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Full Length Research Paper

Modelling the effect of supplementing elephant grass with lablab and desmodium on weight gain of dairy heifers under stall-feeding system

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This study reports on a simulation growth model developed to predict daily gain (DG) of dairy cattle heifers. The model input parameters are gross energy (GE), ash, crude protein (CP), organic matter digestibility (OMD), dry matter (DM), protein degradation variables and heifer initial body weight. Results from the simulation model show that at low levels of CP in elephant grass (*Pennisetum purpureum*) there is improved DG when supplemented with desmodium (*Desmodium* spp.) or lablab (*Lablab purpureus*) but as the CP in elephant grass increases there is reduced benefit from supplementation and at CP $\geq$ 100 g/kgDM there is no improvement in DG due supplementation. Supplementation with either lablab or desmodium at same percentage of diet had similar effect on DG. It is concluded that these two forage legumes could improve heifer growth, consequently reducing the time from weaning to mating weight of heifers in smallholder dairying where the CP content of elephant grass is low.

Key words: Elephant grass, daily gain, supplement, desmodium, lablab.

INTRODUCTION

Stall-feeding of dairy cattle was introduced and promoted in Uganda by non-governmental organizations (NGO) and the Uganda government to improve household nutrition, incomes and food security among resource poor households. A study by MAAIF(1996) found that stall-feeding system had the highest economic returns compared to other cattle management systems. However, reproductive performance reduce the profitability of smallholder dairy farmers Nakiganda et al. (2006). For example, the age at first calving in stall-fed dairy cattle, is 2.5 years (Bebe et al., 2003; Twinamatsiko, 2001) as compared to 2 years in developed world and 28 months recommended for smallholder (MLD, 1991).

In Uganda where smallholder dairying is primarily dependent on elephant grass as the sole source of feed, replacement heifers take long to attain mating weights. Typically for ruminants on forage, energy and then protein are the primary limiting nutritional requirements (Freer et al., 1997), but elephant grass has been found to meet most of the energy requirements in smallholder dairying (Muia et al., 2000a).

According to ARC (1984) content of a diet should be $\geq$ 120 g/kgDM if moderate production in dairy cattle is to be attained. Yet CP in elephant grass has been found to decline from 200 - 50 g/kgDM (Muia et al., 1999) and 200 - 50 g/kgDM (Ogwang and Mugerwa, 1976), from 3 - 15 weeks and 6 - 12 weeks of age respectively. One way to improve the low CP diet is to feed forage legumes. In Kariuki et al. (1999), they reported a significant increase in weight gain of heifers fed elephant grass supplemented with forage legumes. The two most popular forage legumes in Uganda are lablab and desmodium

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Abbreviation: DG, Daily gain; **GE,** gross energy; **CP,** crude protein; **OMD,** organic matter digestibility; **DM,** dry matter.

Table 1. Nutrient composition and digestibility, energy and age of Napier grass[a].

Age	DM	Ash[b]	CP	GE	ADIN	IVDMD	Reference
-	192	159	-	-	-	808	Hassan et al. (1983)
-	234	152.8	196.9		-	-	Hassan et al. (1979)
10	182.7	-	81.8	15.4	-	-	Muia et al. (2001a)
15	238.6	-	53.3	16.9	-	-	Muia et al. (2001a)
10	180	-	83	16	-	-	Muia et al. (2001b)
15	240	-	53	17	-	-	Muia et al. (2001b)
10	183.1	-	84.1	16.1	-	-	Muia et al. (2000)
15	237.8	-	53	16.8	-	-	Muia et al. (2000)
-	176	-	68.4	-	-	-	Nyambati et al. (2003)
-	-	111	115.4	-	1.3	-	Kabi et al. (2005)
M[c]	-	136	61	15.6	-	560	Mlay et al. (2006)
-	-	-	111.5	-	-	638.4	Ogwang and Mugerwa (1976)
6-8	-	124.9	102.5	-	-	692	Mpairwe et al. (1998)

[a] DM, Ash, CP, ADIN, IVDMD in g/kgDM; GE in MJ/kgDM; Age in weeks. [b] Where DOMD is not known, then Ash is used according to Equation 2). [c] M refers to mature, no specific age given.

Table 2. Chemical composition, energy and crude protein degradation of lablab[a].

DM	CP	OMD	Ash[b]	GE	ADIN	a	b	c	Reference
-	170	560	-	-	-	-	-	-	Murphy and Colucci (1999)
-	157	-	-	-	-	0.237	0.691	0.105	Mpairwe et al. (2003a)
-		-	-	-	-	0.244	0.676	0.153	Mpairwe et al. (2003b)
-	158	597	-	-	-	-	-	-	Kabirizi (2006)
-	163	-	-	-	-	-	-	-	Nyambati et al. (2003)
-	180	-	119.4	-	-	0.2479	0.6363	0.14	Melaku et al. (2003)
215	198	-	115.0	-	-	-	-	-	Linga et al. (2003)
-	254	-	114.0	-	2.44	-	-	-	Mupangwa et al. (2006)
-	216	-	114.0	-	0.71	-	-	-	Mupangwa et al. (2006)
170	174	-	-	-	-	-	-	-	Mbuthia and Gachuiri (2003)
-	191.8	-	-	13.16	-	-	-	-	Nworgu and Ajayi (2005)
-	128	-	129	-	-	-	-	-	Osuhor et al (2004)
-	-	-	-	-	1.26	-	-	-	Mupangwa et al. (2003)

[a] DM, Ash, CP, ADIN in g/kgDM; GE in MJ/kgDM; [b] Where DOMD is not known, then ash is used according to Equation (2).

because they are easily intercropped with elephant grass and food crops. However, it is not yet established at what CP level in elephant grass these legumes should be included or whether they have different effect on heifer DG.

The objective of this research was to study the effect of supplementing elephant grass at different levels of CP with lablab and desmodium on DG in dairy cattle heifers, by extending a simulation model of heifer growth developed in Tibayungwa et al. (2009), in a stall-feeding dairy system.

MATERIALS AND METHODS

This section summarises the procedures, assumptions and equations used to develop a growth model of dairy heifers from weaning to mating weight, for elephant grass supplemented with lablab and desmodium in a stall-feeding smallholder dairying system.

Feed composition

Feed parameters of elephant grass, lablab and desmodium are given in Tables 1, 2 and 3 respectively.

Energy value of feed

The energy value of feed was estimated based on AFRC (1993) as follows:

$$ME(MJ/kgDM) = 0.0157\times DOMD(g/kgDM) \quad (1)$$

Table 3. Nutrient composition and digestibility, degradability, energy and age of *Desmodium* spp.[a]

Species	DM	CP	OMD	Ash	GE	ADIN	*a*	*b*	*c*	Reference
D.intortum	-	120		87						Nurfeta et al. (2008)
D.uncinatum	-			84.3			0.311	0.414	0.065	Baloyi et al. (2008)
D.uncinatum	270		496	40						Milford (1967)
D.intortum	486	105			15.0					Aregheore et al. (2006)
D.intortum	-	118.1		55.1			0.214	0.216	0.0 2	Mghen et al. (1996)
D.ucinatum	-	163.1		85.1			0.291	0.423	0.0 24	Mghen et al. (1996)
D.intortum	-	229.4			20.47					Stobbs (1971)
D.intortum	-	199		98						Getachew et al. (2000)
D.uncinatum	-	134.5	642.9	104		2.6				Jingura et al. (2001)

[a]DM = Dry matter (g/kg); DOMD = digestible organic matter (g/kgDM); CP = crude protein (g/kgDM); ADIN = acid detergent insoluble nitrogen (g/kgDM); GE = gross energy (MJ/kgDM); *a* = water soluble fraction; *b* = potentially degradable nitrogen other than water soluble fraction; *c* = degradation rate per hour of the *b* fraction.

where ME is metabolisable energy; DOMD is Digestible Organic Matter in a feed, and is estimated as

DOMD = OMD × (1000 – total ash)/ 1000 (2)

where OMD is Organic Matter Digestibility (g/kg)

$$FME(MJ/kgDM) = ME \times (0.467 + 0.00136 \times ODM - 0.00000115 \times ODM^2) \quad (3)$$

where FME (MJ/kgDM) is fermentable metabolisable energy; ODM is Oven Dry Matter content (g/kg)

Protein value of feed

Estimation of the metabolisable Protein (MP) from Crude Protein (CP) involves the following calculations (AFRC,1993) (definitions of symbols used are in Table 4):

$$UDP = CP - \{QDP + SDP\} \quad (4)$$

$$SDP = \{(b \times c)/(c + r)\} \times CP \quad (5)$$

$$QDP = a \times CP \quad (6)$$

where r is calculated as follows

$$r = -0.024 + 0.179\{1 - e^{(-0.278L)}\} \quad (7)$$

where L is level of feeding as a multiple of MJ of ME for maintenance.

$$MCP = FME \times y \quad (8)$$

where y is microbial protein yield in the rumen (gMCP/MJ of FME), and is calculated as

$$y = 7.0 + 6.0\{1 - e^{(-0.35L)}\} \quad (9)$$

$$DUP = 0.9\{UDP - 6.25ADIN\} \quad (10)$$

$$DMTP = 0.6375MCP \quad (11)$$

$$MP(g/d) = 0.6375MCP + DUP \quad (12)$$

$$ERDP = 0.8QDP + SDP \quad (13)$$

If ERDP supply is less than (or equal to) ERDP required, then

$$MCP(g/d) = ERDP(g/d) \quad (14)$$

Else

$$MCP(g/d) = FME(MJ/d) \times y(gMCP/MJ\ FME) \quad (15)$$

Estimation of intake

According to AFRC (1993) the dry matter intake (DMI) is estimated as follows:

$$DMI(kg/d) = MER/(M/D) \quad (16)$$

where MER is Metabolisable Energy Requirement (MJ/d), M/D is metabolisable energy (MJ/kgDM).

This estimation of DMI is appropriate where daily gain is predetermined and forage is available in adequate amount. In a case where the DMI depends on forage availability and daily gain is not known forehand, the intake can be estimated based on experimental observations. We used an estimate of 2.7% of body weight based on Kariuki et al. (1998) value of 2.94%, Diaz-Solis et al. (2006) value of 2.54% and Blomquist (2005) value of 2.5 - 3.0% of the body weight. Therefore

$$IF \quad Fa \geq 0.027*W, \quad THEN \quad DMI = 0.027*W, \quad ELSE \quad DMI = Fa \quad (17)$$

where Fa is available forage.

Protein requirements

The metabolisable protein is based on AFRC (1993). Metabolizable protein requirement for maintenance (kg/d) is estimated as

$$MP_m = 2.30W^{0.75} \tag{18}$$

Metabolizable Protein requirement for growth (kg/d) is estimated as

$$MP_f = C6\{168.07 - 0.16869W + 0.0001633W^2 \times\{1.12 - 0.1223\Delta W\}\times 1.695\Delta W \tag{19}$$

where MP_f is metabolizable protein requirement for liveweight gain (g/d), $C6$ is a correction factor ranging from 0.8 -- 1.0, W is liveweight of the animal (kg).

Energy requirements

The energy requirement is based on AFRC (1993) and is calculated as follows:

$$M_{mp}(MJ/d) = (E_m/k)\times\ln\{B/(B-R-1)\} \tag{20}$$

where M_{mp} is ME requirement for both maintenance and production, E_m (MJ/d) is the sum of animal's fasting metabolism (F) and activity allowance (A = 0.0071W) for zero-grazed heifers, R is the scaled energy retention.

The fasting metabolism, MJ/(kg fasted weight)$^{0.67}$, is defined as:

$$F = 0.53(W/1.08)^{0.67} \tag{21}$$

The factors B and k are calculated from the efficiencies of utilization of ME as follows:

$$B = \frac{k_m}{(k_m - k_f)} \tag{22}$$

$$k = k_m \times \ln(k_m/k_f) \tag{23}$$

where k is the efficiency of utilization of ME (Metabolizable Energy) for a given metabolic process, B is a derived parameter to predict energy retention, k_m is the efficiency of utilization of ME for maintenance, k_f is the efficiency of utilization of ME for weight gain. Both k_m and k_f can be calculated as follows:

$$k_m = 0.35q_m + 0.503 \tag{24}$$

$$k_f = 0.78q_m + 0.006 \tag{25}$$

where q_m is the metabolizability of [GE] at maintenance, [ME]/[GE], where GE is the gross energy of a diet (MJ/d or MJ/kg DM).

Scaled energy retention (R) is calculated from:

$$E_f = C4(EV_g \times \Delta W) \tag{26}$$

where $C4$ is the correction factor for metabolizable energy for heifers (= 1.1) and then:

$$R = \frac{E_f}{E_m} \tag{27}$$

where E_f is Net Energy retained in growing animal (MJ/d), E_m is Net Energy for maintenance (MJ/d).

Predicting live weight gain

Predicting live weight gain involves the following steps:

Step 1. Energy value of weight gain

This is given by the expression

$$EV_g = \frac{C2(4.1 + 0.0332W - 0.000009W^2)}{(1 - C3 \times 0.1475\Delta W)} \tag{28}$$

where EV_g is energy value of tissue gained (MJ/kg), ΔW is live-weight change (kg/d), $C2$ is a correction factor (range 1.00 - 1.30) for mature body size and sex of animal; $C3$ is a correction factor for plane of nutrition (L), 1 when $L>1$ and 0 when $L<1$. These correction factors are given in AFRC (1993).

Step 2. Energy retention

Scaled energy retention (R) is as defined in Equation (27).

Step 3. Metabolisable Protein requirement for growth

Equation (19) is rearranged to estimate weight gain based on MP_f.

Step 4. Weight gain

Equation (26) is rearranged to give:

$$\Delta W = \frac{E_f}{(C4 \times EV_g)} \tag{29}$$

By combining the two (28) and (29) Equations and that contain the term ΔW, we get:

$$\Delta W = \frac{E_f}{(C4X + 0.1475E_f)} \tag{30}$$

Table 4. The definition of symbols and terminology.

Symbol	Definition	Units
a	Proportion of water soluble Nitrogen in the total Nitrogen of a feed	Unit-less
ADIN	Acid detergent insoluble nitrogen in a feed	g/kgDM
b	Proportion of potentially degradable N other than water soluble N of a feed	Unit-less
c	Fractional rumen degradation rate per hour of the *b* fraction of feed N	Unit-less
CP	Crude protein in of a diet or in a feed	g/kgDM, g/d
DMTP	Digestible microbial true protein (= metabolizable protein from microbes)	g/d, g/kgDM
DUP	Digestible undegraded protein (N x 6.25)	g/kgDM, g/d
FME	Fermentable metabolizable energy of a diet	MJ/d, MJ/kgDM
MCP	Microbial crude protein supply	g/d, g/kg
MP	Metabolizable protein	g/d, g/kgDM
MTP	Microbial true protein	g/d, g/kg
QDP	Quickly degradable protein (N x 6.25) of a diet or in a feed	g/d, g/kgDM)
r	Rumen digesta fractional outflow rate per hour	Unit-less
SDP	Slowly degradable protein (N x 6.25) of a diet or in a feed	g/d, g/kgDM
UDP	Undegradable dietary protein (N x 6.25) of a diet or in a feed	g/kgDM

where $X = C2\left(4.1 + 0.0332W - 0.000009W^2\right)$ is taken from Equation 28

DESCRIPTION OF THE SIMULATION MODEL

It is assumed that the animal is not constrained in any other way except the supply of crude protein. It is further assumed that there are no inhibitory nor synergetic tendencies between the different forages used. The feed input parameters are DM, GE, ash, CP, CP degradation variables (*a, b, c*, see Table 4 for definitions), acid detergent insoluble nitrogen (ADIN). Animal input parameters are initial weight and level of feeding. The dry matter intake without supplementation is set at 2.7% of animal's weight as explained in section 2.4. The dry matter intake of elephant grass supplemented with forage legumes can increase by about 16.7% as reported in Kariuki et al. (1999); in the current study we used this estimate to raise the intake to 3.2% of body weight. All other parameters are calculated by the model using the respective coefficients as indicated in the equations. The microbial crude protein yield (y) is determined by the amount of fermentable metabolisable energy (FME), If effective rumen degradable protein (ERDP) supply is less than (or equal to) ERDP required, then MCP = ERDP else MCP = FME multiplied by y .

After part of ME and MP have been used for maintenance, daily gain (DG) is dependent of the balance between Metabolisable Energy for growth (MEg) and Metabolisable Protein for growth (MPg); if potential growth due to metabolisable protein (Gp) is greater than the potential growth due to metabolisable energy (Ge), then MEg is considered limiting and the growth is determined by Ge. If potential growth due to metabolisable protein (Gp) is less than potential growth due to metabolisable energy (Ge), then MPg is considered limiting and the growth is determined by Gp. The simulated DG for the two forages is added to get the total DG which is then added to the weight to get a new liveweight (LW) and the process is repeated for the desired number of days. Since forages differ in nitrogen degradability, protein intakes were treated separately rather than summing them. The simulation model is coded in VENSIM 5.5 (The Ventana Simulation Environment, Ventana systems, Inc.), based on differential equations with a 1-day time step.

Evaluation of the simulation model

The performance of the simulation model was evaluated by comparing model predictions to field data reported in Tables 1, 2 and 3 that were never used in the development of the model. The daily gain predicted on the basis of forage composition and animal weight and requirements were compared to the values reported in Kariuki et al. (1999).

RESULTS AND DISCUSSION

Model calibration and evaluation

Parameter selection for model calibration was based on the sensitivity of the parameter values in Tables 1, 2 and 3. The experiments from which these datasets were generated were either on the effect of supplementation on degradability or effect of supplementation on weight gain. Degradability parameters required as inputs for the simulation model were obtained from experiments that fall in the degradation category. Parameters that describe protein degradation in the rumen (a, b, c) and ADIN which contributes directly to fecal N levels, are highly variable (Webster, 1993) even when determined for the same samples at different laboratories. Therefore these parameters were selected as the starting point for the calibration. However, in cases where there was lack of data, the calibration datasets are the same ones used to derive parameters for the model, since they provide an indication of the models' performannce following manipulation of model parameters to improve accuracy (Hill et al., 2006). The simulation model predicted DG of 0.43 kg/day when heifers weighing 181 kg are fed elephant

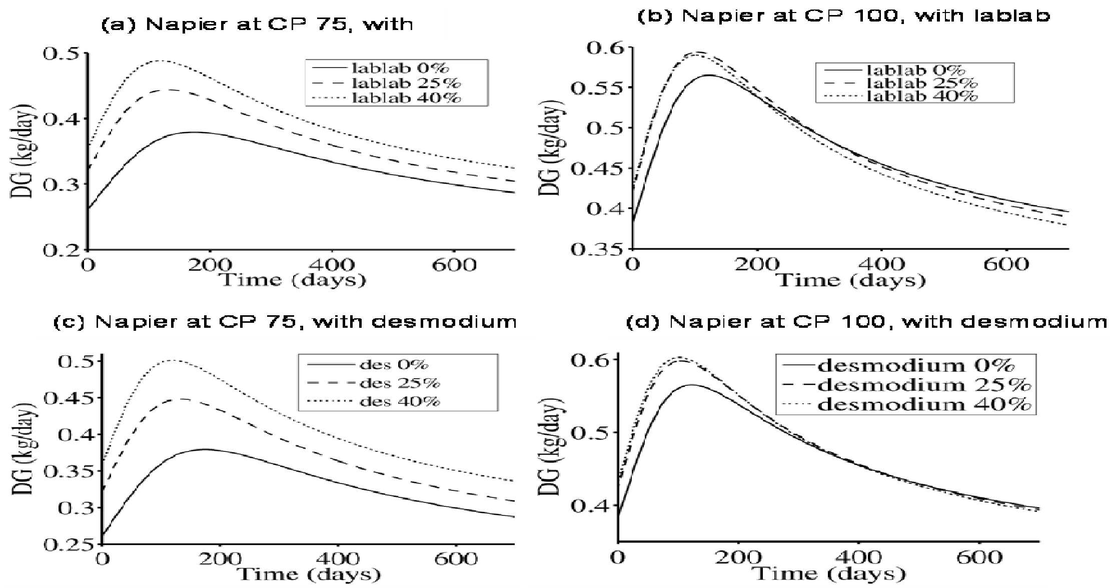

Figure 1. Daily gain when elephant grass is supplemented with Lablab and Desmodium at different levels. (a) Napier at CP 75 g/kgDM supplemented with lablab at different levels (b) Napier at CP 100 g/kgDM supplemented with lablab at different levels; (c) Napier at CP 75 g/kgDM supplemented with desmodium at different levels (d) Napier at CP 100 g/kgDM supplemented with desmodium at different levels.

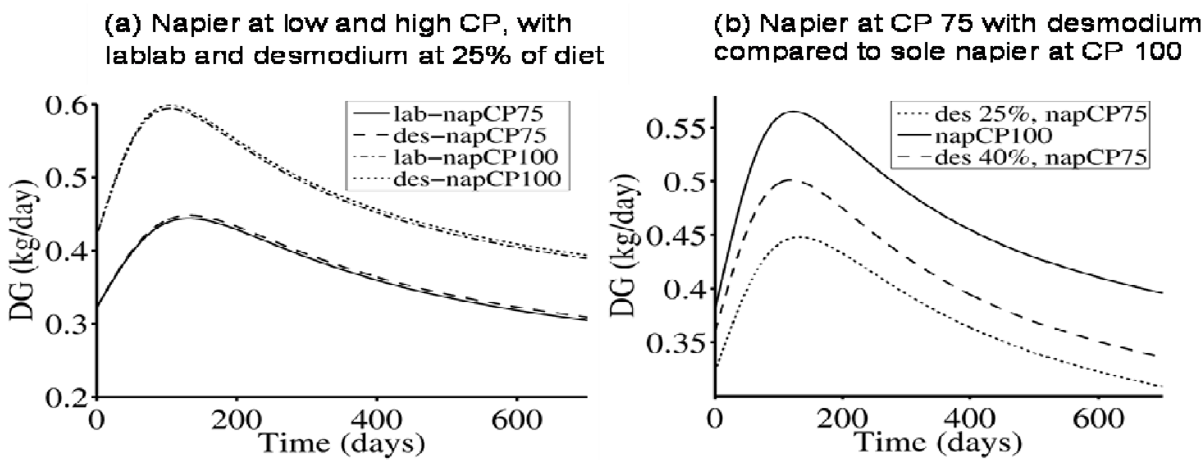

Figure 2. Daily gain of heifers when fed with elephant grass at two levels of CP and supplemented with Lablab and Desmodium. (**a**) Napier at CP 75 and 100 g/kgDM, supplemented with lablab and desmodium at 25% of diet; (b) Napier at CP 100 g/kgDM, compared to napier at CP 75% supplemented with desmodium at 25 and 40% of diet.

grass supplemented with desmodium for 120 days. This result is similar to field results of 0.42 kg/day reported by Kariuki et al. (1999).

Model use

According to Leng (1990), forages are considered as low quality if they have less than 80 g of CP/kgDM and high quality if 100 g of CP/kgDM and above. It is on this basis that CP 75 and 100 g/kgDM were chosen for model use.

Figure 1 shows the DG of heifers fed elephant grass supplemented with lablab and desmodium. DG improved as the level of supplement increased (Figures 1a and c). However, at high levels of Napier CP (100 g/kgDM) the benefit of supplementation becomes less significant (Figures 1b and d), whereas at low napier CP (75 g/kgDM) supplementation up to 40% yielded less DG compared to unsupplemented napier at high CP (100 g/kgDM) as shown in Figure 1b. DG as a result of supplementation was similar for both lablab and desmodium (Figure 2a). Table 5 shows DG and time from weaning to

Table 5. DG and days from weaning to 300 kg LW of heifers fed napier grass supplemented with lablab and desmodium[a].

	%Desmodium in diet			%Lablab in diet		
CP[b]	0	25	40	0	25	40
75	691(0.33)	597(0.39)	533(0.43)	691(0.33)	604(0.38)	551(0.42)
100	461(0.50)	442(0.52)	441(0.52)	461(0.50)	446(0.52)	453(0.51)

[a]Values in parentheses are the DG in kg/day. [b]CP in Napier, g/kgDM.

mating weight of 300 kg LW of heifers fed napier grass supplemented with lablab and desmodium.

According to the MLD (1991) recommendations in the smallholder dairy farming systems, the weaning weight for dairy heifers is 70 kg and a target of 300 kg to be attained by 18 months of age for first service. For this target to be met the heifers are assumed to gain at least 0.5 kg/day. From the results of this study (Table 5) this target DG is not possible on low quality napier grass. Forages are considered as low quality if they have less than 80 g of CP/kgDM (Leng, 1990). As seen from Table 5 low quality elephant grass even when supplemented up to 40% of the diet, it is not possible to attain DG of 0.5 kg/day. However, with high quality elephant grass DG of 0.5 kg/day is possible with or without supplementation (Table 5). The lack of improvement in DG as a result of supplementation was also reported by Kariuki et al. (1999) when elephant grass was supplemented with desmodium; this is because of the high nutritive value of the elephant grass used. Therefore supplementing poor quality elephant grass with forage legumes improves DG but not necessarily so when the nutritive value of elephant grass is high. Although the simulation model predictions were similar to observed values of Twinamatsiko (2001) and Kariuki et al. (1999), the model has limitations in that only the averages for the observed values were available for model development and evaluation. But to optimize growth there is need to know the growth curve so that the appropriate amount of supplement is given at the right time. Therefore further research on heifer performance in smallholder dairy is needed to accumulate adequate data for developing and evaluating the simulation models of dairy heifer growth.

The simulation model indicates that lablab and desmodium have the same effect on DG and if they are to be of value they should be used when the elephant grass is poor quality, usually at an advanced stage of growth when it is low in CP. These two forage legumes could therefore improve heifer growth, consequently reducing the time from weaning to mating weight of heifers in smallholder dairying where the CP content of elephant grass is low.

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