Applied Mathematics in researches from the Instituto de Ciencia Animal. Fifty years of experience

Verena Torres and R. Cobo
Instituto de Ciencia Animal, Apartado Postal 24, San José de las Lajas, Mayabeque, Cuba
Email: vtorres@ica.co.cu, vtorcar@gmail.com

This study reviews advances in Applied Mathematics, developed between 1973 and 2014, at the Instituto de Ciencia Animal, and published in the Cuban Journal of Agricultural Science. These contributions are about estimation and hypothesis testing, experimental designs, informatics and automatic systems, sampling techniques and sample size, mathematical simulation and modeling, econometrics and multivariate methods. During the cited period, the percentages of articles per subject were 8.4, 11.6, 5.3, 16.8, 27.4, 13.7 and 16.8, respectively. Modeling and simulating, sampling techniques and sample size, and multivariate methods were the most published subjects.

Keywords: *Biometry, Economy and Informatics*

INTRODUCTION

Since the foundation of the Instituto de Ciencia Animal in 1965, a department of Biometry was created with the main objective of giving statistical advice to the research developed in the institute. Since the first papers published in the Cuban Journal of Agricultural Science, the experts in statistics appear as coauthors. Studies of Willis *et al.* (1971), Gómez *et al.* (1971), Tomeu *et al.* (1973) and Willis *et al.* (1973), among others, can be cited. The company of the experts remains currently, which evidences the importance of expert advice in this field.

This study will refer to the papers of Statistics and Mathematics published in the Cuban Journal of Agricultural Science, divided into different areas of knowledge.

ESTIMATION AND HYPOTHESIS TESTING

The subject of Biometry is included on Cuban Journal of Agricultural Science in 1973, when the first papers on hypothesis tests appear. These studies began to deal with aspects related to basis hypothesis (Menchaca 1973). After 1980, researches developed in specific topics, like milk production and crops, are included and framed in the area of estimation. Menchaca (1981) introduced a method of correction per bias to the Wood method, and compared different estimation procedures of milk production. Later, Fernández *et al.* (2001) studied the performance of milk production of Siboney breed of Cuba during its first lactation, during rainy and dry seasons.

The study of pests in species and varieties of grasses was treated through statistical methods, due to the damage they provoke to these crops. Martínez Machin *et al.* (2002) studied the space and time distribution of *Heteropsylla cubana* (Crawford) in *Leucaena leucocephala* (Lam).

Torres (1980) showed the estimation of soil homogeneity index in agricultural experiments. Torres and Jordán (1989) estimated the dry matter of Coast cross 1 bermuda grass, regarding other yield components. These authors used the Ridge regression method.

Most of the statistical methods are based on the process of hypothesis tests, which are accompanied by four basic theoretical hypothesis, which include the experimental errors that should be distributed, homogeneous and independent, with a model that should be additive.

Classic literature on this topic proposed to apply Box transformations to the variables under study, when some of these assumptions are not fulfilled. Aguila *et al.* (1998) proposed a transformation based on the integration of a polygonal function, which relates treatment variances with their corresponding means.

Guerra *et al.* (2000) compared parametric and non-parametric procedures through the index of asymptotic relative efficiency (ARE). These authors concluded that the test of Kruskal-Wallis and the Fisher F showed similar efficiency indexes, but lower than that of Friedman. During the 40´s of last century, some techniques were developed, which do not perform numerous or deep suppositions of the population under study. Therefore, they were classified as methods of free distribution, which is widely used in the agricultural and livestock field.

The relationship between errors of type I and II are known after performing a hypothesis testing. However, generally, the inverse relation between these two probabilities is not considered and only the significance levels obtained in the analysis of variance are referred, without regarding that low values of α can obtain high values of β which endangers the decision-making. Torres

and Segui (2001) discussed these topics and their relation with sample size and power function. These authors proposed a practical criterion for determining the *a posteriori* power function, which allowed to analyze the reliability of the results of researches and to design strategies for future studies

EXPERIMENTAL DESIGN

One of the most important topics of experimental design is the definition of the amount of observations per treatment to compare. Menchaca (1975) published procedures for determining sample size in classic designs (simple classification, random blocks and Latin squares design). Venéreo (1976) and Caballero (1979) studied the number of replications to use in balanced square designs.

The response surfaces, as a combination of regression analysis with experimental design, provide economical means to locate a group of conditions for an optimal response. Martínez Machín and Marrero (2000) made a comparison between the factorial design with factorial arrangement and the surface response design, with factorial arrangement of three levels, in order to determine the optimal response of the concentration of short chain fatty acids (SCFA).

Torres and Chongo (1996) presented a mathematical model for consecutive measuring in the same experimental unit, with the purpose of avoiding wrong statistical inferences. Later, Torres *et al.* (2003) proposed the statistical methods of analysis of univariate and multivariate variance, as well as the analysis of indicator sum or average of areas under the curve, in the study of longitudinal data.

Gómez *et al.* (2012a) reviewed the most used statistical procedures in the analysis of designs of repeated measures in the agricultural and livestock field, and recommended the analysis of variance of fixed effects through the use of mix models, where the experimental units are considered as a random factor and time as a fixed factor. These last one included the correlations between repeated measures and the presence of heterogeneous variances. These authors pointed possible methods for estimating the parameters of these models. Nevertheless, they recommended the model of Restricted Maximum Likelihood (REML), and offered criteria of necessary information for selecting the best models.

Gómez *et al.* (2012b), in a study with mutant strains of *Trichoderma viride* cellulolitic fungi, compared the results of models of fixed and mixed effects in experiments with repeated measures.

INFORMATICS

Roche *et al.* (1999) developed a program to optimize resources in the nutrition of ruminants, with the maximum use of grass in the ration and ability of balanced ingestion. Ajete *et al.* (2000) showed a computer system for pig management and their population control. Sotolongo *et al.* (2004) developed a program that guarantees the individual technical control of cattle.

Informatics favored the creation of databases with different information, facilitating its promotion and spreading. Torres *et al.* (2001) created databases with scientific information published in Cuba about milk and meat production, based on grasses, forages and sugar cane. Grenón *et al.* (2008) developed an information system of extensive animal husbandry, with a support on a website, as a new tool that complements the extension process from the Instituto de Ciencia Animal (figure 1).

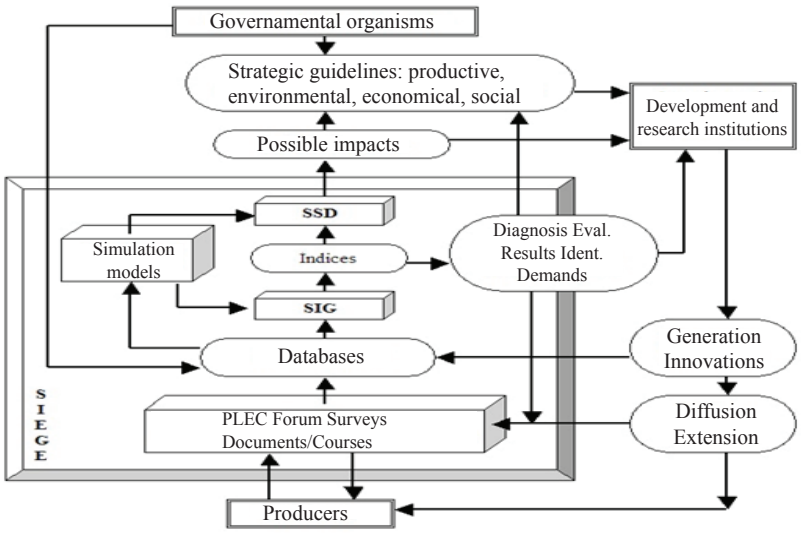

Figura 1. Environmental model of the Platform of Extension and Communication (PLEC, initials in Spanish).

SAMPLING TECHNIQUES AND SAMPLE SIZE

The topic of population sampling is essential in statistics. For studying grasses and forages, this topic is very important in subjective sampling method, like visual ones, developed by Haydock and Shaw (1975), to determine availability and chemical composition of grasses, respectively. Torres and Jordán (1982) compared variants of visual sampling method to estimate availability of creeping grasses. Torres and Martínez (1986) and Torres (1987) performed studies of precision and determination of sample sizes. Torres *et al.* (1988) developed a subjective method, where the concept of grass volume was included, and designed equipment known as MEDIDEN (figure 2). Jordán *et al.* (1989) and Torres *et al.* (1998) applied visual methods to researches on grasses for studying different indicators.

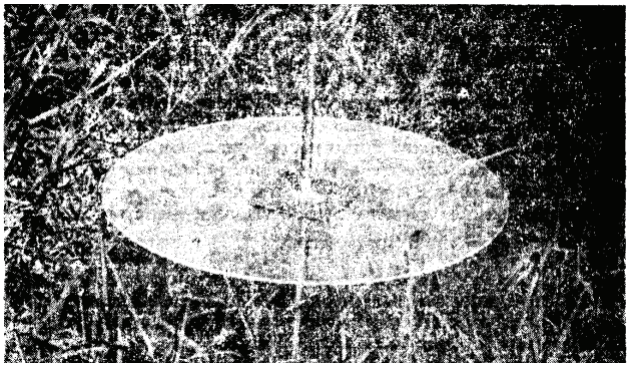

Figure 2. MEDIDEN, equipment for measuring grass volume

Tables were developed for researching on non-ruminant animals, which allow to calculate sample size for experiments, according to completely randomized designs in pre-fattening and fattening pigs (Muñiz 1997).

Remote sensing, through aerial and satellite photos allowed the inventory of large extensions of agricultural areas. Ferrer *et al.* (1988) used these tools for identifying grasslands and Torres *et al.* (1991ab and 1992) studied the correlation degree between the optical density photometric indicator and the grassland indicators, together with the photographic interpretation of synthesized photographs, obtained with a multizonal aerial camera MKS-4. These authors stated productivity criteria of grasslands and spectral indexes of vegetation. Their studies took part of the experiment "Caribe Intercosmos 1988", sponsored by the Cuban Academy of Sciences.

As a result of the researches, Torres *et al.* (1994) presented a methodology for obtaining a physical and geographical description and for performing the photographic interpretation of regions, in order to carry out inventories of different land uses and diagnosis of productivity (figure 3).

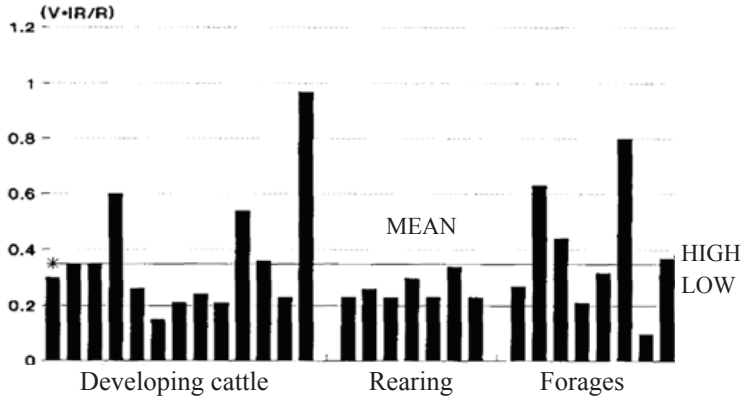

Figure 3. Evaluation of unit, according to vegetative index

MATHEMATICAL SIMULATION AND MODELING

Mathematical modeling is a tool for estimating parameters of biological process. These techniques have been widely used in the field of animal and agricultural production, and allow the development of simulation and prognosis of productive results. The first modeling studies that appear as references in the journal are related to a multiplicative model and its application on the control of lactation curves effect (Menchaca and Jerez 1986), liveweight and intake of dairy cows (Menchaca and Ruiz 1987). López and Menchaca (1989) studied the modeling of growth of claves and heifers, and its variability within time.

Menchaca (1990) proposed stage models for animal growth, allowing the description of animal development curves according to life stages, with differences in feeding and handling that influence on growth rate. These models were created because the birth-age growth curve could not be properly represented by classic models. Later, as a continuation of this study, this author proposed the use of logarithmic transformation for finding estimators with optimal properties and stabilizing variances (Menchaca 1991ab). This same author studied multiplicative models for controlling perpendicular (season) and systematic effects, which affect animal

growth. This author, in 1992, also formulated the union of stage model with the multiplicative model for studying growth in weight of calves in a feeding handling system, applied to growing animals under grazing conditions (Menchaca *et al.* 1993).

La O *et al.* (2013) retaken the modeling of liveweight curves in Cuban goats fed with natural shrubs and grasses from Granma province. This author introduces the concept of elasticity of Gompertz, logistic and non-linear models, in order to achieve a better interpretation of animal performance.

Menchaca and Ruiz (1990) presented a diagram of a simulation model that described the interphase between a model of grass intake (ingestions of dry matter, crude fiber and metabolizable energy in dairy cows) and the animal model, which describes the characteristics of this category (estimation of ME requirements, and estimation of CP ingestion ability).

In order to know the performance of ammonia release through dungs (kg of Nha-1) in the Voisin rational grazing, Torres *et al.* (1996) used non-linear models, regarding the days of dungs.

The use of non-conventional diets in non-ruminant species is an alternative for using by-products and cheapening feeding costs. In growing pigs, from 30 to 90 d, Larduet and Savón (1995) developed a model for simulating growth in this category. These authors considered the partition of ingested nitrogen during maintenance, growth and provision of energy.

Torres *et al.* (1999) described growth dynamics of Cynodon nlemfuensis (star grass), through the fixing of linear and non-linear models, with the use of different statistic criteria and the derivative of biomass dry weight according to time.

Regarding the different statistic criteria to use, when regression models are selected, Guerra *et al.* (2003) presented 14 criteria for reaching adequate theoretical and practical applications. Torres *et al.* (2012) stated other criteria for comparing and selecting non-linear models.

Fernández *et al.* (2004) continued the modeling studies with lactation curve characterization for the genotype of Siboney from Cuba (5/8 H and 3/8 Z). In 2005, these authors determined the factors affecting monthly weighings and estimated the model for lactation curve, corrected for these factors. Torres *et al.* (2009) developed a stochastic approximation of the logistic model, in order to estimate the productive perfomance of water buffaloes in Cuba during growth-fattening stage.

Torres and Ortiz (2005) carried out a summary with the applications of modeling and simulation on the process of production and feeding of farm animals. These authors proposed that every country or region should design and develop their own models for fitting their conditions, in a way that these models can become an useful tool for decision-making, always using statistical criteria that guarantees reliability of the proposed models.

Regarding growth of grass species, Rodríguez *et al.* (2011 and 2013) modelled the growth of *Pennisetum purpureum* cv. Cuba CT-169 and of *Pennisetum purpureum* cv. king-grass, respectively. These authors used linear and non-linear models during rainy and dry periods in the occidental part of Cuba. Also Ruiz *et al.* (2012abc), in three studies, presented the results of growth modeling of *Thitonia diversipholia* plant material during rainy and dry seasons. These authors characterized the best performances in yield components of this variety.

Modeling has also been frequently used for characterizing the dynamics of ruminal degradation. Although many authors have presented several models in *in vitro* gas production, the main objective of these researches is the comparison of feeding systems or of different materials composing these systems. Jay *et al.* (2012ab) carried out four homogeneity tests of non-linear regression models, and presented an evaluation of fixed range tests (lowest significant distance LSD, Tukey´s honest significant distance HSD, Sheffé´s significant distance SSD, and Bonferroni-corrected significant distance BSD) for the multiple comparison of treatment groups for curves, starting from the square mean distance.

MULTIVARIATE METHODS

Most of the scientific researches need the analysis of simultaneous relations among three or more variables. The statistical analysis of these variables will probably suggest, at the beginning, the modification of stated hypothesis. In this process, variables are continuously added and removed, which have a multivariate nature, so they correspond to the measuring on the same individuals.

Torres *et al.* (1993ab) presented the first two results on the application of multivariate techniques, with examples of analysis of principal components and that of multivariate variance, on the selection of variables capable of expressing phenotypic differences found among 16 king grass clones, obtained by tissue culture, and on the study of repeated measuring (years) in the comparison of grass species, respectively.

Varela and Torres (2005) performed a generalization of the principal components analysis, called PCA, for the analysis of several data matrixes, where the three modes were identified according to the interest or characteristics of the studied performed.

For the analysis of variables that explain better the chemical composition and anti-nutritional factors of grains from 14 temporal legumes, Camelo *et al.* (2007 and 2008) used the PCA and classified varieties into four groups. This allowed their characterization for their

further use in feeding non-ruminant animals.

Torres *et al.* (2008 and 2013) introduced the Statistical Model of Impact Measuring (SMIM), which is a coherent and harmonic combination of multivariate methods, in order to achieve the double purpose of identifying variables and indicators, as well as typifying the performance of productive units. The application of this model allows making the correct decisions for establishing models of efficient management, which are appropriate for the characteristics of the ecosystems where cattle rearing systems are located. In addition, it evaluates the impact of processes of technological innovation that are introduced on the productive chains.

After these papers, some studies on the application of this model are also performed. Authors like Benitez *et al.* (2008) used it for establishing the factors that determined productive efficiency of cattle farms in mountain areas of Granma province. Febles *et al.* (2011ab) applied this model to determine the importance of edaphoclimatic factors and to analyze impact indexes of seed production of tropical grasses. Martínez *et al.* (2012) also used this model to evaluate the effect of technologies of *Pennisetum purpureum* (Cuba CT-115) biomass banks on milk production in Villa Clara province. Figures 4 and 5 show the performance of the effect of biomass bank in milk producing units of "Desembarco del Granma" enterprise.

The SMIM has also been applied in different countries like Mexico. Ruiz *et al.* (2012) has used it in this region, in order to characterize beef production systems in Mixquiahuala de Juárez, Hidalgo, through impact indexes reached with the application of different technologies. Vargas *et al.* (2011) reported the use of this model in the typification of cattle farms in Cotopaxi and Los Ríos provinces, Ecuador. Chivangulula *et al.* (2013) applied it on the analysis of sustainability of a familiar pig production system in Kaala, Angola, which allowed to meet and identify the main problems that limit pig production in this province.

Cobo and Borroto (2013) used the SMIM for analyzing the bio-economical efficiency of milk production through the Data Envelopment Analysis (DEA).

Recently, Segura and Torres (2014ab) published two papers with the addition of two new procedures to the SMIM for the treatment of lost and atypical values of databases and the validation of the classification and typification of double purpose farms from the Ecuadorian Amazon.

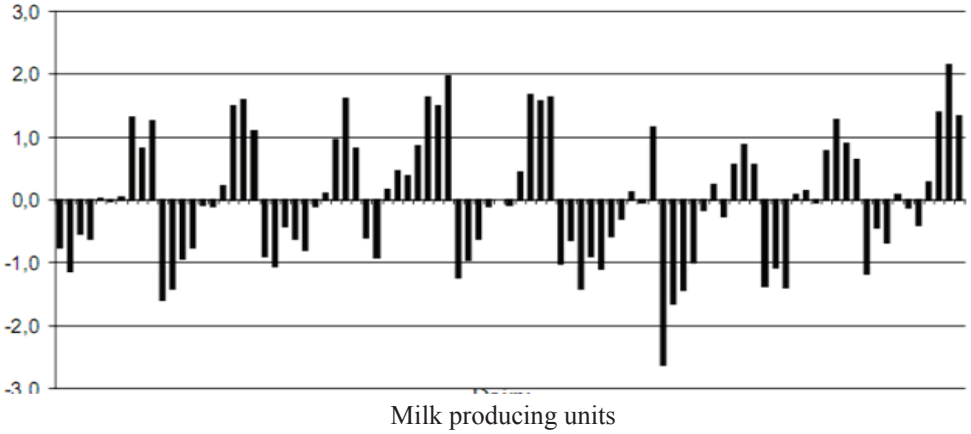

Figure 4. Impact factors per dairy units, CP 1 for the first semester of the studied ten years.

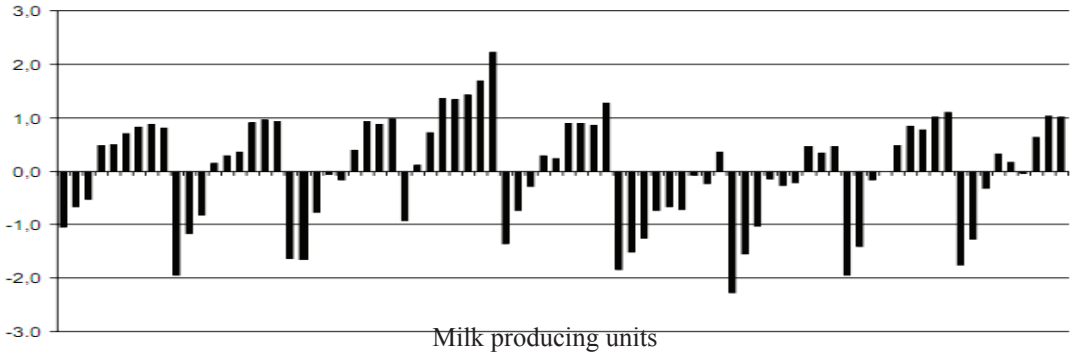

Figure 5. Impact factors per dairy units, CP 1 for the second semester of the studied nine years (Martínez *et al.* 2012)

Table 1. Frequency of papers per topics and publication year

Topics	%	Publication year
Estimation and hypothesis testing	8.2	1973 - 2002
Experimental designs	11.3	1974 - 2012
Informatics	5.2	1999- 2001
Sampling techniques and sample size	16.5	1982 - 1994
Modeling and mathematical simulation	26.8	1986 - 2013
Econometry	13.4	1985 - 2011
Multivariate methods	18.6	1993 - 2014

ECONOMY

Crespo (1976) insisted on the use of fertilization, and recommended, since that moment, the need of evaluating the costs due to the prices of inputs. This fact led to studies on economical efficiency of fertilization in grasses and forage. Cino *et al.* (1985) performed an economical study on the response of N fertilization in *Digitaria decumbens* (pangola grass). These authors determined production functions through square regressions, fitted by the minimum squares, in order to obtain higher gains regarding N doses.

Aguilar *et al.* (1994) applied linear programming to the ration formulation for poultry, taking into account the requirements of amino acids. From an economical point of view, Cino *et al.* (1999) studied some species of grain legumes, and considered everything from meal production process up to their inclusion on poultry diets.

Continuing the mathematical and economical applications, Cino *et al.* (1994) evaluated intercropping of different forage species at the sowing moment of a brachiaria grassland with. Later, Cino and Valdés (1995) made an economical comparison between the Voisin rational grazing system and the traditional fattening system in grazing. There was also an economical evaluation of dairy systems with protein banks of *Neonotonia wightii* (Glycine) and *Leucaena leucocephala* (Cino *et al.* 1996 and Cino and Castillo 1999).

The economical evaluation of fattening technologies was developed by Cino *et al.* (2001), who demonstrated that the cost per animal and per kilogram of liveweight was inferior in systems of low inputs, and the benefit/cost relation showed the best indexes for the technologies of high inputs, due to the best animal performance and the lowest duration of the fattening period. Similar results were found by Rey and Reyes (2003) after studying the economical effect of two methods of rotational grazing. These authors stated that using low inputs, there is no bio-economical stability because of the productivity of animals. Later, Cino *et al.* (2011) found that silvopastoral systems with *Leucaena leucocephala* could be feasible economical option to increase biomass production in units of milk and meat production, which are destined for cattle pre-fattening and fattening.

Regarding the application of econometric methods on cost analysis of milk production, Cobo *et al.* (2011) proposed the regression methods, and used the minimum squares for estimating total costs, regarding other cost elements, so they could be reduced and the volume of incomes could be increased.

FINAL CONSIDERATIONS

The results of this descriptive analysis allow to conclude that, from 1973 up to nowadays, the Cuban Journal of Agricultural Science published systematically papers on mathematics applied to the agricultural and livestock field. Most of these papers were written by Cuban authors, confirming the importance of this subject in researches on agriculture and animal husbandry in Cuba. This analysis also demonstrates the application of this specialty on different scientific fields.

Modeling and simulation was the most frequent topic, and its publication started at the end of the 80´s. Currently, this methodology is still used. Despite the fact that the amount of topics related to estimation, hypothesis test and experimental designs are less, they appear in the 70´s and there are still some studies. Informatics has had less publications in this journal. This is because there are many journals in Cuba that specializes on this field, so the experts prefer them for publishing their results.

Studies related to sampling techniques and sample size were important during the 80´s and 90´s of last century. However, nowadays there are no studies on these subjects. In spite of its importance, many researches do not deal deeply with this subject.

Publications of multivariate methods and their application began to appear in publications at the beginning of the 90´s. Their frequency is considered as high due to the development of informatics, which allows the development of good statistical programs that facilitate these applications

REFERENCES

Aguila, B., Torres, V., Brito, M., Sarduy, L. & Noda, A. 1998. A transformation to homogenize the variances. Cuban J. Agric. Sci. 32:11

Aguilar, I., Larduet, R. & Fraga, L. M. 1994. A note on the economic effect of the utilization of amino acids in broiler rations. Cuban J. Agric. Sci. 28:15

Ajete, A., Díaz, C. P., & Moyongo, J. C. 2000. SCPorcino. Computer programme for the control of the swine herd. Cuban J. Agric. Sci. 34:101

Benitez, D., Ramírez, A., Guevara, O., Pérez, B., Torres, V., Díaz, M., Pérez, D., Guerra, J., Miranda, M. & Ricardo O. 2008. Determinant factors in the biomass production of three pasture species in rational grazing systems in the Cauto Valley, Cuba. Cuban J. Agric. Sci. 41:221

Caballero A. 1979. Sample size for completely randomized and randomized blocks designs where the experimental unit is a group of animals. Cuban J. Agric. Sci. 13:227

Camelo, S., Torres, V. & Díaz M. F. 2007. Multivariate analysis of the chemical composition of seasonal legume grains. Cuban J. Agric. Sci.. 41:101

Camelo, S., Torres, V. & Díaz M. F. 2008. Multivariate analysis of the anti- nutritional factors of the seasonal legumes grains. Cuban J. Agric. Sci. 42:329

Chivangulula, M., Torres, V., RMorais, J., Nalissimo Mário, J. & Gabriel , R. 2013. Multivariate evaluation of the family pig production System in Caála, Angola. Kaála, Angola. Cuban J. Agric. Sci. 47:279

Cino, D. M. & Váldes, G.1995. Simulation of the economical feasibility of the utilization of the Voisin grazing system in beef fattening. Cuban J. Agric. Sci. 29:145

Cino, D. M., & Castillo, E. 1999. Note on costs and benefits of rotational cattle fattening systems with leucaena (*Leucaena leucocephala*) under non-irrigation conditions. Cuban J. Agric. Sci. 33:339

Cino, D. M., Crespo, G & Sardiñas, O. 1985. A study on economical efficiency of N fertilizationto pangola grass (*Digitaria decumbens*) during the rainy season. Cuban J. Agric. Sci. 19:323

Cino, D. M., Díaz, M. F., Lon-Wo, E. & González A. 1999. Economical evaluation of raw legume grain meals and their potential use in poultry feeding. Cuban J. Agric. Sci. 33:121

Cino, D. M., Larduet, R & Jordan , H. 1996. Economical results in a dairy system with a protein bank of Glycine (*Neonotonia wightii*) Cuban J. Agric. Sci. 30:235

Cino, D. M., Sierra, D., Martín, P. C. & Valdés, F. 2001. An economic evaluation of beef production alternatives. Cuban J. Agric. Sci. 35:123

Cino, D. M., Sistechs, M. & Melendez J. F. 1994. Economical evaluation of the use of intercropped cultures for the feeding of dairy cows in milk production systems. Cuban J. Agric. Sci. 28:149

Cino, D., Díaz, A., Castillo, E. & Hernández J. L. 2011. Cattle fattening in *Leucaena leucocephala* grazing: some economic and financial indicators for making decisions. Cuban J. Agric. Sci. 45:7

Cobo, R. & Borroto, O. 2013. Determination of the bio-economical efficiency of milk production throughout data envelopment analysis models Cuban J. Agric. Sci. 47:233

Cobo, R., Torres, V., Machado, Y. & Fraga, M. 2011. Econometric methods in the analysis of duary total production costs. Cuban J. Agric. Sci. 45:227

Crespo, G. 1976. Differred nitrogen fertilization and annual production of pangola (*Digitaria decumbens* Stent) and guinea (*Panicum maximun* Jacq.) grass pastures. Cuban J. Agric. Sci. 10:223

Febles, G., Torres, V., Baños, R., Ruiz, T. E., Yañez, S. & Echeverria, J. 2011. Multivariate analysis application to determine the preponderance of edaphoclimatic factors in the production of sedes from tropical prairie grasses. Cuban J. Agric. Sci. 45:45

Febles, G., Torres, V., Baños, R., Ruiz, T. E., Yañez, S. & Echeverria, J. 2011. Utilization of the impact index to interpret the relative influence of edaphoclimatic factor son the production of tropical pasture seeds. Cuban J. Agric. Sci. 45:53

Fernández, L., Menéndez Buxadera, A. & Guerra, C. W. 2004. Comparative study of different functions for the analysis of the location curve in the genotype Siboney de Cuba. Cuban J. Agric. Sci. 38:343

Fernández, L., Menéndez Buxadera, A. & Guerra, C. W. 2005. Factors affecting milk yield in the siboney de Cuba genotype. Linear models with controlled lactation curve effect. Cuban J. Agric. Sci. 39:255

Fernández, L., Menéndez, A., Guerra W. & Suárez, M.2001 Estimation of the standard lactation curves of the Siboney de Cuba breed for their use in lactation extensions. Cuban J. Agric. Sci. 35:93

Ferrer, E., Torres, V. & San Martín, E. 1988. Preliminary study on the application of remote sensing in grassland identification. Cuban J. Agric. Sci. 22:235.

Gómez, J., López, D., Menchaca, M. & Rico, C. 1971. Estimation of optimum slaughter age in broilers. 1. Feed and protein efficiency related to live weight and carcass traits. Cuban J. Agric. Sci. 5: 313

Gomez, S., Torres, V., García, Y. Fraga, L. M., Sarduy, L., & Savón, L. 2012. Comparison of models of fixed and mixed effects on the analysis of an experiment with mutant strains of cellulotic fungus *Trichoderma viride*. Cuban J. Agric. Sci. 46:127

Gomez, S., Torres, VGarcía, Y. & Navarro, J. A. 2012. Statistical procedures most used in the analysis of measures repeated in time in the agricultural sector. Cuban J. Agric. Sci. 46:1

Grenón, D. A., Lizazo, D. & Torres, V. 2008. Proposal of the System of Information and Extension in Extensive Cattle Rearing (SIEGE). Cuban J. Agric. Sci. 42:339

Guerra, C. W., Cabrera, A. & Fernández, L. 2003. Criteria for the selection of statistical models in scientific research. Cuban J. Agric. Sci. 37:3

Guerra, C. W., De Calzadilla, J. & Torres, V. 2000. Efficiency indicators regarding non-parametric methods in statistics. Cuban J. Agric. Sci. 34:1

Haydock, K. P. & Shaw, N.H. 1975. The comparative yield method for estimating dry matter yield of pastures. Tech Paper Div. trop. Pasture CSIRO, Australia.

Jay, O., Torres, V., Marrero, Y. & Torres, P. 2012. Tests assessment for multiple comparisons of *in vitro* gas curves, from the root of the mean square distance. Cuban J. Agric. Sci. 46:133

Jay, O., Torres, V., Marrero, Y. &Torres, J. P. 2012. Sensibility analysis of homogeneity tests of *in vitro* gas production curvesby Monte carlo simulation. Cuban J. Agric. Sci.

46:15

Jordan, H. Torres, V. & Pérez, I. 1989. Some considerations on visual samplings with 5 reference frames. 1. Relationship between reference frames and various indicators of Coast cross bermuda grass. Cuban J. Agric. Sci. 23:93

La O, M. A., Guevara, F., Fonseca, L. Rodriguez, R., Pinto, R. Gómez, H. Medina, F. J. & Hernández, A. 2013. Application of the logistical and Gompertz models to the analysis of live weight curves in Cuban Creole kids. Cuban J. Agric. Sci. 47:1

Larduet, R. & Savón, L. 1995. Prediction of protein quality from a model of N digestion and metabolism in pigs with non-conventional rations. Cuban J. Agric. Sci. 29:1

López, V. & Menchaca, M. A. 1989. Statistical characterization of calf and heifer growth throughout liveweight performance. Cuban J. Agric. Sci. 23:131

Martínez Machin L. & Marrero Y. 2000. Application of the response surface methodology on the study of the *in vitro* ruminal fermentation. Cuban J. Agric. Sci. 34:279

Martínez Machín, L., Valenciaga, N., Ruiz, T. E., Mora, C. & Noda, A. 2002 Localization in time and space of *Heteropsylla cubana* (Crawford) in a *Leucaena leucocephala* (Lam) de Wit grassland. Cuban J. Agric. Sci. 36:3

Martínez, R. O.; Torres, V. & Aguilar, P. I.. 2012. Impact of biomass bank with *Pennisetum purpureum* (Cuba CT – 115) on milk production. Cuban J. Agric. Sci. 46:253

Menchaca, M. 1973. A short method for analysis of statistical transformations. Cuban J. Agric. Sci. 7:141

Menchaca, M. A. 1975. Determination of sample size in Latin square designs. Cuban J. Agric. Sci. 9:1

Menchaca, M. 1980. Bias correction in Wood´s method for the estimation of milk yield in total lactation. Cuban J. Agric. Sci. 14:107

Menchaca, M. 1981 Comparison of estimation methods and sampling intervals in the prediction of milk production. Cuban J. Agric. Sci. 15:1

Menchaca, M. 1990. The use of the stage models for describing animal growth curves. Cuban J. Agric. Sci. 24:31

Menchaca, M. 1991a. Modelling of bovine weight growth. 1. An intrinsically linear model for growth representation. Cuban J. Agric. Sci. 25:125

Menchaca, M. 1991b. Modelling of bovine weight growth. 2. Multiplicative model controlling the growth curve and other effects. Cuban J. Agric. Sci. 25:231

Menchaca, M. A. & Jérez, I. 1986. Evaluation of three tropical grasses 1. Statistical treatment. Cuban J. Agric. Sci. 20:223

Menchaca, M. A. & Ruiz, R. 1987. A note on the algebraic representation of liveweight and consumption during lactation of dairy cows. Cuban J. Agric. Sci. 21:1

Menchaca, M & Ruiz, R. 1990. Simulation of dry matter, crude fiber and metabolizable energy consumptions in an experiment with dairy cows grazing coast cross 1 bermuda grass (*Cynodon dactylon* Pers). Cuban J. Agric. Sci. 24:251

Menchaca, M., Valdés, G. & Brito, M. 1993. A study on the performance of grazing animals through the use of a growth multiplicative model. Cuban J. Agric. Sci. 27:11

Muñiz, M. 1997. Tables used to estimate sample size in performance experiments with pigs in the pre-fattening and fattening stages. Cuban J. Agric. Sci. 31:1

Rey, S. & Reyes, J. J. 2003. Economical effect of two rotational grazing methods with dairy cows and two gazing intensities. Cuban J. Agric. Sci. 37:107

Roche, A., Larduet, R., Torres, V. & Ajete A. 1999. CalRac: a microcomputer programme for the estimation of ruminant rations. Cuban J. Agric. Sci. 33:13

Rodríguez, L., Larduet, R., Martínez, R. O., Torres, V. Herrera, M., Mesa, Y. & Noda, A. 2013. Modeling of the biomass accumulation dynamics in *Pennisetum purpureum* cv. King grass in the Western region of Cuba. Cuban J. Agric. Sci. 47:119

Rodríguez, L., Torres, V., Martínez, R. O., Jay, O., Noda, A. & Herrera M. 2011. Models to estimate the growth dynamics of *Pennisetum purpureum* cv. Cuba CT - 169. Cuban J. Agric. Sci. 45:349

Ruiz, M., Ruiz, J., Torres, V. & Cach, J. 2012. Study of beef meat production systems in a municipality of Hidalgo State, Mexico. Cuban J. Agric. Sci. 46:261

Ruiz, T. E., Torres, V., Febles, G., Díaz, H. & González, J. 2012a. Use of modeling to study the growth of the plant material 23 of *Tithonia deversifolia*. Cuban J. Agric. Sci. 46:23

Ruiz, T. E., Torres, V., Febles, G., Díaz, H.& González, J. 2012c. Use of modeling for studying the growth of Tithinia diversifolia collection 17. Cuban J. Agric. Sci. 46:243

Ruiz, T. E., Torres, V., Febles, G., Díaz, H., Sarduy, L. & González, J. 2012b. use of modeling for studying the growth of *Tithonia diversifolia* collection 10. Cuban J. Agric. Sci. 46:237

Segura, E. O. &Torres, V. 2013a. Comparison criteria strengthened in classification and type representation, according to the Statistical Model of Impact Measuring, in a case study in Pastaza, Ecuador. Cuban J. Agric. Sci. 48:4

Segura, E. O. & Torres, V. 2013b. Treatment of missing and atypical values in the application of the Statistical Model of Impact Measuring in a study of 90 dairy farms in Pastaza province, Ecuador. Cuban J. Agric. Sci. 48:4

Sotolongo, A., Mederos, R. E., Roche, A., Gutiérrez. M., & Artiles, M. 2004. Automated system for the individual technical control of cattle. Cuban J. Agric. Sci. 38:227

Tomeu, A., Peña, J. A. & Menchaca, M. 1973. Diallel cross among the F3 of six sorghum crosses. Cuban J. Agric. Sci. 6:267

Torres, V. 1980. Estimation of the homogeneity index of the soil through random block experiment. Cuban J. Agric. Sci. 14:213

Torres, V. 1987. Visual method for estimating pasture availability. II Determination of sample size. Cuban J. Agric. Sci. 21:113

Torres, V., Barbosa, I., Meyer, R., Noda, A. & Sarduy, L. 2012. Criteria of goodness of fit test in the selection of non-linear models for the description of biological performances. Cuban J. Agric. Sci. 46:345.

Torres, V., Barch, H. Ytzerott & Weichett H. 1991a. Remote sensing in grassland studies. 2. Productivity criterium. Cuban J. Agric. Sci. 25.129

Torres, V. & Chongo, B. 1996. A mathematical model for experiments with repeated measurements in the same experimental unit. Cuban J. Agric. Sci. 30:13

Torres, V., Cobo, R., Sanchez, L. & Raez, N. 2013. Statistical tool for measuring the impact of milk production on the local development of a province in Cuba. Livestock Research for rural Development 25:9

Torres, V., Crespo, G. & Cuesta, A. 1996. A note the modelling of the ammonia losses of cow dung under Voisin´s rational grazing system. Cuban J. Agric. Sci. 30:131

Torres, V., Crespo, G., Martínez, O. Martín, P. C., Roche, A., Vega, Y., Sarduy, L., Pérez, & Brito, M. 2001. A database for Cuban publications on beef and milk production using sugarcane, pastures and forages. Cuban J. Agric. Sci. 35:9

Torres, V., Ferrer, E. & San Martín, E. 1991b. Remote sensing in grassland studies. 1. Photographic interpretation and optical processing. Cuban J. Agric. Sci. 25:1

Torres, V., Ferrer, E. & San Martín, E. 1992. Remote sensing in grassland studies. 3. Plant indices from spectrometric measurements. Cuban J. Agric. Sci. 26:1

Torres, V., Ferrer, E., San Martín, E., Cino, D. M. & Ramos, N. 1994. Remote sensing for the inventory and evaluation of grasslands. Cuban J. Agric. Sci. 28:263

Torres, V., Jerez, I. & Valle, R. 1988. Method of subjective sampling for estimating creeping pasture availability. Cuban J. Agric. Sci. 22:1

Torres, V. & Jordan, H. 1982. A comparison of variants of the visual sampling method in the estimation of the availability of Coast Cross 1 bermuda grass (*Cynodon dactylon* cv. Coast Cross 1) Cuban J. Agric. Sci. 16:233

Torres, V. & Jordan, H. 1989. Estimation of dry matter in Coast cross 1 bermuda grass as a function of other yield components: Ridge regression and least squares. Cuban J. Agric. Sci. 23:1

Torres, V., Lazo, J. A., Ruiz, T. E. & Noda A. 1998. The extension of the sampling method of Haydock and Shaw to estimate the morphological components of a *Cynodon nlemfluensis* cv. Jamaican sward. Cuban J. Agric. Sci. 32:235

Torres, V., Lazo, T. E., Ruiz, T. E. & Noda, A. 1999. Mathematical modelling to estimate C. nlemfuensis pasture availability Cuban J. Agric. Sci. 33:343

Torres, V., López, V. & Noda, A. 1993a. Example for application of multivariate techniques in different stages of the evaluation and screening of pasture species. 2. Multivariate analysis of variance. Cuban J. Agric. Sci. 27:243

Torres, V. & Martínez, J. 1986. Visual method for estimating pasture availability. 1. Precision studies. Cuban J. Agric. Sci. 20:1

Torres, V., Martínez, R. O. & Noda, A. 1993b. Example for application of multivariate techniques in different stages of the evaluation and screening of pasture species. 1. Principal components. Cuban J. Agric. Sci. 27:125

Torres, V., Navarro, J. R. &Pérez, T. 2003. Statistical models for processing experiments with repeated measurements in the same experimental unit. Cuban J. Agric. Sci. 37:225

Torres, V. & Ortiz, J. 2005. Application of modelling and simulation to the production and Feeding of farm animals. Cuban J. Agric. Sci. 39:385

Torres, V., Ramos, N., Lizazo, D., Monteagudo, F. & Noda, A. 2008. Statistical model for measuring the impact of innovation or technology transfer in agriculture. Cuban J. Agric. Sci. 42:131

Torres, V., Sampaio, I. and Fundora, O. 2009 Stochastic model of the productive performance in the growing stage of water buffaloes in Cuba. Cuban J. Agric. Sci. Volume 43:111

Torres, V. & Seguí, Y. 2001 Practical procedure for the determination of the *a posteriori* power function. Cuban J. Agric. Sci. 35:297

Varela, M. & Torres, V. 2005. Application of three-mode principal components analysis in the multivariate characterization of King grass somaclones. Cuban J. Agric. Sci. 39:527

Vargas, J., Benitez, D., Torres, V., Velazquez, F. & Erazo, O. 2011. Typification of the cattle farms in the mountain feet of Los Ríos and Cotopaxi provinces of the Republic of Ecuador. Cuban J. Agric. Sci. 45:381

Venereo A. 1976 Number of replications in Latin square change-over designs for the estimation of residual effects. Cuban J. Agric. Sci. 10:231

Willis, M. B., Menchaca, M. & Preston, T. R. 1973 The use of Brahman, Brown Swiss, Charolais, Criollo and Holstein bulls on Zebu cows: post weaning performance and carcass characteristics. Cuban J. Agric. Sci. 7:1

Willis, M. B., Preston, T. R. & Menchaca, M. 1971. The use of Brahman, Brown Swiss, Charolais, Criollo and Holstein bulls on Zebu cows: performance to weaning. Cuban J. Agric. Sci. 5:247

Received: