Volume 58, January-December 2024, ISSN: 2079-3480

BIOMATHEMATICS

CUBAN JOURNAL OF AGRICULTURAL SCIENCE

Journal site: https://cjascience.com Cu-ID: https://cu-id.com/1996/v58e23

Growth model in crossbred dairy calves on grazing with protein-energy-mineral supplementation

Modelo de crecimiento en terneros lecheros mestizos en pastoreo con suplementación proteica-energética-mineral

María I. Viamonte Garcés[1]*, D. Acosta Iglesias[1], F.A. Calva Moreno[2], D.J. Naula Campoverde[1]

[1]*Universidad Estatal Amazónica (UEA), Facultad de Ciencias de la Tierra, Carrera Agropecuaria, km 2 ½, vía Puyo a Tena (Paso Lateral), Ecuador*
[2]*Empresa Utopía-Farms, Grupo Esmeralda, Ecuador*

Email: mviamonte@uea.edu.ec, miviamontegarces@gmail.com

The research was conducted from March to May 2020 to develop functions to estimate growth and increase in live weight and average daily gain in dairy cattle in pre-fattening stage, in rotational grazing, with grasses association and protein-energy-mineral supplementation. Information was taken from the botanical composition in percentage, fresh and dry matter in a hectare divided into four equal plots, the chemical composition of the grasses association and the cattle stocking rates capacity of the system, live weights and weight gains in the animals. From this information, functions were developed to estimate growth and increase in live weight and average daily gain in crossbred dairy calves until their future productive performance. The grazing area consisted of 51.51 % plant biomass of ratana grass (*Ischaemum indicum*) and 20.74 % forage peanut (*Arachis pintoi*). The quality of the grasses association with the highest contributions of crude protein was in forage peanut and ratana (20.75 and 23.44 %, respectively). The average gross energy contributions were 1023.9 kJ/kgDM, with the best values for forage peanut (1107.24 kJ/kgDM). The total grass yield was 3488.50 kg/ha. The prediction of future productive performance in fattening was influenced by weight increases in the first three months of age of the calves, regardless of birth weight. These changes in the growth curve are due to the diet with energy-protein-mineral supplementation.

Key words: *grazing, growth curves, simulation, stocking rates capacity, weight gain*

La investigación se desarrolló de marzo a mayo del año 2020 para desarrollar funciones destinadas a la estimación del crecimiento e incremento de peso vivo y ganancia media diaria en bovinos lecheros en etapa de preceba, en pastoreo rotacional, con asociación de pastos y suplementación proteica-energética-mineral. Se tomó la información de la composición botánica en porciento, materia fresca y seca en una hectárea dividida en cuatro cuartones iguales, la composición química de la asociación de pastos y la capacidad de carga bovina del sistema, los pesos vivos y las ganancias de peso en los animales. A partir de esta información se desarrollaron funciones para la estimación del crecimiento e incremento de peso vivo y ganancia media diaria en terneros lecheros mestizos hasta su futuro desempeño productivo. El área de pastoreo estuvo constituida por la biomasa vegetal de 51.51 % de pasto ratana (*Ischaemum indicum*) y 20.74 % de maní forrajero (*Arachis pintoi*). La calidad de la asociación de pastos con los mayores aportes de proteína bruta fue en maní forrajero y ratana (20.75 y 23.44 %, respectivamente). Los aportes promedio de energía bruta fueron de 1023.9 kJ/kgMS, con los mejores valores para el maní forrajero (1107.24 kJ/kgMS). El rendimiento total del pasto fue de 3488.50 kg/ha. La predicción del comportamiento productivo futuro en la ceba estuvo influenciada por los incrementos de peso en los tres primeros meses de edad de los terneros, independientemente del peso al nacer. Estos comportamientos del cambio en la curva de crecimiento obedecen a la dieta con suplementación energética-proteica- mineral.

Palabras clave: *capacidad de carga, curvas de crecimiento, ganancia de peso, pastoreo, simulación*

Received: March 23, 2024
Accepted: September 01, 2024
Conflict of interests: There is no conflict of interest between the authors.
CRediT Authorship Contribution Statement: María I. Viamonte Garcés: **Conceptualization, Formal analysis, Investigation, Methodology, Supervision, Writing - the original draft.** D. Acosta Iglesias: **Data curation, Formal analysis, Methodology, Software, Writing - the original draft.** F.A. Calva Moreno: **Funding acquisition, Investigation, Project administration, Resources, Validation.** D. J. Naula Campoverde: **Funding acquisition, Investigation, Project administration, Resources, Validation.**

Introduction

Beef production is an important source of protein in the diet and represents 21.59 % of the total meat produced in the world (FAO 2023). In Ecuador, according to data from INEC (2023), between 2017 and 2023, the cattle population gradually decreased each year. A decrease of 5.08 % was recorded compared to 2022. However, livestock is the one that contributes the most to the agricultural sector, with 3.9 million animals. However, 37.7 % and 23.8 % of the national total are respectively crossbred and Creole breeds, of which 60 % correspond to dual-purpose cattle.

In recent years, the Ecuadorian Amazonia region has an increase in the expansion of the agricultural frontier, with the purpose of cultivating grasses that allow sustaining the considerable increase in livestock production, approximately 50.67 % of the total deforested area at the national level, which corresponds to 5.58 million hectares (Corral *et al.* 2021).

The cattle production systems under Amazonian conditions face the challenge of efficiently use scarce resources by the continuous improvement of their productive processes and, in turn, to offer the quality meat that the market demands, without affecting the profitability. That is why Zhang *et al.* (2019) highlight the importance of determining the animal stocking rates capacity of the grasses area, since in this area the grazing method used is rope grazing, with stocking rates of 0.75 to 1.0/ha on low nutritional content grasses, mainly gramalote (*Axonopus scoparius*). In addition, in dairy breeds, males are a problem on farms (Benítez *et al.* 2018). However, if feeding alternatives and adequate management of animals in grazing are used, they could be an income for farmers, taking advantage of the true yields that the land can offer.

The knowledge of growth curves is of great importance, not only for scientific work, but also for farmers engaged in fattening, since it can appreciate the periods of high and low weight gain over the course of an animal's life, and to know when attention should be paid to it so that it is profitable during the fattening process.

Given that grasses in the Amazonia are the staple food in the cattle diet, and do not satisfy all their dietary needs due to limited concentrations of energy, protein and minerals, the objective of this study was to develop functions to estimate growth and increase in live weight and average daily gain in dairy calves in the pre-fattening stage, fed with protein-energy-mineral supplementation and with an grasses association under the Ecuadorian Amazonia conditions.

Materials and Methods

The study was carried out during twelve weeks, between March and May 2020, in the cattle production program from Centro de Experimentación e Investigación de Producciones Amazónicas de la Universidad Estatal Amazónica, located between the cantons Santa Clara, Pastaza province, and Carlos Julio Arosemena Tola, Napo province. The Experimentation Center is located at kilometer 44, Puyo-Tena road, next to the mouth of Piatúa and Anzu rivers. Its geographical location is 01° 14’ 4.105” south latitude and 77° 53’ 4.27” west longitude, at an altitude of 584 m o. s. l and average temperatures between 23-24 °C.

Measurements in grasses: A total of 10 to 15 subsamples were collected in each paddock (four paddocks) of 1 ha. The collected samples were taken at a height of 5 to 10 cm above the soil surface. The subsamples were mixed into one and 1 kg of fresh material was taken. The sampling method and technique described by Redjadj *et al.* (2012) was applied, a mixed method that uses sampling techniques such as visual appreciation in the evaluation of botanical composition, with manual separation (weight and volume record) and visual appreciation by a specialist in Amazonian grasses.

To determine the yield and availability of grass, the visual estimation method described by Senra and Venereo (1986) was used. The first sampling was carried out before the animals entered and after they left the grazing.

Grass availability was calculated from available biomass (AB) and rejected biomass (RB):

$$GA(\%) = [(AB - RB)/AB] \text{ x } 100$$

Chemical composition of the grass: Grass availability samples were used, for which a pool was prepared with the five reference points in each paddock and a sample of fresh matter (FM) was taken from the grass, to determine the percentages of dry matter (DM), protein, fat, ash and fiber fraction using the AOAC (2023) methodology. The energy was determined by an equation to estimate its requirement, according to (Rostagno *et al.* 2017). The chemical analyses were carried out in the bromatology laboratory from Universidad Estatal Amazónica.

Animal management and feeding: Under these conditions, 10 male calves of three dairy breeds were considered: Brown Swiss (3), Girolando (4) and Sahiwal (3) with an average age of 45 d and initial weight ranges between 29 and 35 kg, which were subjected to combined management with 7 hours of grazing with an association of protein-rich forage species. For the rotation of the paddocks, the stocking rate capacity was taken into account to fulfill the food requirements and then in the shed, nutritional supplements (protein-energy-mineral) were supplied with seven days of adaptation before data collection, described in table 1. Supplementation was formulated according to the nutritional requirements for growing cattle (Posada *et al.* 2016). The animals had water *ad libitum* while grazing and in the stable.

Table 1. Formulation and nutrient contribution of the protein-energy-mineral supplement (% DB).

Ingredients, (raw matters)	Dry base, %
Yellow corn	48.47
Soybean meal	6.99
Protein concentrate	24.97
Wheat bran	12.99
Palm oil	4.99
Iodized salt	0.48
Mineral salt	1.10
Nutrients contribution	
CP, %	19.83
Lignin, %	3.45
GE kJ/kg DM	11073.44
NDF, %	55.38
ADF, %	6.32
N.F.E, %	61.54
Fat, %	6.63
Ash, %	8.15

Mathematical model for monitoring fattening: There are several methods for describing the growth curves of cattle according to age and weight (table 2). Among them, the Brody (1945) equation, according to this author the weight of an animal at a given age is defined as the live weight reached by an animal when it has completed its bone development and the body condition is average. Bourdon and Brinks (1987) modified the model by assuming linear growth until one year of age (puberty), after which the Brody (1945) post-inflection curve was fitted from puberty to maturity. As for other studies, the use of non-linear models for growth curve fitting has proven to be very useful, as is the case of the models of Gompertz (1825), Von Bertalanffy (1957) and Nobre *et al.* (1987), among others.

Table 2. General form of nonlinear models

NONLINEAR MODELS	
Gompertz (1825)	$y = Ae^{\left(-B^{-kt}\right)}$
Brody (1945)	$y = A\left(1 - Be^{-kt}\right)$
Von Bertalanffy (1957)	$y = A\left(1 - Be^{-kt}\right)^3$
Logistic (Rosa *et al.* 1978)	$y = A\left(1 + Be^{-kt}\right)^{-M}$

Source: Olson (2010)

In the referred models, the parameter A represents the adult weight of the animal when time tends to infinity. The parameter B is the integration factor that fits the initial weight values and is generally associated with the birth weight (degree of maturity of the animal at birth). However, the parameter k, maturity rate, is a function between the maximum growth rate and the adult weight of the animal (growth velocity). The "t" component of the function represents the age of the calf in days.

Growth rate can be described in different ways. In the average growth rate during a period influenced the feeding system used in animal rearing, which can often be corrected as an accelerated compensatory growth (Solórzano 2022).

In this study, to carry out the perspective analysis of the growth and increase in live weight and expected average daily gain in dairy cattle at the calf stage, the data on the weights at birth, one and three months of crossbred dairy cattle were used, obtained from the physical grazing experiments, carried out from March to May 2020. For this purpose, a logistic model of population growth was used, which simulates processes at the individual level (live weights, change in live weight and weight gains by stages), processed by the mathematical assistant Matlab version 9.9 (R2020b). These processes are integrated at the herd level and generate a monthly evolution of live weight according to categories. It was possible to infer the weight that fattened animals can reach in the yearling category and the rest of the productive performance during the fattening stage.

The logistic model applied to the fattening performance of calves can be presented as follows:

$$\frac{dP(t)}{dt} = kP(t)\left(1 - \frac{P(t)}{P_m}\right) \quad (1)$$

The general solution of (1) is, where $P(t)$ is the weight of the individual in the time, P_m is the estimated maximum weight at the end of the fattening period and k is a constant, which partly includes the intrinsic growth rate.

The relation between birth weight and weight gain in the initial stage considered can be seen in the expressions for the parameters "k" and "C", although the latter is not directly related to time in the weight function and is not analyzed. The weight gain rate is, as shown by formula (2), which is given by:

$$P(t) = \frac{P_m Ce^{kt}}{1 + Ce^{kt}} \quad (2)$$

The model is used as a predictor of the weight that each specimen should reach in the time periods. An ideal performance was simulated by using the average weights at birth and at the end of the initial period, and from this a range of acceptable performances for the animal category can be formed, when modifying the average weights downwards and upwards in a fraction of interest of the standard deviations of the sample, which facilitates obtaining a range of weights for each period.

In addition to the model, an Excel spreadsheet was used to analyze individual performance, according to how the process occurred at the beginning and to obtain information that allows to made corrections and take correct decisions during fattening, where it is only required to include birth weight and an initial period of time and weight, to obtain the weight estimate in daily and monthly periods.

Results and Discussion

Table 3 shows the botanical composition of the grazing area where the growing cattle remained in the CEIPA dairy farm. The highest percentage of plant biomass was made up of 51.51 % of ratana grass (*Ischaemum indicum*), 20.74 % of forage peanut (*Arachis pintoi*) and, to a lesser percentage, Pitillo (*Ixophorus unicetus*) and Comino (*Homolepsis aturensis*) grasses, 15.51 and 12.24 %, respectively.

The highest availability of green matter was 1868.20 and 752.40 kg/ha corresponds to the species of ratana (*Ischaemum indicum*) and forage peanut (*Arachis pintoi*) respectively, because they were established species. The latter helps protect the soil due to its growth habit and rooted stolons. When managed correctly in the Amazonian, it has high persistence, in addition to the benefits of its ability to fix atmospheric nitrogen and make it available for association with grasses; it is an excellent alternative due to the climatic conditions and favorable soils for its establishment (Song *et al.* 2023).

Figure 1 show the yield of grass production in each of the paddocks where the animals grazed. It is well known that, despite the enormous supply of forage resources, livestock in the Latin American tropics faces a hard battle with stability in the production of plant biomass and the quality of grasses.

Likewise, during the experiment execution period, tropical grasses have low energy-protein quality and their structure offers poor density of green leaves, which affects the efficiency of intake by the animal and causes a deficit of protein and digestible energy. This phenomenon has forced to opt to supplement the dry matter, energy and deficient

Table 3. Description of the botanical composition of the grazing areas of the growing-developing cattle from CEIPA dairy farm

Botanical composition, % and availability						
	Paddocks					
SPECIES	I		II		III	
	FM (g)	DM (g)	FM (%)	DM (%)	FM (kg/ha)	DM (kg/ha)
Forage peanut (*A. pintoi*)	75.24	25.1	20.74	21.16	752.40	251.00
Ratana (*I. indicum*)	186.82	54.16	51.51	45.67	1868.20	541.60
Comino grass (*H. aturensis*)	44.40	20.95	12.24	17.67	444.00	209.50
Pitillo grass (*I. unicetus*)	56.25	18.38	15.51	15.50	562.50	183.75
TOTAL	362.71	118.59	100	100	3627.10	1185.85

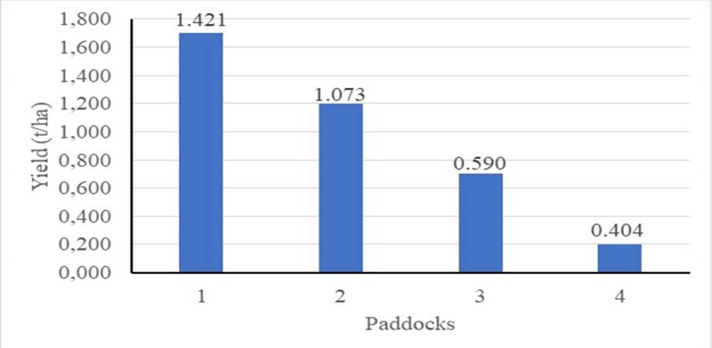


Figure 1. Grass yield per each paddock for rearing males from dairy breeds

protein in their production systems with energy-protein and mineral supplements. Honig *et al*. (2022) in a study on the body chemical composition of growing Fleckvieh (German Simmental) dual-purpose cattle recommend about energy and nutrient requirements. These authors showed that body composition changed during growth, but was not affected by dietary energy concentration, attributing the changes in body composition to the increasing proportion of fatty tissue and ether extract.

Picard and Gagaoua (2020) report that during postnatal growth, muscle fibers increase in size and diameter (hypertrophy) and changes in fiber types occur, therefore, a constant protein content may be necessary to allow muscle function and frequent reorganization of muscle fibers during bull growth.

It is important to highlight that an adequate nutrition not only satisfies essential needs, but the compounds that guarantee the basic needs of cattle guarantee a perfect physical and structural development. The calves of the breeds involved in the experiment have a bone-muscle structure suitable for the management, with the purpose of producing meat. Razanova *et al.* (2023) highlight the importance of combining grazing with food containing protein, energy and minerals in young fattening cattle as a closing factor of the production system.

In addition to the demands of the livestock production process, a sigmoid growth model was developed, which, by using data on birth weights and weights at one month of age, allows making a forecast of how weight gain should behave throughout the fattening process, for each animal individually as well as for an expected average performance. Ranges in which the expected weight can be found are estimated, determined by the value of the weight increase in the initial stage considered.

For the predictive study of the relation between time and weight of a bovine for decision making regarding the management of animal behavior, expression (2) can be used in which the involved parameters "C" and "K" can be identified from the initial weight values, at a month and live weight (UGM) for each animal. Based on these functions, an Excel spreadsheet was designed as an easy-to-use contribution to the management process to predict productive performance for fattening from the calf category, taking an initial weight and that of the following month as a reference (table 4). Columns 4 and 5 represent the expected weight for each month and the average daily weight gain.

The constants k and C are determined from the initial information (initial weight and weight at a month of birth of the animals) and will allow to find the weight function that governs the performance of this variable in time and to estimate, together with the initial data, the average and extreme productivity of the herd, which will allow to estimate a range of weight variation, in which it is considered to be adequate, and fits to some extent to the expected or average value.

Figure 2 describes the weights performance of the average live weights increases for each animal. In the first section of the figure, it can see the graphs of the average weight performance and increases $(-)$ for the case in which the average weights at birth and at one month of age are considered, increased in an standard deviation for the two sets of measurements respectively $(+)$. In a similar case, the experimental mean weights (o) are reduced by one standard deviation.

The upper and lower graphs represent a range around the average performance of weights gain, in which most animals are expected to be with respect to weight development.

Table 4. Spreadsheet to predict the productive performance of weight gains at different stages of development of a crossbred dairy calf

Weight calculation in stages				
Initial data		**Time in months**	**Weight per month**	**Average weight day**
Initial weight, kg	32	0	32.000	-
Final weight, kg	45	1	45.000	0.433
Weight UGM (Pm)	500.000	2	62.575	0.586
Initial time	0	3	85.721	0.772
Final time	1	4	115.174	0.982
Initial constant (C)	0.06837607	5	151.058	1.196
Growth constant (k)	0.36909746	6	192.527	1.382
Weight function		7	237.629	1.503
$(Pm * C * \exp(k * t))/(1 + C * \exp(k * t))$		8	283.552	1.531
		9	327.280	1.458

The functions that describe the time-weight relation for these cases allow the calculation of the interval in which the weights of the cattle must be found in each time (table 5). These values are obtained with the average weights decreased or increased by 30 % of the respective standard deviations.

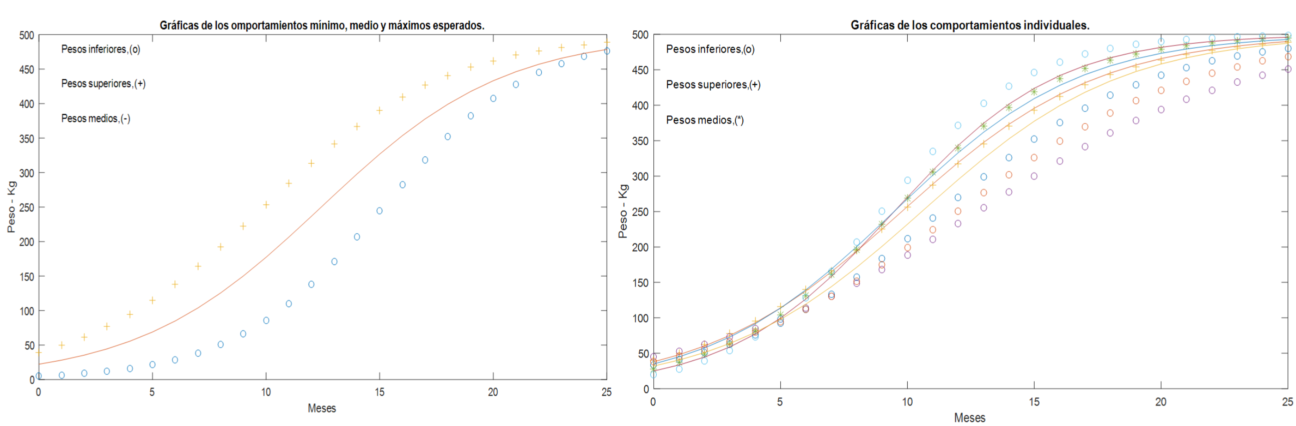
In the second section, the individual data of the 10 animals under study have been considered, distinguishing the expected performance for the cattle with the highest weight gain in the first month $(+)$, with the lower weight gain (o), with weight gains in a range of 20 % of the standard deviation of the set of weight gain measurements in the first month, around the average performance $(*)$, and below and above this range centered on the average performance $(-)$. The model and the quantitative manipulations that facilitates allow the establishment of expectations for management control, in terms of simulating the development that an animal could have by measuring the weight at two initial stages of growth. Figure 2 shows a control option, as it could indicate the fattening performance that, due to the initial weights and weight gains, would not reach the expected weight in a 25-month management and which would achieve it in less time.

In the expression (3) the following analysis can be performed: if the influence of the variables P_0 and P_1 in the constant "k" is assessed, it happens that if the first decreases (birth weight) and the second (weight at the end of the initial period) increase, "k" increases.

$$k = \frac{ln\left(\left(\frac{P_m - P_0}{P_m - P_1}\frac{P_1}{P_0}\right)^{\frac{t_1}{t_1 - t_0}}\right)}{t_1} \quad (3)$$

This characteristic can be interpreted as that the ability to gain weight is higher in an animal from a lower birth weight. It gains the same as another calf with a higher birth weight. This is related to what Kertz (2022) reported, who says that after two months of age, growth should be enough linear with daily gains of 1.8 to 2.0 pounds. However, height is not linear and has three segments: 50 % occurs in the first six months, 25 % in the next six months and then only 25 % in the entire second year, which is due to bone growth that can be indirectly measured by mineral deposition in the body.

In terms of the previous interpretation, table 6 shows that the sample object designated with number 4 of the Girolando breed, despite experiencing the highest birth weight and the best weight gain in the first month, goes through a slower weight development, given that the weight gain rate is of the order of 0.1814, indicative of a lower use of birth weight to generate new muscle biomass, when compared to the designated sample element. However, the weight gain rate is of the order of 0.3533, which reflects better conditions for generating biomass, under conditions of a birth weight lower by just over 50 %, but better performance in weight gain, surpassing the rest of the



Animals with real data, of lower (o), medium (-) and higher (+) live weights

Weights of each of analyzed animals

Figure 2. Performance of the average live weights and for each animal under study

Table 5. Prediction intervals for cattle weight under initial weight and birth weight conditions over the course of five months

Months	**5**		**10**		**15**		**20**		**25**	
Interval	54.851	82.907	150.326	202.288	299.993	349.519	419.783	444.070	474.036	482.232

Table 6. Comparison of weight gains related to initial weight and weight gain in the first month

				Real case				
Number of animals	**At birth**	**1**	**5**	**10**	**15**	**Initial gain**	**Rate**	**Breed**
4	45.00	53.00	98.37	188.78	300.17	8.00	Lower relative rate of weight gain 0.18	Girolando
1	33.00	41.00	92.86	211.99	351.89	8.00	In month seven. It goes ahead 0.23	Girolando
8	35.00	45.00	113.84	267.95	409.47	10.00	Lower relative rate of weight gain 0.27	Brown Swiss
5	28.00	37.00	104.17	269.32	419.09	9.00	In month ten, it goes ahead 0.30	Sahiwal
6	20.00	28.00	97.99	293.88	446.47	8.00	Lower birth weight 0.35	Sahiwal

animals in the following months. The experimental units marked with numbers 1, 8 and 5 sustain an intermediate weight gain process with respect to the two detailed cases, in correspondence with the respective weight gain rates.

These observations can be related to what Quinteros *et al.* (2023) showed, who report that there are populations of animals with extreme phenotypes that can be the basis of a selection process. The large differences can also be attributed to greater maternal ability in those lactating cows, which provides a greater quantity of milk to their calves, in addition to other environmental and management factors that can modify the individual response of the animals.

Wegner *et al.* (2020) confirm that the number of muscle fibers is determined in the embryonic development. Over the course of the study, the double-muscled Belgian Blue bulls had almost twice as much fiber as the other breeds, emphasizing a more extensive hyperplasia of muscle fibers during embryonic development compared to the other three breeds.

The association of the fattening monitoring model makes easy to make conjectures about what the performance of this characteristic may be, detailing the process individually and collectively, punctually or by expected weight ranges. For dairy farmers with similar climatic and management conditions, and to correctly adopt strategies in the management and feeding of animals to achieve a fattening in less time resulting useful a reference of this type, with the use of the Excel spreadsheet designed in this study, so that it facilitates the prediction of future productive performance for fattening calves, with good final weights.

Conclusions

The rotational grazing system composed of the association of the species ratana (*Ischaemum indicum*), forage peanut (*Arachis pintoi*) and food supplement allowed a stocking rate capacity of 2.2 UGM/ha and intake of 18.34 GM kg/UGM*d with adequate growth and development. The model confirms that the productive performance of crossbred calves for dairy purposes is related to gain in the initial stage and birth weight, and shows slower growth in the development of calves with similar weight gain and higher birth weight. The predictions obtained can be useful for evaluating the performance of future dairy animals for fattening and for making fits in the management of each productive stage.

References

AOAC. 2023. Official Methods of Analysis. [En línea]. 978-0-935584-87-5. In food e agriculture, we set the standard. 22ªed. Vol. 2. ISBN 978-0-19-764909-1.

Benítez Jiménez, D.G., Torres Cárdenas, V., Vargas Burgos, J.C., Soria R., S., Navarrete, H. & Ríos Núñez, S. 2018. Organization of livestock farms in the Ecuadorian Amazon. Case study "Luis Ceballos". *Cuban Journal of Agricultural Science*, 52(1): 7-18, ISSN: 2079-3480. http://scielo.sld.cu/scielo.php?script=sci_arttext&pid=S2079-34802018000100007.

Bourdon, R. & Brinks, J. 1987. Simulated efficiency of range beef production. I. Growth and milk production. *Journal of Animal Science*, 65(4): 943-955, ISSN: 1525-3163. https://doi.org/10.2527/JAS1987.654943X.

Brody, S. 1945. Bioenergetics and growth. Capítulo 15. Hafner. New York.

Corral Zambrano, C.A., Zambrano Solórzano, L.J., Pincay Vargas, D.M. & Calo Gómez, S.G. 2021. Impactos ambientales generados por la ganadería en la provincia de Santo Domingo de Tsáchilas: impactos ambientales generados por la ganadería. UNESUM - Ciencias. *Revista Científica Multidisciplinaria*, 5(2): 69-78, ISSN: 2600-6030. https://doi.org/10.47230/unesum-ciencias.v4.n3.2020.255.

FAO. 2023. Evolución Global en la Producción de Carne y Cultivo. Available at: https://porcinews.com/fao-evolucion-global-en-la-produccion-de-carne-y-cultivo/.

Gompertz, B. 1825. On the nature of the function expressive of thr law of human mortality and on a new mode of determining of the value of life contingencies. *Philosophical Transactions of the Royal Society of London,* 115: 513-585, ISSN: 0264-3820. https://doi.org/10.1098/rstl.1825.0026.

Honig, A.C., Inhuber, V., Spiekers, H., Windisch, W., Götz, K.U., Schuster, M. & Ettle, T. 2022. Body composition and composition of gain of growing beef bulls fed rations with varying energy concentrations. *Meat Science*, 184: 108685, ISSN: 1873-4138. https://doi.org/10.1016/j.meatsci.2021.108685.

INEC. 2023. Instituto Nacional de Investigación Agropecuaria. Available at: https://www.ecuadorencifras.gob.ec/doc umentos/webinec/Estadisticas_agropecuarias/espac/espac_2022/Bolet%C3%ADn_tecnico_ESPAC_2022.pdf.

Kertz, A. 2022. Principles of growth and body composition of cattle. *Feedstuffs*. Available at: https://www.feedstuffs.com/livestock-and-poultry-market-news/principles-of-growth-and- body-composition-of-cattle.

Nobre, P.R.C., Rosa, A.D.N., da Silva, L.O.C. & Evangelista, S.R.M. 1987. Curvas de crescimento de gado Nelore ajustadas para diferentes frequencias de pesagens. *Pesquisa Agropecuária Brasileira,* 22(9/10): 1027-1037, ISSN: 1678-3921.

Olson, K. 2010. Búsqueda de alternativas para mejorar la producción bovina de carne de Magallanes. Informe Técnico. Centro Regional de Investigación Kampenaike. INIA. Punta Arenas. Chile. Available at: https://bibliotecadigital.fia.cl/bitstreams/5a43e554-3da3-4081-bf96-946dd6488444/download.

Picard, B. & Gagaoua, M. 2020. Muscle Fiber Properties in Cattle and Their Relationships with Meat Qualities: An Overview. *Journal of Agricultural and Food Chemistry*, 68(22): 6021-6039, ISSN: 1520-5118. https://doi.org/10.1021/acs.jafc.0c02086.

Posada, S. L., Santiago, C. & Rosero, R. 2016. Mezclas minerales múltiples para la alimentación de bovinos Aplicación y formulación. Fondo Editorial Biogénesis, p. 46, ISBN: 978-958-8947-25-9. Available at: http://editorialbiogenesis.udea.edu.co/.

Quintero Bastidas, D.E., Bejarano Garavito, D.H., Ospina Hernández, S.D., Vargas Vivas, L.F. & Ramírez Toro, E.J. 2023. Parámetros y tendencias genéticas para peso al nacimiento y peso al destete en ganado Hartón del Valle en Colombia. *Chilean Journal of Agricultural & Animal Sciences*, 39(2): 177-187, ISSN: 0719-3890. https://dx.doi.org/10.29393/chjaa39-15ptde50015.

Razanova, O.P., Farionik, T.V. & Skoromna, O.I. 2023. The Influence of the Type of Feeding on Meat Productivity of Young Cattle and Meat Quality. *Publishing House "Baltija Publishing"*. https://scholar.google.es/citations?view_op=view_citation&hl=es&user=5yv7j4UAAAAJ&cstart=20&pagesize=80&citation_for_view=5yv7j4UAAAAJ:_Ybze24A_UAC.

Redjadj, C., Duparc, A., Lavorel, S., Grigulis, K., Bonenfant, C., Maillard, D., Saïd, S. & Loison, A. 2012. Estimating herbaceous plant biomass in mountain grasslands: a comparative study using three different methods. *Alpine Botany,* 122: 57-63, ISSN: 1664-221X. https://doi.org/10.1007/s00035-012-0100-5.

Rostagno, H.S., Teixeira, L.F., Donzele, L.J., Gomes, P.C., Oliverira, Rita., Lopes, D.C., Ferreira, A.S., Toledo, S.L. & Euclides, R.F. 2017. Tablas Brasileñas para aves y cerdos. Composición de Alimentos y Requerimientos Nutricionales. 3era Edición. Universidad Federal de Viçosa - Departamento de Zootecnia, Brasil, 167 pp. Available at: https://eliasnutri.files.wordpress.com/2018/09/tablas-brasilec3b1as-aves-y-cerdos-cuarta-edicion-2017-11.pdf .

Senra, A. & Venereo, A. 1986. Métodos de muestreo. En: Los pastos en Cuba. Producción. Ed. Instituto de Ciencia Animal. La Habana, Cuba. Tomo1: 649p.

Solórzano, J., Barboza, D., Vásquez, P. & Paniagua, J. 2022. Optimización del costo de alimentación para ganado de engorde en Guanacaste, Costa Rica. *Revista e-Agronegocios*, 8(1): 25-44, ISSN: 2215-3462. https://doi.org/10.18845/ea.v8i1.5654.

Song, H., Huang, Y., Ding, L., Duan, Z. & Zhang, J. 2023. Arachis species: High-quality forage crops-nutritional properties and breeding strategies to expand their utilization and feeding value. *Grassland Research*, 2(3): 212-219, ISSN: 2770-1743. https://doi.org/10.1002/glr2.12059.

Von Bertalanffy, L. 1957. Leyes cuantitativas en el metabolismo y el crecimiento. Revisión trimestral de biología. 3. 218.

Wegner, J., Albrecht, E., Fiedler, I., Teuscher, F., Papstein, H. J. & Ender, K. 2000. Growth- and breed-related changes of muscle fiber characteristics in cattle. *Journal of Animal Science*, 78(6): 1485-1496, ISSN: 1525-3163. https://doi.org/10.2527/2000.7861485x.

Zhang J., Zhang L., Liu X. & Qiao Q. 2019. Research on sustainable development in an alpine pastoral area based on equilibrium analysis between the grassland yield, livestock carrying capacity, and animal husbandry population. *Sustainability*, 11: 4659, ISSN: 2071-1050. https://doi.org/10.3390/su11174659.