Predicting the growth and feed intake of Bonsmara cattle on forage based rearing systems

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Abstract

This study aimed at estimating models to predict the growth and feed intake of Bonsmara bulls and heifers in backgrounding or pasture-based production systems (Ethical clearance number A16-SCI-AGR-001). Growth and intake data were collected from the Kromme Rhee Bonsmara stud in the Stellenbosch region. The growth curves of steers and heifers were modelled using the Gompertz function. Parameter estimates of the function showed that the mature weight (A) parameter was greater ($P < 0.05$) for bulls than heifers (*ca.* 878.4 vs 562.1 kg, respectively). The maturation rates (parameter B) did not differ between the sexes, while the days at maximum growth (parameter C) was higher for bulls (291.5 days) than for heifers (182.4 days). Linear functions were used to describe the average feed intakes, as well as cumulative intakes, with body weights from growing bulls and heifers from the ages 6-20 months reared on lucerne hay and protein supplement. On average, it was observed that on the lucerne hay-based diet, Bonsmara bulls and heifers consumed about 2.43% of body weight daily throughout the study period. These models can be used in precision beef rearing systems to predict the production and market weights of Bonsmara calves that are either reared on hay or pasture.

Introduction

The Bonsmara breed was developed between 1937 and 1963 to produce a beef animal suited for the extensive subtropical climates (Bonsma, 1980). It has become a popular beef breed in Southern Africa, with Bonsmara animals contributing 41.7% of the records of the Logix beef database (SA Studbook, 2016).

A National survey showed that Bonsmara (54%), as well as Bonsmara crossbreeds (46%), were the most popular (15.9%) breed found in South African beef feedlots (Scholtz et al., 2008). Beef farming in Southern Africa mainly takes place on natural grazing, with greater carrying capacity in higher rainfall areas. Nevertheless, there is a variety of production systems, where extensive systems as well as feedlot finishing (60% of cattle marketed) play a major role in the beef market sector (Kirsten, 2014). The Bonsmara is regarded as a medium framed breed, with slaughter weights of ~415 kg, when adjusting slaughter weights for subcutaneous fat thickness (Strydom et al., 2001).

In an industry that strives toward intensification and precision rearing, to optimise efficiency, it is necessary to understand the growth and intake trends of growing cattle. This study therefore aims at modelling the growth curve of Bonsmara bull and heifer calves, as well to describe trends in intake from weaning up until maturity on a roughage-based diet. These models and trends can then be used by producers to make predictions of growth and intake at different rearing stages.

Materials And Methods

Growth data from 19 bulls and 22 heifers were collected from the Kromme Rhee Bonsmara stud on the Kromme Rhee Research Farm of the Western Cape Department of Agriculture in Stellenbosch. Calves,

born during the wet winter months (May-June), were identified and weighed at birth and were then weighed at monthly intervals up until the age of ~24 months. Therefore, a total of 456 (19 x24) and 528 (22x24) data points were collected throughout the growth trial for the bulls and heifers, respectively.

Calves born from multiparous stud cows were used in this study. The year of birth was used to distinguish between the two production years used (2014 and 2015). Bull calves were not castrated in this study. The calves were reared on extensive grazing with their dams while also receiving creep feed preweaning at a rate of 1kg/calf/day. The calves were weaned at about six months of age, where they grouped according to sex and group fed in camps. In the camps, the calves received lucerne (*Medicago sativa*) hay (90.68% dry matter, 58.48% total digestible nutrients, 31.17% crude fibre, 15.45% crude protein and 8.31% ash) *ad libitum* and a protein supplement (Table I) at 2 kg/animal every second day. The amount of protein supplement supplied was increased up to 3 kg/animal when body weights of heifers and bulls exceeded 350 kg and 380 kg, respectively. The calves were reared in the camps up until ~24 months of age, when they were assumed to have attained maturity. Growth data of the calves were collected from two production years, namely the 2014 and 2015 production years.

Statistical analysis was performed using SAS Enterprise guide (SAS version 7.1). Growth data was modelled using the Gompertz growth curve of the form $A \cdot \exp(-\exp(-B(C-t)))$, where A denotes the asymptotic mature weight, B denotes the maturation rate, C refers to the age at maximal growth and t denotes the age of the animal in days (Emmans, 1990). The Gompertz function has shown to be well suited in describing the growth datasets obtained from continuous measurements of individuals (Van der Merwe et al., 2019)

Literature studies indicated that the Gompertz model was used in a diversity of research studies. A previous study investigating a more appropriate model describing broiler growth, identified the Gompertz model to be the fittest model, relative to Bertalanffy and the Logistic nonlinear regression (Al-nasrawi, 2018). Gompertz also adequately established the mean growth patterns and predicted body weight of Nelore female cattle (Forni et al., 2009). Additional instances where the Gompertz model were a fit model and frequently used include a study by (Chakraborty et al., 2014) where it was found to be the most suitable growth curve modelling fitness traits on Japanese quail. Castro *et.al* also used the Gompertz model reviewing growth patterns in cells. Overall the Gompertz model was used by reason of being more useful; having easily interpretable parameters (Tjørve & Tjørve, 2017).

The Gompertz function was fitted to the individual growth curves of each animal and parameter estimates were compared by a two-way analysis of variance, with the main effects of sex and production year. Statistical differences were observed at the $P < 0.05$ significance level. The R^2 coefficient of determination was determined by regressing the observed weights against the predicted weights using Proc REG (SAS version 7.1), in order to indicate the amount of variation of the data that is accounted for by the model.

Results And Discussion

The ingredient and nutrient composition of the protein supplement provided to Bonsmara calves can be seen in Table I.

Table I The ingredient and nutrient compositions of protein supplement provided to Bonsmara calves

Ingredient	g/kg As fed	Nutrient	Composition
Maize	576.0	Dry matter (%)	89.90
Cottonseed oilcake	286.0	Metabolisable energy (MJ/kg)	10.89
Salt	11.0	Crude protein (%)	29.60
Urea	40.0	Crude fiber (%)	0.28
Monocalcium phosphate	28.0	Fat (%)	2.96
Molasses powder	28.0	Ash (%)	3.15
Limestone	22.0	Calcium (%)	1.32
Sulphur	6.0	Phosphorous (%)	1.12
Commercial vitamin and Mineral premix	3.0		

With regards to the Gompertz parameter estimates (Table II), an interaction between sex and year was only observed for the *A* parameter ($P=0.026$). The interaction indicated that bulls in 2015 tended to have heavier mature weights than in 2014, while the mature weights of heifers from the different production years did not differ.

Comparing the main effects separately, animals from 2015 tended to have heavier asymptotic weights (*A*) than that of the 2014 production year ($P<0.10$). With respect to the other parameter estimates, no differences were observed between the two production years ($P>0.05$). For the effect of sex, bulls had heavier mature weights than heifers (878.96 and 564.36 kg, respectively; $P<0.001$) and were also older than heifers at the point of maximal growth (*C*) (290.50 and 184.03 days, respectively; $P<0.001$). No differences were observed between bulls and heifers for the maturation rate (*B*) parameter (~ 0.0043 ; $P=0.810$). The models determined for the different sexes accounted for more than 92% of the variation of the data, while with regard to production year, 89% of the variation was accounted for by the respective models. The sexual dimorphism between bulls and cows accounts for the differences observed with the Gompertz parameter estimates. Males are heavier than females when at the same age. Males are also later maturing than females as they reach heavier mature weights. The growth curves of bulls and heifers estimated by the Gompertz function are illustrated in Figure I. The Gompertz parameters estimates obtained in this study indicate heavier weights for heifers than for bulls (Figure I) which contradicts the notion that bull calves are heavier than heifer calves at the same age. Actual birth data showed that the

average birth weights of bull calves (40.7 kg) were in fact heavier than heifer calves (36.5 kg) ($P < 0.05$). This unexpected trend illustrated by the Gompertz growth curve, may be partially due to the significantly lower C parameter estimate of heifers which indicates that the point of inflection of heifers is reached almost 100 days before that of bulls. The inflection point in various sheep breeds has been shown to occur shortly after the weaning age; thus adjusting the C parameters of both sexes to coincide with shortly after weaning age (e.g. 220 days) should give a better indication of early growth.

It is also suggested that dam age affects the heifer progeny growth and reproductive performance; not necessarily the dam live weight (Beard et al., 2019). Mature beef cows have a tendency to wean heavier calves (Beard et al., 2019), that possibly may expand the number of heifers reaching puberty earlier than that of bull calves. In terms of post-weaning growth, these models are still appropriate to predict body weights of bulls and heifers with more than 92% of the variation being accounted for by the Gompertz models fitted to the respective growth curves of bulls and heifers.

Table II Comparison of the Gompertz growth parameter estimates between bull and heifer calves for the 2014 and 2015 production years (LSM $\pm$ S.E)

Main effect		Parameter			R ²
		A	B	C	
Sex	Bull	878.96 $\pm$ 23.06	0.0045 $\pm$ 0.0007	290.50 $\pm$ 12.07	0.929
	Heifer	564.36 $\pm$ 29.90	0.0042 $\pm$ 0.0009	184.03 $\pm$ 15.64	0.920
P-value		<i><0.001</i>	<i>0.810</i>	<i><0.001</i>	
Year	2014	689.11 $\pm$ 19.30	0.0038 $\pm$ 0.0006	226.31 $\pm$ 10.10	0.891
	2015	754.21 $\pm$ 32.46	0.0049 $\pm$ 0.0010	248.23 $\pm$ 16.99	0.899
P-value		<i>0.093</i>	<i>0.337</i>	<i>0.274</i>	

To determine intake trends of calves reared on a hay-based diet, two groups of five bull calves and five heifer calves, of similar body weights born from the Kromme Rhee Bonsmara stud cows, were group fed in 0.25 ha camps from weaning until about two years age. The animals were reared on lucerne hay which was provided *ad libitum* in hay racks and a protein supplement (Table I) which was provided every second day at a rate of 2 kg per animal for heifers and bulls weighing under 350 kg and 380 kg, respectively. When the average weights of the animals exceeded these body weights, the proportion of supplement was increased to 3 kg per animal. Wastage from the hay rack was monitored daily over a two week period and was used to correct intake over the rearing period. The hay racks were positioned on concrete slabs to facilitate the collection of wastage hay that was pulled from the trough and trampled. The wastage was collected before feeding each day, weighed and expressed as a proportion of hay supplied the previous day. The average wastage was calculated from the two week monitoring period and was used to correct the amount of hay consumed by subtracting the average wastage proportion. Feed

refusals were determined weekly, with fresh hay being supplied daily. Feed intakes and body weights were recorded on a monthly basis. From the intake study, the average production performance characteristics for bulls and heifers over the study period were determined and presented in Table III. The end weights of bulls tended to be heavier than that of heifers ($P=0.109$), while the growth rates of bulls (0.837 kg/day) were significantly higher than that of the heifers (0.633 kg/day).

Overall, no differences in average daily feed intake (~9.88 kg/day) or feed conversion ratio (FCR) (~13.72 kg feed / kg gain) were observed in this study. Under feedlot conditions, De Bruyn (1991) observed growth rates of 1.094 kg/day and FCR of 7.09 kg feed/kg gain for Bonsmara steers. Esterhuizen et al., (2008) observed growth rates of 1.52 kg/day for Bonsmara steers in a feedlot, while steers on pasture receiving supplement grew at a rate of 0.98 kg/day. Under feedlot conditions (high energy and protein), Bonsmara steers present FCRs of less 5-6 kg feed/kg (Strydom et al., 2001), while in the current prolonged study the cattle were reared on simulated pasture rearing conditions on a forage based diet.

Table III Production performance means of group fed Bonsmara bull and heifer calves reared for 369 days under simulated backgrounding conditions (LSM $\pm$ S.E.)

Trait	Bulls	Heifers	<i>P</i> -value
Start age (days)	222 $\pm$ 45	236 $\pm$ 43	0.789
Starting weight (kg)	274 $\pm$ 56.3	271 $\pm$ 24.0	0.941
End age (days)	599 $\pm$ 40	605 $\pm$ 31	0.916
End weight (kg)	583 $\pm$ 39.5	504 $\pm$ 8.1	0.109
Average daily gain (kg/day)	0.837 $\pm$ 0.046	0.633 $\pm$ 0.043	0.045
Average daily intake (kg/day)	10.12 $\pm$ 0.530	9.64 $\pm$ 0.339	0.398
Feed conversion ratio (kg/feed/ kg weight gain)	12.13 $\pm$ 1.30	15.30 $\pm$ 1.58	0.160

Average feed intake was regressed against average body weight of the calves for both sex groups in order to determine how intake increases in growing cattle. Linear regressions were then developed that can be used to predict the average daily intake as well as cumulative feed intake (CFI). The regression coefficients of bulls and heifers could not be compared statistically due to there being only two repetitions per sex group.

Intake of bulls can be predicted by:

$$\text{Daily feed intake (kg)} = 0.1653 + 0.0235 W$$

$$(R^2=0.783)$$

$$\text{CFI (kg)} = 7.973W - 1895.8$$

$$(R^2 = 0.680)$$

Intake of heifers can be predicted by:

$$\text{Daily feed intake (kg)} = 0.0284W - 1.4199$$

$$(R^2 = 0.763)$$

$$\text{CFI (kg)} = 7.889W - 1802.0$$

($R^2 = 0.673$). Where W represents the average live weight of the cattle (kg).

These equations can be utilised to predict the level of growing calves consuming a forage based diet. Under these conditions, calves are reared on grass/ forage-based systems with the provision of a protein supplement (contributing ~37% of daily intake) on alternate days to meet growth requirements of the animals. Under feedlot conditions, Van der Westhuizen et al., (2009) estimated intake of Bonsmara bulls using a polynomial function to show that intake increases from 8.4 kg to 11.0 kg in the first 10 weeks of feedlot finishing, after which intake tends to level out. In the current study, the animals were not reared on concentrate diets and so intake of the growing animals kept increasing in order to meet the requirements of the animal.

Hence intake increased linearly through the study period. At each monthly weighing, average daily intake was expressed as a percentage of average body weight and the average intake as a percentage of body weight was calculated over the rearing period. The intake expressed as a percentage of body weight was calculated every month and analysed between the groups. No differences were observed between the sexes ($P = 0.453$) with an average percentage intake of 2.43% being observed in this study. This is lower than average percentage intake calculated from the models determined by Van der Westhuizen et al., (2009) which showed that bull calves consumed ~3% of body weight. The bulkiness of the forage consumed, physically limit the intakes of the animals and therefore calves consuming a forage based diet are expected to present lower intakes than feedlot calves in relation to body weight

Conclusion

Using the growth curves and intake models developed in this study for Bonsmara bulls and heifers, producers can perform simulations to estimate the production of calves reared on pasture. The growth curves can be used to predict live weights and by incorporating economic indexes be used to predict optimal marketing weights. The intake models that were developed can assist producers in planning their pastoral stocking rates and assist in the calculation in the level of supplementation required.

Further research is required to increase the size of the database and to test the application of various growth functions, while also incorporating data of calves reared on different nutritional planes, so as to produce more robust models. These models allow producers to make a step towards precision rearing of beef cattle, in particular for pasture, or roughage based, rearing systems.

Declarations

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Conflicts of interest Not Applicable

Availability of data Not Applicable

Authors' contribution Not Applicable

Ethics approval Research Ethics Committee Animal (RECA) A16-SCI-AGR-001

Consent to participate Not Applicable

Consent for publication The authors declare that they give consent for publication of this article.

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Figures

Figure 1

The Gompertz growth curve illustrating the growth of Bonsmara bulls and heifers