen balance in Nellore ram lambs. Tropical Animal Health and Production, 46, 759–764.

McDonald, P., Edwards, R.A., Greenhalgh, J.F.D., Morgan, C.A., Sinclair, L.A. and Wilkinson, R.G., 2011. Animal nutrition. Seventh Edition, Pearson Education Limited, Edinburgh Gate, Harlow, Essex CM20 2JE, England, 692 p.

Miles, J.W., Valle C.B do; Rao, I.M. and Euclides, V.P.B., 2004. Brachiaria grasses. In: Moser, L.E., Burson, L.E. and L.E. Sollenberger (eds), Warm-season (C_4) grasses. Agronomy, Monograph 45. ASA, CSSA, SSSA, Madison, WI, USA, pp. 745–783.

Mohd Nor, N., Steeneveld, W., Mourits, M.C.M. and Hogeveen, H., 2015. The optimal number of heifer calves to be reared as dairy replacements. Journal of Dairy Science, 98, 861–871.

Morais, J.A.S., Queiroz, M.F.S., Keli, A., Vega, A., Fiorentini, G., Canesin, R.C., Reis, R.A. and Berchielli, T.T., 2014. Effect of supplementation frequency on intake, behavior and performance in beef steers grazing Marandú grass. Animal Feed Science and Technology, 189, 63–71.

Moran, J.B., 2011. Factors affecting high mortality rates of dairy replacement calves and heifers in the tropics and strategies for their reduction. Asian-Australia Journal of Animal Science, 24, 9, 1318–1328.

Mutimura, M. and Everson, T.M., 2012. On-farm evaluation of improved *Brachiaria* grasses in low rainfall and aluminium toxicity prone areas of Rwanda. International Journal of Biodiversity and Conservation, 4, 137–154.

Mutimura, M., Lussa, A.B., Mutabazi, J., Myambi, C.B., Cyamweshi, R.A. and Ebong, C., 2013. Status of animal feed resources in Rwanda. Tropical Grasslands – Forrajes Tropicales, 1, 109–110.

Mutimura, M., Ebong, C., Rao, I.M. and Nsahlai, I.V., 2015. Nutritional values of available ruminant feed resources in smallholder dairy farms in Rwanda. Tropical Animal Health and Production, 47, 1131–1137.

Ngim, M.S., Pha, K., Savouth, H., Young, J. and Bush, R., 2011. Introduced forage productivity and quality in the smallholder environment. In: Young, J., Rast, L., Sothoeun, S. and P. Windsor (eds), Cattle health, production and trade in Cambodia. Proceedings from three ACIAR-funded projects presented at an international workshop held in Phnom Penh, Cambodia, 7–8 June 2011, pp, 14–18.

Rahman, M.M., Rahman, M.R., Nakagawa, T., Abdullah, R.B., Wan Khadijah, W.E. and Akashi, R., 2015. Effects of wet soya waste supplementation on the intake, growth and reproduction of goats fed Napier grass. Animal Feed Science and Technology, 199, 104–112.

SAS, 2010. Statistics, Version 9.3. SAS Institute, Inc., Cary, NC, USA.

Singh, S., Kushwaha, B.P., Maity, S.B., Singh, K.K. and Das, N., 2015. Effect of dietary protein on intake, nutrients utilization, nitrogen balance, blood metabolites, growth and puberty in growing Bhadawari buffalo (*Bubalus bubalis*) heifers. Tropical Animal Health and Production, 47, 213–220.

Sinha, D., Neog, B.N., Sarmah, S., Prakash, B., Rajkhowa, C. and Baruah, K.K., 2011. Intake, digestibility and nitrogen balance in Mithun (*Bos frontalis*) offered urea-treated paddy straw based feed blocks. Tropical Animal Health and Production, 43, 383–387.

Wang, C., Liu, J.X., Makkar, H.P.S., Wei, N-b. and Xu, Q-m., 2014. Production level, feed conversion efficiency, and nitrogen use efficiency of dairy production systems in China. Tropical Animal Health and Production, 46, 669–673.