Husbandry and Nutrition

Review article

A Procedure to Design New Nutritional Composition Charts of Feeds for Ruminants

Feisy Pérez Amores *, Oscar Romero Cruz **, Alicia Centurión Fajardo **

*University of Las Tunas, Las Tunas, Cuba.
**University of Bayamo, Granma, Cuba.

Correspondence: feisypa@ult.edu.cu

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ABSTRACT

Background. Feed Composition charts are becoming obsolete due to new production practices, plant breeding, changes in analytical methods, and the characterization and introduction of new feeds. Consequently, the current Cuban charts must be updated. **Aim.** To implement a procedure that enables feed data processing, according to the literature, to design reliable feed composition charts for ruminants. **Materials and methods:** Software AliCuba was used to generate feed composition charts for livestock, based on collected and processed results from published research in the literature. A procedure was designed to regulate the different stages of the process using the mentioned software, to generate reliable nutritional composition charts. The empirical data were determined through single variant techniques. The missing values were estimated through equations. A bootstrap sampling was used with a percentile confidence interval. The procedure was validated according to information gathered from *Megathyrsus maximus* cv. *Likoni (*30-60 day-old fresh leaves and stems from the western region, regardless of data referring to the time of year and irrigation; with fertilization) **Results:** The different stages of the procedure were suitable for identifying and adjusting the database anomalies, wrong measure units, analytical errors, mistaken identification of feeds, etc., which proved its validity for assuring information quality. **Conclusion:** A procedure was implemented to enhance the design of feed composition charts for ruminants.

Keywords: database, normal distribution, livestock, confidence interval, software (*Source*: *DeCS*)

INTRODUCTION

Feed Composition charts are becoming obsolete due to new production practices, plant breeding, changes in analytical methods, and the characterization and introduction of new feeds (Schlageter-Tello *et al*., 2020).

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Tran *et al*. (2020) noted that knowing accurate ingredient variability estimations in the diet leads to lower risks of nutrient deficiency. Besides, to meet the nutritional requirements of livestock, as well as their production indicators, and reduce production costs, stochastic optimization is required, as described by Vitoriano and Ramos (2023). Therefore, accurate feed charts provide more information than average concentrations, such as standard deviation (SD) and confidence intervals (CI) in nutrient composition.

The current Cuban feed charts for ruminants (Cáceres *et al*., 2002, and García-Trujillo and Pedroso, 1989) lack SD and CI data. Moreover, many of the results from research studies done in Cuba have not been added, which makes it difficult to identify the resources available locally with a potential for livestock nutrition.

To address this situation, the software AliCuba (Pérez *et al*., 2021) was designed to generate feed composition charts for livestock, based on collected and processed results from published research in the literature.

Schlageter-Tello *et al*. (2020) referred to the enormous challenge of developing feed composition charts since the data collected by different sources tend to have errors in feed identification, incorrect sampling procedures, small samples, and other complications that might lead to inaccurate estimations of averages and standard deviation.

Accordingly, this paper aims to implement a procedure that enables feed data processing, based on the literature, to design reliable nutritional composition charts for ruminants.

MATERIALS AND METHODS

AliCuba software

The Cuban nutritional composition charts were designed using AliCuba 8 (Pérez *et al*., 2021) in three stages:

(1) Information collection

The feed composition charts from the information sources selected were recorded and saved. A suitable system of feed registration was organized based on classification, scientific and common name, variety, part, processing, the forms of administration, and the elements influencing their nutritional value (region, season, irrigation, fertilization, age, etc.). Also, the equations for estimating the missing values were added.

(2) Review and evaluation of the information collected

During that stage, the feed composition charts were generated, following a statistical-descriptive analysis of dispersion (mean, median, standard deviation, and variation coefficient), and distribution (kurtosis and skewness) of every nutrient. Two statistical procedures were included to identify the atypical values, the interquartile ranks, and the k standard deviation, as described by Figueroa-Mata *et al*. (2012). The analyses were shown in box diagrams and standard deviation graphs, respectively.

The box diagrams were extracted from the spssjavaplugin.jar library, SPSS (2019). However, the standard deviation graph reports were generated through a software' s in-built procedure, supported with a chart containing all the sample values and the characterization of atypical values and bibliographic references it belongs. The SD thresholds were 2 and 3.

(3) Feed composition chart design

First, the values were estimated using the equations in the software, and then uniform bootstrap resampling (Fernández *et al*., 2023) was made for every nutrient containing at least five samples. Lastly, the feed composition charts were generated.

That process used the Jep 4.0 library (Singular Systems, 2021) for lexical and syntactic analysis and the evaluation of mathematical expressions used to estimate the values. The confidence interval obtained in the bootstrap sampling was calculated through the basic percentile method, as described by Cao and Fernández (2021). A feed labeling system was designed as well to help describe all related information simply and clearly (origin, part, presentation, and the elements influencing the nutritional value).

Chart-generation procedure

Exploring, deducting, and evaluating the data volume was a previous condition for the generation of feed charts. A painstaking analysis helps identify possible errors (incorrect data input, missing values, or poor variable codification), to reveal the presence of atypical values and perform an atypical descriptive data analysis. Therefore, a procedure was designed to regulate the different stages of the process using AliCuba to generate reliable nutritional composition charts. The criteria shared by Schlageter-Tello *et al*. (2020) were assessed, as well as the methodologies used by Yoder *et al*. (2014) and Tran *et al*. (2020).

Validation of the procedure

Information about the nutritional composition of *Megathyrsus maximus* collected from previous published studies was used to validate the procedure. Revista Cubana de Ciencia Agrícola (ICA, 2019) from 1967 to 2019, Revista Pastos y Forrajes (EEPF IH, 2019) from 1978 to 2019, Revista de Producción Animal (UC, 2019) from 1985 to 2019, and Revista Computarizada de Producción Porcina (IIP, 2015) from 1994 to 2015. The data from current Cuban feed charts (Cáceres *et al*., 2002; García-Trujillo and Pedroso, 1989; MINAG, 2009) were also added.

The feed composition charts were generated from every piece of information about *Megathyrsus maximus*. The factor metadata corresponded to the variety, region, season, irrigation, fertilization, age, and treatment. The validation was in cv. *Likoni*, with the following features: studies conducted in the western part of the country on fresh leaves and stems, with no specification of season of the year or irrigation. the data included fertilization and age between 30 and 60 days old. A bootstrap sampling was used in 10000 with a percentile confidence interval (95%).

RESULTS AND DISCUSSION

Chart-generation procedure

A common error of feed databases is the incorrect codification of variables which will alter the population statistics, depending on the number of incorrect observations. Schlageter-Tello *et al*. (2020) and Vila (2020) claimed that accurate statistics demand proper data classification into anomalous and not.

To check proper metadata and nutritional value codification, a procedure was put into practice (Fig 1. The execution has to go through three stages necessarily to ensure the quality of the information added to the feed composition charts. That way, the software user makes the necessary analyses and adjustments at a time.

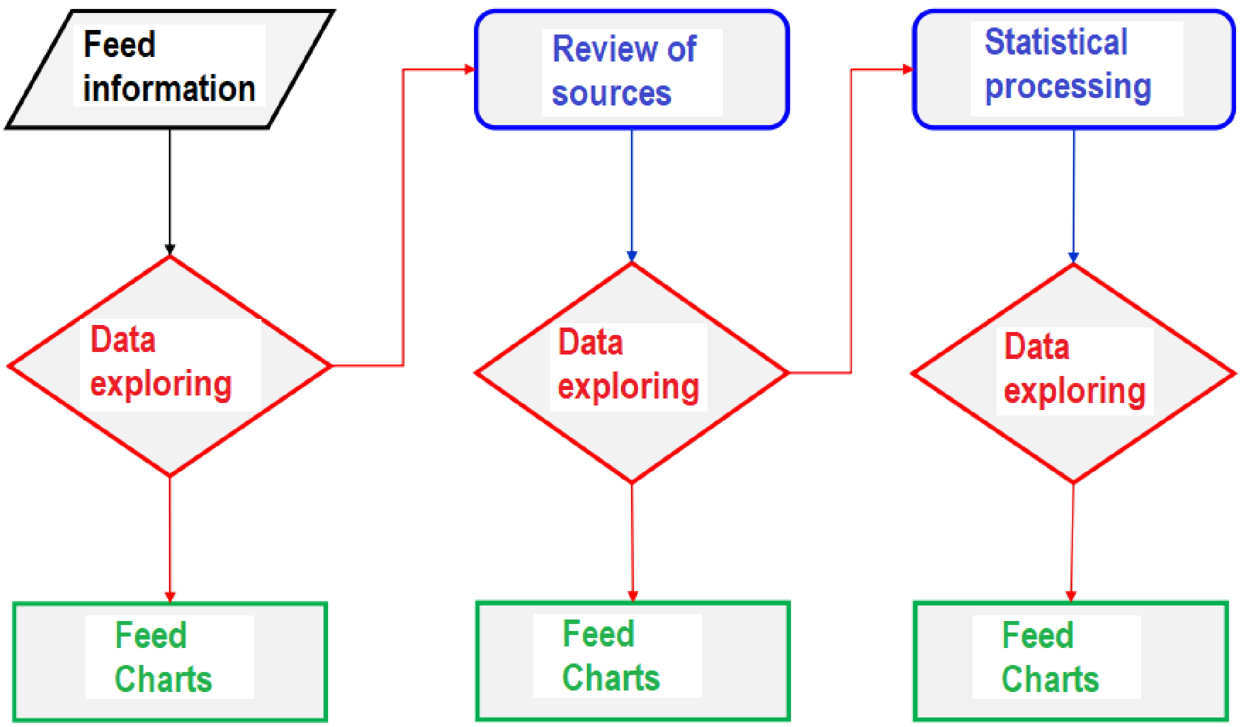

Figure 1. Graphic representation of the procedure to generate feed composition charts for livestock.

Firstly, all the feed charts are generated, and then the data area is explored to identify anomalies. At that stage, a sample of the dataset is collected to detect the overall behavior pattern for variable distribution. Moreover, box diagrams and standard deviation graphs are used to make the analyses.

The causes of every atypical value are verified. Accordingly, the bibliography is reviewed for anomalies, to check that every stored variable has its corresponding value.

Every decision made in terms of atypical values requires a second application of the methodology, with or without the unusual values to measure the effect of the results obtained. If the effect is minimal, they are eliminated or replaced. On the other hand, if it is relevant, the causes are examined again.

Lastly, the missing values are estimated with the equations that can be used and bootstrap sampling is rerun. Before being admitted, each chart undergoes an exploratory data analysis.

Validation of the procedure

Overall, 6052 papers from livestock journals were examined. *Megathyrsus maximus* was input 1165 times, in 140 bibliographic references, which generated 143 feed composition charts, according to the metadata inputs.

At the beginning of the procedure to design the feed nutritional chart, DM, CF, and CP had atypical values (Table 1), with high SD. To determine the cause of these anomalies the data underwent an exploratory analysis.

Table 1. Initial report of the nutritional composition of the feed evaluated

Variables	N	Mean	SD	Min	Max	Var	SE	Observations
DM (%)	9	27.2	3.93	20.34	34.5	15.44	1.31	Containing atypical values
Ash % DM	2	9.11	0.18	8.99	9.24	0.03	0.12	
CF % MS	7	28.58	10.03	7.4	37.45	100.7	3.79	Containing atypical values
OM (%) DM	2	91.33	0.04	91.3	91.35		0.02	
CP (%) DM	8	10.06	8.8	5.8	31.6	77.39	3.11	Containing atypical values
Ca, % DM	2	0.81	0.01	0.8	0.81			
P, % DM	2	0.28	0.02	0.27	0.3		0.02	
MEN, Mcal/kg DM	2	1.99	0.22	1.84	2.15	0.05	0.15	
MES, Mcal/kg DM	1	2						
DMCS, g/kg MP	1	60.2						
OMDS (vv-rec), %	1	58.9						

DM: dry matter; Ash: ashes; CR: crude fiber; OM: organic matter; CP: crude protein; Ca: calcium; P: phosphorous; MES: metabolizable energy in sheep; DMCS: dry matter consumption in sheep; OMDS (vv-rec): seeming *in vivo* rectal organic matter digestibility in sheep.

The box diagram identifies two atypical values in DM (3: 34.5 and 6: 20.34). However, a standard deviation analysis did not show it because all the values were inside the variation zone, as shown in Figure 2.

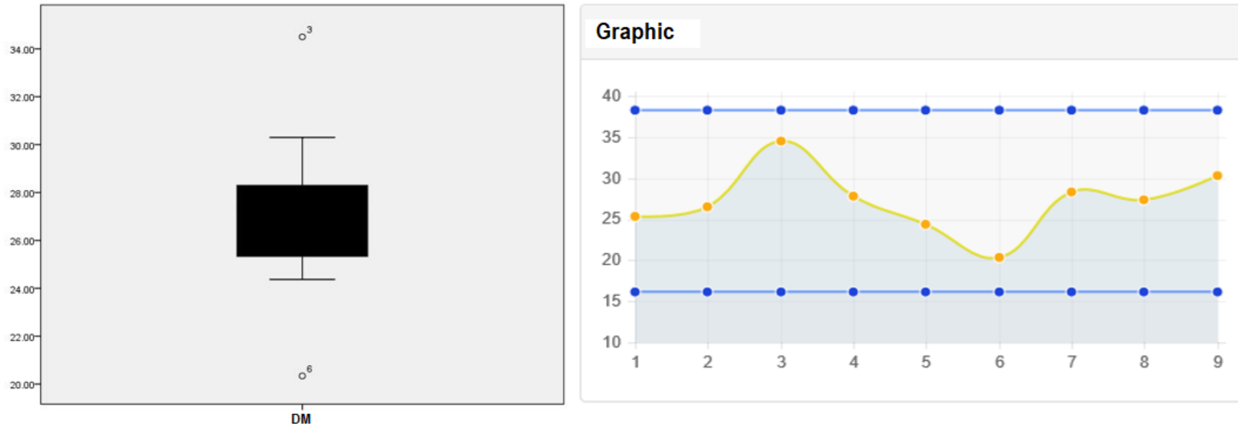

Figure 2. Box diagram and standard deviation graph to identify the atypical values in DM

The examination of references corresponding to the anomalous values found in DM showed that the data input was correct. The cause of such deviations could be associated with not considering the season of the year since this factor generates nutritional variability in the forage (López-Vigoa *et al*., 2019). Likewise, Milera *et al*. (2017) said that though *Megathyrsus maximus* is characterized by an adaptation to a broad type of soil, some of them determine their productivity.

The atypical values identified in CF and CP (Figure 3) correspond to the same reference (Ojeda, 1994), and were copied and published with the values inverted. Accordingly, this error was corrected.

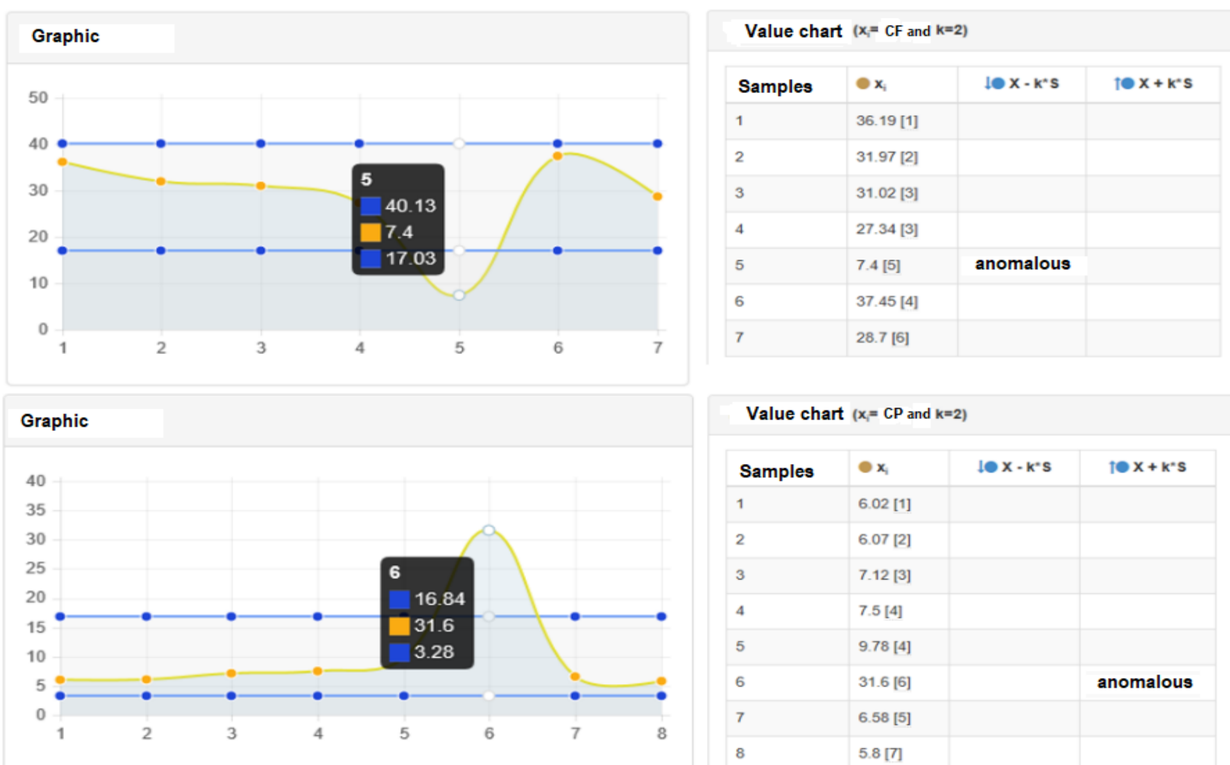

Figure 3. Standard deviation analysis for identifying the CF and CP atypical values

Upon completing the changes, a new feed composition chard was designed. In the new nutrient value analysis, DM and CF reported a high SD (3.93 and 3.67, respectively).

The analysis of CF showed no anomalous values; however, the references showed that the CF value 27.34 (case 4, figure 3) is influencing such deviation and that it is linked to one of DM atypical values (20.34), as described by Otero and Esperance (1994). It matches these authors’ findings, as well as those of Ojeda-García *et al*. (2020), who noted that the forage’ s ripe state (40 days) influences the nutritional value (less DM and CF content, and greater CP tenor).

Following the validation of the data stored, the missing values were estimated using the equations added to the software. As a result, a larger number of observations of Ashes, OM, CP, and MES were produced. There were also reports of N, DCPC, and DES. Table 2 shows the final nutritional composition report of the feed evaluated.

Table 2. Final report of the nutritional composition of the feed evaluated

Variables	N	Mean	SD	Min	Max	Var	SE	Observations
DM (%)	9	27.21	1.25	24.8	29.72	1.55	0.01	Bootstrap
Ash % DM	6	8.97	0.09	8.78	9.16	0.01		Bootstrap
CF % DM	7	32.05	1.3	29.61	34.64	1.69	0.01	Bootstrap
OM (%) DM	6	91.18	0.09	90.99	91.33	0.01		Bootstrap
CP (%) DM	16	7.03	0.3	6.49	7.67	0.09		Bootstrap
N, % DM	8	1.12	0.07	1.01	1.27			Bootstrap
Ca, % DM	2	0.81	0.01	0.8	0.81			
P, % DM	2	0.28	0.02	0.27	0.3		0.02	
MEC, Mcal/kg DM	2	1.99	0.22	1.84	2.15	0.05	0.15	
DCPC %	8	3.77	0.37	3.14	4.57	0.14		Bootstrap
MES, Mcal/kg DM	2	2.02	0.02	2	2.03		0.02	
DES, Mcal/kg DM	1	60.27						
DMCS, g/kg MP	1	60.2						
OMDS (vv-rec), %	1	58.9						

DM: dry matter; Ash: ashes; CR: crude fiber; OM: organic matter; CP: crude protein; N: nitrogen; Ca: calcium; P: phosphorous; MEC: metabolizable energy in cattle; DCPC: Digestible crude protein in cattle; MES: metabolizable energy in sheep; DES: digestible energy in sheep; DMCS: dry matter consumption in sheep; OMDS (vv-rec): seeming *in vivo* rectal organic matter digestibility in sheep.

The validity of the procedure was proven thanks to djustments of the anomalies detected in the database. Moreover, on average, 16.06% of SD was cut down, especially in those with a nutrient concentration higher than 3.5 units of SD from the mean (DM: 3.93 at 1.25; CF: from 10.03 to 1.3; CP: from 8.8 to 0.3).

The results described in this paper confirm the recommendations of Obaid and Jasim (2021), about data exploring before deciding on the type of treatment for the atypical values. Likewise, the advantages of bootstrap were corroborated, as better indicators were found in SD and CI. Furthermore, the percentile bootstrap confidence interval has shown several theoretical advantages over the normal standard interval, as well as better performance in practice.

Standard deviation was almost always lower after the application of the bootstrap resampling. However, the utilization of methods for atypical value detention helped detect simple data input errors, incorrect measure units, analytical errors, incorrect feed identification, and feeds correctly identified, which represent different populations due to their genetics, processing, or region.

CONCLUSIONS

This study implemented a procedure to enhance the design of feed composition charts for ruminants.

The implementation of this procedure offered more accurate estimations of standard deviation and confidence intervals in nutrient composition, which are important for stochastic programming and the economic assessment of feeds.

REFERENCES

Cáceres, O., Ojeda, F., González, E., Arece, J., Milera, M., Lamela, L., Esperance, M., Montejo, I. L., & Soca, M. (2002). *Valor nutritivo de recursos forrajeros tropicales para los rumiantes*. Editorial Estación Experimental de Pastos y Forrajes Indio Hatuey. https://biblioteca.ihatuey.cu/link/proyecto/tablavalornutritivo/tbn.pdf

Cao Abad, R., & Fernández Casal, R. (2021). *Técnicas de Remuestreo*. https://rubenfcasal.github.io/book_remuestreo

EEPF IH. (2019). *Revista Pastos y Forrajes*. Editorial de la Estación Experimental de Pastos y Forrajes Indio Hatuey del Ministerio de Educación Superior de la República de Cuba. https://payfo.ihatuey.cu

Fernández Casal, R., Cao, R., & Costa, J. (2023). *Técnicas de Simulación y Remuestreo*. https://rubenfcasal.github.io/simbook/Simulacion.pdf

Figueroa-Mata, G., Carrera, E., & Jiménez, A. (2012). *Análisis de Componentes Principales en Paralelo*. Instituto Tecnológico de Costa Rica. https://repositoriotec.tec.ac.cr/bitstream/handle/2238/2910/Informe_Final.pdf?sequence=1&isAllowed=y

García-Trujillo, R., & Pedroso, D. M. (1989). *Alimentos para rumiantes. Tablas de valor nutritivo.* EDICA.

ICA. (2019). *Revista Cubana de Ciencia Agrícola*. Editorial del Instituto de Ciencia Animal del Ministerio de Educación Superior de la República de Cuba. https://cjascience.com

IIP. (2015). *Revista Computadorizada de Producción Porcina*. Editada por el Instituto de Investigaciones Porcina de la República de Cuba. http://www.iip.co.cu

López-Vigoa, O., Lamela-López, L., Sánchez-Santana, T., Olivera-Castro, Y., García-López, R., Herrera-Villafranca, M., & González-Ronquillo, M. (2019). Evaluación del valor nutricional de los forrajes en un sistema silvopastoril. *Pastos y Forrajes*, *42*(1), 57-67.

http://scielo.sld.cu/scielo.php?script=sci_abstract&pid=S0864-03942019000100057

Milera, M. C., Machado, R. L., Simón, L. R., García Trujillo, R., Mesa Sardiñas, A. R., González Rosado, Y., Hernández Chávez, M. B., Pérez Vargas, A., Remy López, V. A., Ojeda García, F., Esperance Matamoros, M. J., Lamela López, L., Hernández Torrecilla, D., Cáceres García, O., Paretas Fernández, J. J., López Gutiérrez, M., Machado Martínez, H. C., Segui Cartaya, E., Martín Martín, G. J., & Miret Prieto, R. (2017). *Tecnologías, metodologías y resultados generados por la EEPFIH* (M. C. Milera y T. Sánchez (eds.)). Editorial Estación Experimental de Pastos y Forrajes Indio Hatuey. https://biblioteca.ihatuey.cu/link/proyecto/2017electronicos/tecnologias.pdf

MINAG. (2009). *Tablas de especificaciones nutricionales de los piensos y composición nutritiva y límites de inclusión de las materias primas.* UECAN.

Obaid Merza, E., & Jasim AL-Anber, N. (2021). Formas rápidas de detectar valores atípicos. *Revista de Técnicas*, *3*(1), 66-73. https://doi.org/10.51173/jt.v3i1.287

Ojeda-García, F., Esperance-Matamoros, M., Milera-Rodríguez, M. C., & Cáceres-García, O. (2020). Capítulo 12. Conservación de pastos y forrajes en zonas tropicales. En M. C. Milera, T. Sánchez, y M. Hernández (Eds.), *Recursos forrajeros multipropósitos* (pp. 251-277). Editorial Estación Experimental de Pastos y Forrajes Indio Hatuey. https://biblioteca.ihatuey.cu/link/nuestraspublicaciones/recursos_forrajeros_multipropositos2020.pdf

Ojeda, F. (1994). Evaluación de la interacción conservante-miel final sobre la calidad fermentativa de los ensilajes de la guinea cv. Likoni. *Pastos y Forrajes*, *17*(3), 267-276. https://payfo.ihatuey.cu/index.php?journal=pasto&page=article&op=view&path%5B%5D=1164

Otero, M., & Esperance, M. (1994). Estudio de la ensilabilidad de la guinea likoni (P. maximum Jacq.) según el índice azúcar/capacidad tampón. *Pastos y Forrajes*, *17*(3), 277-281. https://payfo.ihatuey.cu/index.php?journal=pasto&page=article&op=view&path%5B%5D=1165

Pérez, F., Romero, O., & Centurión, A. (2021). AliCuba : software de gestión de composición de alimentos para el ganado en Cuba. *Revista Cubana de Ciencias Informáticas*, *15*(4), 15-28. https://rcci.uci.cu/?journal=rcci&page=article&op=download&path%5B%5D=2059&path%5B%5D=889

Schlageter-Tello, A., Fahey, G. C., Freel, T., Koutsos, L., Miller, P. S., & Weiss, W. P. (2020). ASAS-NANP Symposium: Ruminant/nonruminant feed composition: Challenges and opportunities associated with creating large feed composition tables. *Journal of Animal Science*, *98*(8), 1-13. https://doi.org/10.1093/jas/skaa240

Singular Systems. (2021). *Java Math Expression Parser*. http://www.singularsys.com/jep

SPSS. (2019). *Statistical Package for the Social Sciences (Versión 27.0.0.0) [Programa de ordenador]*. IBM Corporation. http://www.ibm.com

Tran, H., Schlageter-Tello, A., Caprez, A., Miller, P. S., Hall, M. B., Weiss, W. P., & Kononoff, P. J. (2020). Development of feed composition tables using a statistical screening procedure. *Journal of Dairy Science*, *103*(4), 3786-3803. https://doi.org/10.3168/jds.2019-16702

UC. (2019). *Revista de Producción Animal*. Editada por Ediciones Universidad de Camagüey del Ministerio de Educación Superior de la República de Cuba. https://revistas.reduc.edu.cu/index.php/rpa

Vila, S. D. (2020). *Detección de outliers en grandes bases de datos* [Tesis de maestría]. Universidade da Coruña. http://eio.usc.es/pub/mte/descargas/ProyectosFinMaster/Proyecto_1780.pdf

Vitoriano, B., & Ramos, A. (2023). *Programación matemática: Métodos de optimización*. Universidad Complutense. http://blogs.mat.ucm.es/bvitoriano/wp-content/uploads/sites/69/2023/02/MM_PMII_I_IIb.pdf

Yoder, P. S., St-Pierre, N. R., & Weiss, W. P. (2014). A statistical filtering procedure to improve the accuracy of estimating population parameters in feed composition databases. *Journal of Dairy Science*, *97*(9), 5645-5656. https://doi.org/10.3168/jds.2013-7724

AUTHOR CONTRIBUTION STATEMENT

Research conception and design: FPA, ORC, ACF; data analysis and interpretation: FPA, ORC, ACF; redaction of the manuscript: FPA, ORC, ACF.

CONFLICT OF INTEREST STATEMENT

The authors state there are no conflicts of interest whatsoever.