

Main genetic researches developed at the Instituto de Ciencia Animal since its foundation

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This paper presents the main results of the researches developed at the Instituto de Ciencia Animal from the Republic of Cuba in the field of genetics. These researches were mainly aimed to the study of those species of economical interest to the country. These species are beef and dairy cattle, buffaloes, pigs, sheep, goats, birds and rabbits. This review can be useful for designing new contributions in topics not deeply researched yet and, due to their importance, could help to achieve a more efficient animal production.

Key words: *genetics*,

INTRODUCTION

Creating and transferring technologies of genetic improvement, appropriate for genotypes/species/breeds and production systems from Cuba, has been the main purpose of the researches developed by the Group of Genetics from the Instituto de Ciencia Animal. Modern methodologies of quantitative genetics and the use of more advanced computer techniques, applied to this specialty, as well as their relation with

the main producing units and those that help animal genetics, have been essential elements for fulfilling this objective.

During 50 years of research, the Cuban Journal of Agricultural Science has published all the achievements in genetic researches at the Instituto de Ciencia Animal.

DAIRY CATTLE

Bovine characteristics, under tropical conditions, have been described by López (1985 and 1986), who mainly referred to the results with this species in the Latin American region. This author had special interest on the study of aspects related to age at the first parturition and reproductive intervals.

Planas *et al.* (1979) studied aspects of this species related to the crossbreeding application, and milk production.

Cuba has imported Holstein cattle from Canada, with the objective of improving the cattle destined to milk production. Ribas *et al.* (1978) analyzed the performance of the first imported Holstein and confirmed that correlations between productive and reproductive features of this kind of cattle in Cuba were similar to those reported for temperate countries. Ribas *et al.* (1980) also studied the evaluation of Holstein cows, born in Cuba or in Canada, regarding their performance in milk production up to 244 d and total production, total fat production, duration of gestation and period between parturitions. These authors found no differences among the considered features, although they pointed out the importance of cattle effect, as an element to be considered in further studies on fat and milk production.

Between 1976 and 1988, there were also different

studies on breed comparisons, in which the conditions have been homogenized and there has been a total coexistence between the evaluated genotypes. In a first comparative study (Ponce de León *et al.* 1982), the first 76 lactations of Holstein, 80 lactations of 3/4 H x 1/4 Z and 72 of 5/8 H x 3/8 Z, from two herds, were analyzed. The effect of genotype was significant in milk production at 100, 200 and 244 d, lactation length and weight at birth. Weight at birth was higher in 5/8 H x 3/8 Z. Milk productions were superior in the crossbred species, with maximum differences of 143, 339 and 358 kg of milk at 100, 200 and 244 d, between Holstein and 3/4 H x 1/4 Z, respectively. Weights after birth and pregnancy duration were also studied, and body measurements were performed to Holstein calves and to the first generation of mating of 3/4H 1/4Z and of 5/8H 3/8Z (Ponce de León *et al.* 1983). There were no differences of weight at birth between genotypes. Mean values were 34.5 ± 0.08 kg, being the males 2 kg heavier than females. Pregnancy duration was 6.5 d shorter in Holstein than in 5/8 H x 3/8 Z. Holstein had highest thoracic perimeter/wither height and 3/4 H x 1/4 Z, and the lowest metatarsal circumference/wither height.

Another study compared the 424 first and second lactations of 5/8 H 3/8 Z, 3/4 H 1/4 Z and pure Holstein

(Ponce de León *et al.* 1988). Crossings had a high potential for milk production (4,018 and 3,692 kg for 3/4 and 5/8 respectively), which surpassed that of Holstein (3,533 kg) and also achieved a good reproductive performance. There were no differences of liveweight and reproduction between crossings, but milk production was better in the 3/4. Holstein performance was affected by their coexistence with the crossings, particularly in the worst herd. This breed had three times more losses than the crossings, due to reproductive and health problems until the third lactation.

Ponce de León and Guzmán (1991a) characterized longevity from a sample of Holstein cows that were retired from an enterprise, and analyzed the influence of determined environmental and genetic effects on this trait. A group of 68 herds were evaluated in this study, which represented 59 progeny groups. In a general sense, general means of longevity were confirmed to be among the highest reported in literature. During the last final years of the evaluated period, from 1971 to 1981, there was a tendency to an earlier elimination of cows.

Ponce de León and Guzmán (1991b) also evaluated Holstein traits. Correlations among class, score, general appreciation and milk character were high (0.97-1.00), and the correlations between these last and other traits were mean (0.40-0.70). Size, height, body capacity and rump (0.09-0.37) were excluded. According to this appreciation system, low improvement of these traits is expected and its modification is suggested.

Ribas *et al.* (1992) studied extension factors of the first lactation up to 244 d of 7/8 Holstein x 1/8 Zebu, 3/4 Holstein x 1/4 Zebu, Mambí and Holstein crossbred genotypes. These authors found that correlations between extended and real lactations were between 0.90 and 0.97. Besides, all the reported factors were considered to be of interest for the extension of lactation in the evaluated genotypes.

Ribas *et al.* (1999) evaluated milk production of crossbred Siboney de Cuba, as well as the environmental and genetic factors that affect them. The general mean of milk production was 2,138 ± 7.9 kg, with a lactation length of 237.34 ± 0.29 d. The analysis of variance showed that all studied factors were important. However, partial coefficients of determination showed that the dairy farm had the largest effect (23.48%), followed by the year of parturition (7.8%). It was evident that the highest milk production was obtained from the fifth parturition, which corresponds to a maximum age of production, between 68 and 98 months, a period of stability in the production curve. The heritability, of 19.2 ± 0.04, demonstrates the possibilities of genetic improvement

in this population.

Ponce de León and Guzmán (1993) evaluated the genetic relations between growth of Holstein heifers and milk production, reproduction, type and survival. There were no negative effects between the genetic values of growth and the different traits of economical interest.

Hernández *et al.* (2007) studied genetic tendencies and heritability of milk production and reproduction of Mambí de Cuba breed, in Granja Bijirita, since the beginning of the formation of this genotype.

The analyzed traits were accumulated milk up to 244 d, total milk, lactation length, amount of services per gestation, parturition-first service interval, and interval between parturitions. Mean values per each were 2,682 ± 16 kg, 3,035 ± 20 kg, 294 ± 1d, 2.6 ± 0.1, 89.7 ± 1.8 d and 444.2 ± 2.2 d, respectively. Heritability estimates were 0.17 ± 0.01, 0.19 ± 0.00, 0.09 ± 0.03, 0.01 ± 0.02, 0.01 ± 0.01 and 0.07 ± 0.03, respectively. Genetic tendency was 4.91 kg/year for total milk production, 0.14 d/year for parturition-first service interval, and 0.35 d/year for interval between parturitions.

Hernández (2009) presented a historical study that gathered information of over than 20 years of rearing (1983-2007), regarding productive and reproductive traits of Mambí de Cuba breed. The study was mainly developed in Empresa Pecuaria Genética de Matanzas, although other enterprises were considered. This research also included crossbred animals. The results were very important for spreading the use of this dairy breed (Mambí de Cuba) and its crossings to other areas of Cuba and regions with similar environmental conditions and scarcity of resources.

Previous studies have confirmed that all the traits between 1991 and 2006 were affected, regarding those between 1981 and 1990, period in which the environmental conditions were more favorable. The age at beginning of reproductive life increased in 6.1 months, and weight per age at the beginning of reproductive life decreased in 85.3 g/d. Parturition-first service intervals, parturition-pregnancy, parturition-parturition and services/pregnancy increased in 30, 104, 101 and 0.5 d, respectively. Milk production up to 244 and 305d decreased in 997 kg and 1,056 kg. Daily milk production decreased in 3.78 kg/d and the L/IPP decrease to 2.87 kg/d. Mambí de Cuba breed is certified by the productive information and individual controls, which allowed to characterize 42 traits in the four genetic enterprises used for this study during 26 years (Hernández *et al.* 2011). Means of zootechnique indicators of studied traits were a contribution to the knowledge of genotype under production conditions during this period.

BEEF

Zebu. Willis *et al.* (1968) evaluated carcass composition of Zebu bulls, consuming diets rich in energy, through different indicators, including the index of conformation (first quality meat as proportion of total meat), which had a correlation of -0.50 with the excessive fat percentage, and of -0.39 with carcass weight. Researchers pointed out the importance of conformation index as an economical indicator of carcass quality.

Later, Rico *et al.* (1984) studied different sources of genetic and environmental variation. For that purpose, these researchers used information of 3,535 Zebu calves of four livestock enterprises from four provinces. Effects of herd, birth year and bimester, sex, sire and year/bimester relation were evaluated, and the age of the mother was adjusted by quadratic regression. Weights at birth, at three and six months old were considered. The effect of sex favored males and calves born between September and December, when the lowest weights at birth occurred. Regarding growth period, Rico and Planas (1994) studied the influence of environmental and genetic effects on Zebu growth up to 18 months old. Differences among years explained the 9-20 % of weight and weight per age variations. Animals born from March to June had higher weight at weaning, and those born from May to June had higher weight at 18 months old, with a tendency to gain 8.1 g/year.

In order to know the genetic parameters of Zebu for the pre-selection at weaning, Rico *et al.* (1985) confirmed that the h^2 between enterprises was 0.13-0.38 of weight at birth, 0.12-0.24 of weight at three months old, 0.01-0.33 at six months old, and 0.013-0.28 for weight gain up to three months and 0.02-0.31 up to six. Genetic correlations went from medium to high.

Performance tests in Cuba are carried out under grazing conditions. Depending on the places for the study, environmental conditions were better or less favorable. In studies of genotype/environment interaction, Rodríguez and Guerra (2013) demonstrated, using 203 Cuban Zebu sires as descendants, that it is advisable to select parents according to the characteristics of the place where progeny will be raised. Values of $h^2 = 0.22 \pm 0.04$ in a favorable environment and $h^2 = 0.15 \pm 0.03$ in an unfavorable environment indicated differences according analyzed conditions. Values of Spearman and Pearson correlation of the trait measured in both environments were 0.39 and 0.46, respectively. This demonstrates that the same trait measured in both environments is equivalent to two different characters, because the correlation is not equal 1.

Santa Gertrudis. This breed has been the object

of several genetic studies. Molina (1977) analyzed aspects related to carcass composition of this genotype, regarding that of Charolais x Brahma, according to the administration of different diets. The breed x diet significant interaction showed that the highest gains of Santa Gertrudis with concentrate diets demonstrated the ability of this breed to synthesize body fat. Morales *et al.* (2013a) studied the age at the beginning of reproductive life and at first service, first parturition, weight at inclusion and weight per age in heifers between 1975 and 2006, with information of enterprises "Rancho Vallina", "Turiguanó" and "Camilo Cienfuegos". Using a multi-character model, higher h^2 values were obtained for reproductive indicators of 0.16, 0.15 and 0.07, respectively. However, genetic correlations with weight were high and significant. This way, the possibility that the weight per age could be an important selection criterion was demonstrated.

In studies on genetic parameters and genetic tendency in this breed, Morales *et al.* (2013b) found that the h^2 for growth traits were from medium to low, with high and positive correlations. However, there was no genetic progress for daily mean gain.

Other studies have characterized the performance of Santa Gertrudis breed at "Rancho Vallina" enterprise. Sánchez (2012) evaluated the effects of parturition year and season, farm and age at the first parturition. This author considered that the effect of parturition year had the best contribution to the total variation of all the studied traits, with partial coefficients of determination of 86.8 - 88.0% in growth traits up to the beginning of reproductive life, 51.3-81.8 % in reproduction traits and 59.3- 64.0 % in longevity traits. This study concluded that it is important to work on reducing the age of the first parturition and the interval between parturitions.

Charolais. This breed comes from animals imported from France at the beginning of the 20th century. Willis and Preston (1967) stated its productive advantages when they reported that weight per age at 400 kg of liveweight with concentrate diets was 1.24 kg/d, with a range of 1.02-1.57 and 5.16 ± 1.00 of conversion. These authors indicated that there was enough variation for achieving some genetic progress through performance and selection tests.

In order to know the elements that identify this breed, characteristics of the B system of blood groups were studied. Ribas and Mitat (1975) found some important differences regarding that reported about French Charolais.

This breed has, among its main characteristics, high rates of gains, good maternal ability and excellent carcass quality, although there are some disadvantages

related to incidence of dystocic parturitions due to high weights of calves at birth. However, this characteristic has been considered as its main advantage in Cuba, because its incidence is not higher than 2 % (López *et al.* 1977). López and Seitz (1979) found that males were 1.14 kg heavier than females and heifers delivered less heavy calves. In addition, the calculated h^2 from half sibs reached values between 0.13 and 0.37 at the different genetic centers studied, with 0.29 for total population, which included 1,082 calves from 22 parents.

At the Instituto de Ciencia Animal, seasonal performance tests were carried out with this breed fed with concentrates. Using 320 calves for the test, which were the offspring of 28 sires, López and Menchaca (1982) reported that h^2 of daily gain was 0.50, and this indicators should be considered as a selection criterion of this system. Rico *et al.* (1987) indicated that weight at birth and at weaning (180 d) of this breed, fitted for 65.2 months of mean age of mothers at parturition, were 34.3 and 140 kg, respectively. Estimates of h^2 were low (0.10 and 0.20 respectively). In this case, the information included 4,743 calves, from five Cuban herds, offspring of 43 parents, which represented another rearing system. These conditions endangered the possibility of genotype/environment interaction, as well as the validity of the system of performance tests, with the inclusion of concentrated food.

Crossings in beef production. After evaluating five crosses obtained from Zebu cows with energy-rich diets (Willis *et al.* 1973), significant effects of paternal breed were confirmed on most of the evaluated growth traits (143) and carcass (131). There were also effects of the sire on the confirmation index and first quality meat. More use of European breeds, mainly Cuban Charolais, was suggested.

Menéndez *et al.* (1977 a and b) compared the result of crossing sires from Charolais, Holstein, Red Poll, Criollo and Santa Gertrudis breeds with Zebu and Holstein cows, over F1 Holstein x Brahman, with molasses-based diets and ages at slaughtering from one year up to 350, 410, 470 and 530 kg. These authors found significant interaction in breed per weight at slaughtering for daily gain, weight per age and carcass characteristics. These researchers pointed out that each breed or crossing has an optimal final point for slaughtering, and presented contradictory results, regarding the way of expression of carcass characteristics.

Zebu breed has been used for creating new breeds like Siboney (5/8 H 3/8 Z) and Mambí de Cuba (3/4 H 1/4 C), mainly with dairy purposes. However, its performance in growth has been important, because this indicator is essential for future sires and direct production of male meat.

Performance of dairy cattle as meat producer was evaluated by López and Menchaca (1982) under grazing conditions and in a pilot season (concentrated),

with 190 animals of Holstein (50), 3/4 H 1/4 Z (49), 5/8 H 3/8 Z (43) and 3/4Z 1/4 H (48) genotypes. Each group was represented, at least, by four sires. Results indicated that in feeding systems based on concentrates, animals with a larger proportion of Holstein showed a superior performance. However, the best gains in grazing were found in animals with higher proportion of Zebu. The 5/8 H 3/8 Z showed a proper performance under non-irrigation grazing conditions, without differences on mean daily gains regarding 3/4 Z 1/4 H, which had the best performance of all the four compared genotypes (0.44 kg/d and 0.48 kg/d, respectively).

The 3/4 H 1/4 Z, 5/8 H 3/8 Z, 3/4 Z 1/4 H and pure Holstein genotypes were also compared with traditional diets of molasses/urea. Performance was measured through final weight, weight per age and daily mean gain (López 1985). There were significant differences among genotypes in daily gain and weight per age. The study concluded that the genotype with the best performance was 5/8 H 3/8 Z, which represents wide perspectives to be used for fattening purposes. According to reports of López and Mejías (1994), these animals need proper management and feeding systems because the growth rates obtained indicate that crossed Holstein x Zebu genotypes have high potentialities of growth.

These statements are also supported on other results, like those of Ruiz *et al.* (1991), who, in order to study meat production through dairy herd, evaluated weight at birth, perinatal and postnatal losses of meat bulls (Zebu, Charolais, Santa Gertrudis and 3/4 Limousin x 1/4 Criollo) crossed with 3/4 Holstein x 1/4 Zebu and 5/8 Holstein x 3/8 Zebu females. Paternal genotype and genetic groups differed in total mortality of rearing, pre-fattening and total. Total mortality was 4.8, 12.5, 14.9 and 9.1 % for the different hybrids, respectively.

Ruiz *et al.* (1992a) evaluated the growth performance of male and female hybrids of these breeds under commercial conditions. Hybrids of Zebu bulls, with 3/4 Holstein x 1/4 Zebu females, had 11.6 kg and 115 g/d more, for weight and daily mean gain at 120 d, without differences in periods evaluated later. At 26 months old, weight and daily mean gain up to this age favored the use of Zebu bulls as paternal genotype (Ruiz *et al.* 1992b). These males, with 3/4 Holstein x 1/4 Zebu females, reached 409 kg of liveweight and 0.48 kg/d of gains. Ruiz *et al.* (1993) also evaluated these crossings up the beginning of reproductive life, and considered that any of the evaluated genotypes was proper, if the studied meat production system is considered as a whole. These authors recommended the use of Zebu as paternal due to the superiority of growing males and the similar performance of heifers at the beginning of reproductive life. They also considered that females

reproduce under not improved conditions.

Rodríguez (2009) evaluated the performance of dairy Zebu (3/4 Zebu x 1/4 Holstein) in a rearing system of double purpose (calf lactation up to six months old).

This author showed the advantages of this system under difficult feeding and management conditions, and obtained 4 kg of milk/d, plus the rearing of a weaning calf.

GOATS

Studies related to Cuban Criolla goat have been an object of attention. This species was introduced in Cuba by colonizers, and it came from different parts of Iberian Peninsula. Ribas *et al.* (1998) carried out a first study in which they compared Cuban Criolla goat with other breeds imported at the end of the 80's (Saanen, Nubia, Toggenburg and Alpina). These authors focused on abortions, offspring per parturition, and time between parturitions in two enterprises. Nubia had the highest incidence of abortions (0.20 %), while Toggenburg had the lowest amount of offspring per parturition (1.43 kids). This last breed also had the highest time between parturitions (407.8 d). Criolla and Nubia had the lowest values for time between parturitions (357.5 and 347.9 d, respectively). The low reproductive performance of Toggenburg breed under Cuban conditions makes it to be inadequate for its use in the country. Later, Ribas *et al.* (2003b) evaluated again the reproductive performance of Criolla breed using other indicators. In this study, herd effects (4), year and bimester of parturition (6) or year and bimester of birth (5), number (4) and type of parturition (2) were considered as fitted models, according to the considered trait. This study concluded that it is necessary the conservation of this genotype because of its proper reproductive performance, resistance and use in protein production, among other productive advantages. However, low milk production indicators of these animals suggested continuing the evaluation of other goat genotypes.

The study of Ribas and Gutiérrez (2001) with Saanen,

Toggenberg, Alpina and Nubia breeds showed that Toggenburg and Saanen breeds are superior to Alpina in the monthly weighing of milk. On the other hand, it was demonstrated that milk production and lactation length of Alpina breed were 216 kg in 213 d of lactation, while that of Nubia breed were only 149 kg and 186 d, respectively. Using this information, profiles of imported genotypes were evaluated for their use in goat milk production.

Ribas *et al.* (2003b) also studied different fixed effects of mathematical model used (breed, herd, year, bimester of parturition, number of parturition and type of parturition), with variations according to traits. These authors confirmed that breed effect was important on age at first parturition and at the end of reproductive life, as well as the number of parturitions at the end of reproductive life. Nubia breed had higher number of parturitions at the end of reproductive life (2.28), and between 1.2 and 0.6 kids during the useful life, regarding the others. It also had the lowest incidence of culled animals due to food problems, and higher incidence of culled animals due to enteritis and pneumonia than the others.

Artiles (2009) analyzed the reproductive performance of different breed genotypes existing in the country. This author concluded that Nubia breed had the best productivity values, followed by Toggenburg, Saanen, La Mancha, Mestiza and Alpina breeds, respectively. Further studies are still needed in order to identify breeds and crossings that will make an integral report of the best economical benefits.

SHEEPS

Diéguez *et al.* (1973) carried out a study for knowing heritability of weight at birth in Corridale sheep, from the offspring of 55 sires, according to the method of half-brothers. Males were 0.11 kg heavier than females and the obtained h^2 was 0.11. Rico and Planas (1996) also studied this characteristic in Pelibuey crossbred sheep. These authors evaluated

the influence of different environmental factors with a mixed model, with information of 13 sires. The minimal square mean at birth was 2.3 kg, and the effects of number of parturition, type of parturition, kid sex, and year of birth were significant, although the effect of sire was not significant.

BUFFALOES

Studies on the milk production capacity of buffaloes have been carried out. Fraga *et al.* (2007a) considered the milk obtained through milking, plus that estimated from weight gain of the calf, per the milk it consumed since birth. General management was performed under grazing conditions, without

supplementation, using mechanical milking (1 per day) and support with the calf. Mathematical models of fixed effects were applied for studying the influence of parturition number, kid sex, season of parturition (July-August, September-June) and birth year. Linear and square adjustments were performed for age of

mothers at parturition in the measurements. General means obtained were gathered milk/female buffalo (820 kg), milk destined to weight gain of calves (889 kg), potential total milk (1,709 kg), weight of the calf adjusted to eight months (126 kg), gain from birth to weaning (89 kg) daily weight gain before weaning (0.368 kg). Calf sex had no influence on the studied measurements. Parturitions out of season had higher productive indicators. It was considered that, under the indicated conditions, female buffaloes (Buffalypso) had the capacity for producing milk and rearing calves.

Milk and reproductive information from a Genetic Enterprise from Havana province (Fraga *et al.* 2007b) was used for 20 years (1985-2005). Data belonged to a part of buffalo herd (Buffalypso), which was initially imported. Using the GLM of SAS, the effects of herd (4), calf sex (2), season of parturition (2), parturition number (1-10), and whether the mother was elite or not, were considered according to a previous evaluation carried out by the enterprise. The analysis of variance evidenced a significant effect of herd only for total milk and milk production/d of lactation. The best herd produced 941 kg and the worst produced 744 kg of milk per lactation. Units differed for milk per days of lactation (from 3.18 to 3.87 kg). Parturition number and herd explained the highest variability percentages of evaluated measures, according to calculated partial coefficients of determination. Female buffaloes, considered as elite, had the best percentage values for all the indicators. However, its absolute means did not reach the statistical significance, which explains the low selective pressure on this effect.

Similar indicators have been studied in other Cuba enterprises, like "Macún", from Villa Clara province, and "El Cangre", in Mayabeque, places in which projects of research and extensionism are developed. In "El Cangre" enterprise, mixed models were used (García *et al.* 2012), which considered year (7) and season (2) of parturition, herd (37), lactation number (9) and nested animal in the herd (1,377), with means of 3.4 kg of milk/d and milk yield of 860 kg at 244 d. Female buffaloes with parturitions between July and October had better productive and reproductive yield than those who did it out of this season (November-June). This was attributed to the highest food availability of grasses during this period.

Another aspect studied is lactation curves, which express the productive performance of this species, using the milk controls. Fraga *et al.* (2003), in an experimental unit with 25 female buffaloes and 28 lactation stages of 10 d each, evaluated incomplete gamma, multiple regression, square logarithmic, and hyperbolic linear functions. For each period of ten days, there was a mean, standard deviation, standard error (SE) and coefficient of variation (CV). Means of

milk production reached values between 4.87 and 1.59 kg/d, while the highest values of SE± and CV belonged to the end of lactation, as expected. The goodness of adjustment and discrimination among the used models demonstrated high adjustment in the four models, with R² over 99 %, as well for the values of R² A and Durbin-Watson test (higher than 2.09). Nevertheless, the square logarithmic expression had the highest fit values ($Y_t = 1.86 - 0.03 t + 0.0003 t^2 + 1.13 \ln t$, where $t = \text{days}$). This expression described better the milk production of female buffaloes under these rearing conditions.

García *et al.* (2013) used a production enterprise with a large amount of records of the day of the monthly control, and evaluated hyperbolic, square logarithmic, incomplete gamma, Wilmlink, linear-square segmented polynomial, square-square polynomial functions, and the linear and polynomial function with three segments through the NLIN procedure of SAS. Milk production means from the control day were between 2.15 ± 0.04 kg and 4.19 ± 0.03 kg. Production peak occurred in the second month, with 4.03 kg. The highest adjustments happened with square-logarithmic and polynomial models, with two or three square segments ($Y = 3.5281 + 0.6903X - 0.1791X^2 + 0.1818Z_1 + 0.0922Z_2$). This last one described better the shape of the mean lactation curve of the enterprise.

In Granma province, several studies were also developed with four herds from two municipalities, with the purpose of characterizing their productive and reproductive situation. Méndez and Fraga (2009, 2010), using the partial correlation coefficients, indicated that the main non genetic factors affecting the productive performance were parturition year (52.2 %) and herd (25.8 %). The remaining factors (parturition season and age at the first parturition; linear, square and cubic models) ranged between 6.9 and 3.8 %. For weight of calves at birth and at weaning, service period and time between parturitions, there were general means of 36.4 kg, 121 kg, 70 d and 392 d, respectively. The application of corrections to the general management of production units (mainly feeding) was recommended, which will allow the increase of indicators. In this same province, studies on lactation persistence (Méndez *et al.* 2013) have been carried out, with information of 500 lactations obtained between 1997 and 2005. Mixed models were applied with that purpose, which considered the female buffalo nested in the herd as random, and the correlations between lactation times were also evaluated up to 100 and from 101 to 200d. Persistency was calculated using $P1 = (M200 - M100) / L100 * 100$ and $P2 = (M200 - M100) / M200 * 100$ methods. Herd, year and season of parturition factors affected both persistency measurements and correlations between persistency and productive characters were mean

and negative. P1 method showed the best results and variability.

Likewise, studies on the weight of calves at birth were developed, and the performance of these animals under production conditions has been evaluated (Fraga *et al.* 2006). Three herds and four years of parturition were considered. Weight at birth reached 37.8 kg, as minimum square mean. Males weighted 1.3 kg more than females (38.5 vs. 37.2 kg). The highest partial coefficients of determination were reached by the unit and years of parturition (24.2 and 58.4 % respectively). However, the season of parturition did not reach the statistical significance. It is important to highlight that there was no significant linear, square or cubic

adjustment in this indicator at the age of mothers at parturition.

Mendez (2007) evaluated the productive and reproductive performance of buffaloes in Granma province (six herds). This study allowed to know what happens with this species in the Eastern region of the country. García (2011) evaluated this species in an enterprise from Mayabeque province (Western region), which also included the study of the individual and mean lactation curve. These results, together with those obtained in the central region are reference indicators on the performance of buffaloes in Cuba.

PIGS

Rico (1991) conducted population genetic studies of pigs in Cuba. This research explained most of the work carried out with this species in our country since the 70's, a period in which the national plan of genetic improvement was implemented.

Evaluation of pure breeds. Yorkshire. In order to determine differences between line, for growth and thickness of back fat, Rico and Gómez (1991) evaluated 10,340 female of Yorkshire breed, which passed the performance test in the field, between 1978 and 1985, and belonged to 18 different paternal lines. These studies confirmed differences among lines for final weight, weight per age and daily gain, with differences between the extreme values of 7.5 kg, 16 and 19 g/d, respectively, and without them for the thickness of back fat.

In Cuba, Rico *et al.* (2000a) characterized the performance of English Large White sows, with animals of both sexes in two consecutive years, using performance tests in the field, from weaning (35 d) to 7 months old. Heritability was practically zero for growth and back fat thickness traits. The performance shown by the pigs of English origin allowed to be recommended for its use in Cuban Yorkshire populations, of Canadian origin. This could have positive results in leanness, besides maintaining low levels of consanguinity of the lines that represent the basic maternal breed for genetic improvement of this population in Cuba.

Hampshire. Reproductive performance of Hampshire breed has been little studied. In spite of being globally classified as meat producer, this breed is included in most of the breeding programs carried out in the world, including the crossing program implemented in Cuba. Rico (1988) evaluated the reproductive performance of this breed and found that the numerical productivity reached during the studied period was 13.2 weaned piglets/sow/year. This study showed that the effect of parent or sire was extremely low in the evaluated traits.

Duroc. Using the information of this breed between 1965 and 1969, from three genetic centers and 54 sires, Rico and Menchaca (1975) evaluated different sources of variation in reproductive performance. These authors discussed the importance of the effect of the genetic center, as well as parity, as important factors to consider. However, the direct effect of sire for these features had little significance. Later, Rich *et al.* (1981) described the participation of Duroc breed in the pyramidal structure, using the database of a genetic center that registered information of twelve years. Reducing the lactation length, and other changes in management after weaning (which allowed to obtain higher growth rates) led to the reduction of the period between parturitions and age at first parturition, as well as the increase of the numerical productivity of herd.

Several studies have been carried out with Duroc breed, including a PhD thesis (Rico 1978). In an initial study, Rico (1981) evaluated the genetic (sire of the litter) and environmental (parturition number and seasonal period) factors that influenced on the size and weight of the litter (individual and total). The sire had almost no influence on the studied characters, and the effect of the parturition number showed a progressive increase in the size and weight of the litter until the third parturition, with a later decrease. The environmental differences between seasonal periods had highly significant effect on these characters, tending to a better performance during dry period, with respect to the rainy one. In other study, Rico and Gómez (1982a), when analyzing the reproductive performance and, particularly, the litter mortality, also showed the low influence of the sire on the evaluated traits. Results suggested that the studied sources of environmental variation also had a significant influence on the offspring mortality. In this regard, Rico *et al.* (1982) reported that production costs per pig increased in 32 cents per day of increase in the age at first parturition, and that genetic centers

of this race in Cuba should have this indicator of economic efficiency.

Rico and Gómez (1982b) also studied genetic correlations between litter size at different ages, size and weight of the litter, and litter weight and average weight. These authors confirmed that genetic correlations, among other factors, were high and positive. Values obtained suggested a higher influence of litter size on its weight, regarding the average weight of the piglets. Correlations between litter size and mortality were high and positive, and those between mortality and average weight were high and negative (superior to -0.70). This indicated that the cause of mortality in large litters is the low average weight of piglets. Another important aspect, besides the selection per litter size, is to consider the average weight of piglets as a selection criterion.

In other studies, Rico and Menchaca (1985) evaluated the environmental influences and genetic parameters of Duroc pigs from both sexes. These authors used the information of 1,497 pigs that passed the performance test between 1977 and 1982. This test included weight per age (WPA), mean daily gain (MDG), fat thickness (FT) and the selection index that combines these traits. Each day of increase on final age represented a decrease in 0.008 cm of back fat thickness. Differences between sexes was more favorable for males with 8.8 and 8.0 g/d more in weight per age and mean daily gain, and 0.6 cm less in back fat thickness. Estimates of obtained h^2 were 0.23, 0.18 and 0.40 for WPA, MDG, and FT, respectively. Results indicated the possibility of replacing the mean daily gain by the weight per age in the selection index. Rico and Menchaca (1987) reported about the environmental, phenotypic and genetic tendencies of this population on weight per age, daily gain and back fat thickness. There was a favorable genetic tendency of 8.1 g/d, 6.0 g/day and -0.12 cm for these indicators, respectively

Cuban Creole pig. Rico *et al.* (2000c) studied, in Cuban Creole breed, the indicators litter size at birth, born alive, alive piglets at 21 d and at weaning, as well as weights at birth, at 21 days and at weaning, which minimum square constants were 7.7, 7.4, 6.8 and 6.4 units and 10.7, 27.4 and 43.8 kg, respectively. Differences between sires were not significant, with low values of h^2 for these measures.

Breed comparisons. Apart from the evaluations carried out for individual breeds, several studies were conducted to compare them. Velázquez *et al.* (1972) compared the Yorkshire and Duroc breeds in molasses-rich diets in restricted amounts or *ad libitum*, from 30 to 150 kg of liveweight. These authors noted that the Duroc pigs had higher gains than Yorkshire in the restricted feeding, while the opposite occurred in *ad libitum*. Yorkshire pigs were longer than the Duroc. There were no interactions between breed and weight

Cuban Journal of Agricultural Science, Volume 49, Number 2, 2015 at slaughter (60, 90, 110 and 130 kg) in any of the evaluated traits.

Later, Diéguez and Castro (1974) compared Yorkshire, Duroc, Hampshire and Landrace breeds in traits of performance and carcass composition in castrated, non-castrated and female pigs. Females had better carcass composition than castrated males. There were breed x sex interactions in edible meat, bone, main cuts, ham and solomo as a percentage of carcass weight. These interactions were caused by the most marked differences between sexes in the Duroc breed regarding the others.

Diéguez (1974) studied the phenotypic correlations of two breeds in *ad libitum* and restricted feeding systems. This author confirmed that correlations between daily gain and conversion were high in both breeds ($r = -.84$ and $-.85$), but there was no relationship between intake and daily gain or intake and conversion. The results suggest that daily gain mainly depends on feed conversion in restricted systems, while the former seems to be based on intake, when it is provided *ad libitum*.

Rico *et al.* (1978) evaluated different crossings of Yorkshire females and Duroc, Landrace and Hampshire males, regarding pure Yorkshire. These authors confirmed significant differences between F1 and pure breed in conversion and intake, which are favorable for crossings. There were no differences in gain and weight per age. Carcasses of Duroc and Hampshire x Yorkshire crossings were better in fat thickness, and differed from the pure breed. Among the crossings, Landrace x Yorkshire had the highest weight of valuable cuts and the largest longitudes. Results justified the use of Duroc x Yorkshire and Landrace x Yorkshire crossings, and the national program of pig crossing.

Rico and Menchaca (1979) also studied the evaluation of differential performance of two breeds (Duroc and Yorkshire), with both sexes in two feeding systems (16 and 30% of final molasses), and found that there were no differences between breeds for back fat thickness. However, there were differences for the fat content in the main cuts plus panceta. Yorkshire was the leanest, besides having higher proportion of ham and tenderloin and the highest weight of main cuts regarding the Duroc. Rico and Gómez (1989) compared the productive potential of Yorkshire and Hampshire breeds, and demonstrated that Yorkshire breed is superior in growth rate and Hampshire breed is superior in back fat thickness, because the first deposited almost the double of fat per test day.

Pig crossbreeding. Rico *et al.* (1992) evaluated the performance of CC21 genotype (synthetic, created in Cuba from Yorkshire, Landrace, Duroc, Hampshire and Lacombe), regarding Yorkshire breed or Yorkshire x Landrace hybrid in indicators of growth and back fat thickness. The comparisons indicated similar behavior

of CC21 and Yorkshire x Landrace, as well as Yorkshire superiority in growth rate over CC21. Rico *et al.* (1998) compared Hampshire, Duroc and L63 x Hampshire genotypes, regarding growth and fat thickness in animals of both sexes. There was significant superiority of the hybrid in all the evaluated traits, except for mean daily gain.

Diéguez *et al.* (1993) compared gilts from different origins (crosses between boars of English origin and Cuban sows with F1 Yorkshire x Landrace gilts) with restricted feed and high levels of B molasses. There were few differences in the growth of gilts in the considered environment. Rico *et al.* 2000b carried out a similar study, but during the period of pregnancy and lactation, with non-traditional feeding

and using Yorkshire x Landrace, Yorkshire x Duroc and x Duroc and Hampshire females. These authors found a differential performance between the first two, regarding the last one, in pregnancy and lactation, although the second had some superiority in regard to the low incidence of reproductive problems.

Rico *et al.* (2000c) also evaluated prolificacy and pre-weaning growth of three female hybrid genotypes (Duroc x Hampshire, Yorkshire x Duroc and Yorkshire x Landrace) with a non-traditional feeding (system with final molasses). The first ones had inferior performance to the others. Thus, it was demonstrated that it was not necessary to establish changes in the improvement policy, established in Cuba when non-traditional diets are used.

BIRDS

Genotype-environment interaction. The interaction between genotype and environmental factors has always been an object of research in the genetic field at ICA. In the first studies, López *et al.* (1970) compared four lines of broilers with two diets based on sugar and maize, and found interactions of first order, which were significant for feeding conversion. These authors pointed out that Cornish K line was better adapted to sugar diet and, generally, the interactions were important enough to be considered in the future. Fraga and Thanh (1979) compared Cornish and Plymouth Rock barrada animals on diets that represented possible feeding systems to use in Cuba, but variable regarding their basic sources (soy bean/maize, torula 10%, final molasses 20% and rice powder 30%). There was only sex x crossing interaction for liveweight at eight weeks, without affecting the classification of both main effects. Cornish birds were the best in several productive indicators, which was according to the global tendency of broiler production.

Genetic parameters. As for the h^2 of live weight at nine weeks, Vachal (1969) confirmed that the estimated values in a line of Plymouth Rock barrada broilers were equal in both sexes (0.26 ± 0.11). Fraga *et al.* (1985) also studied factors such as parental influence, batch and sex in liveweight and breast angle, in a pure line of Cornish broilers at 42, 49 and 56 d old. These authors considered that, due to the high significance for the effects in both traits of studied ages, they should be considered in selection programs. The genetic correlations between body weight and breast angle confirmed the criterion of selecting for both characters at the age of 49 d, which represents an advance in genetic selection work.

Superior genes: naked neck (Na) and dwarfism (dw). Fraga *et al.* (1994) summarized the studies carried out with the naked neck (Na) gene and that of dwarfism (dw). This review gathered the advantages of these genes, obtained by a group of researchers that

highlighted, through genotypes developed in light and heavy strains, the advantages of these genes either alone or combined for poultry farming in the tropics. Several studies were published regarding this (Fraga 1980a; Fraga and Lam 1987, 1990, 1991; Berrío *et al.* 1987; González *et al.* 1990, 1994, 1995; Fraga *et al.* 1992; Pérez *et al.* 1992, 1993 and Fraga and Febles 2001). These studies referred to advantages associated to Na gene related to yield, noble cuts, best use of low protein diets, resistance to post-confrontation diseases (coccidiosis, Newcastle and others), lower pecking and cannibalism, less ectoparasites, heavier eggs and harder shell, among other advantages.

This theme was presented in a doctoral thesis by Fraga (1980b) about the selected broilers per liveweight, which consumed diets that did not meet the requirements of sulfur amino acids and high levels of torula yeast (low in methionine + cystine), at the same time that the Na (Na na⁺ or na+na⁺) locus alleles were segregated in the experimental population. This research demonstrated the existence of genetic variation with these diets and confirmed the function of Na gene in this adaptation process, as well as some of its productive advantages.

Regarding the dwarfism gene (dw) linked to sex, Fraga (2002) explained the importance of this gene in Cuba, particularly when these birds are raised in cages, at a rate of five instead of four, as heavier commercial birds do, with better mass conversion per cage. This author highlighted the potential interest of this gene to the unconventional family poultry rearing, due to the attention of breeders in relation to these birds.

Other birds (ducks, helmeted guineafowls and ostriches). Studies were carried out to have a population of ducks (*Cairina moschata*), which constitute an autonomous material of the country, not evaluated before and exists in family yards. Fraga *et al.* (1990) carried out studies on their performance, and informed,

for the first time in Cuba, about duck qualities and its productive interest. Pekin duck (*Anas Platirrynchus*) is the most generalized species in Cuba, but it has a less known performance. Therefore, this species was studied in aquatic habitats and in soil fattening. Fraga *et al.* (1998) provided information of this species, slaughtered at two ages (9 and 10 weeks old) and also evaluated their carcasses using 29 measures. These authors found that age at slaughter affected 21 (72 %) of the evaluated measures, while sex only affected 6 (21%) of them. Correlations between carcass measures were significant, mainly among absolute values.

In order to evaluate the performance of native genetic resources, the performance of Cuban creole helmeted guineafowl (*Numida meleagris*) was also analyzed due to its productive interest for family rearing and consumption. Fraga and Valdivié (1986, 2006) published a book on this species. Fraga and Valdivié (1997) also described the productive and reproductive performance of these helmeted guineafowls raised in Cuba, in semi-confinement paddocks. In this case, these authors studied the laying curve that was developed for 161 d with 94 eggs, 164 g of feed/egg and 78% of fertility in this rearing system (breed paddocks of one male and four

females). Fraga *et al.* (1989) presented the results of genetic parameters obtained from liveweight of these birds (raised in cages and using 22 parents) at 28, 56 and 84 d of age. These authors found that the helmeted guineafowl can be selected by the liveweight at 28 or 56 d old, considering the genetic correlations between these ages.

Few studies have been carried out on ostrich (*Struthio camelus*), although there has been advising for its reproduction and genetic improvement in basic groups of Black Neck breed, which basically reproduces in Cuba, and the management of incubation process. As for the latter, Fraga *et al.* (2002) found higher variability in egg weight than in its diameter. The highest egg diameter was slightly more variable than the lowest, and the coefficient of variation of shell area was higher than that of egg volume. Differences between extreme values were more marked in volume, weight and area of the shell of eggs, in order of importance. These authors proposed equations of square and linear regression between egg weight and the different measurements. The obtained values of r^2 were over 0.65, in order to manipulate less the eggs selected for incubation and classification. This way, their previous weighing was avoided.

RABBITS

There have been many researches aimed to evaluate rabbit breeds and different types of crossings. Ponce de León (1977) and García (2013) studied simple, triple and four-breed crossings. Besides, these authors studied the order of importance for pre-weaning traits of diallelic crossings and F1 reproducers, using California (C), Chinchilla (CH), New Zealand (N) and Semigiant (S) breeds, in three experiments for thirty years. Effects of paternal and maternal breeds, their interactions, specific crossings and differences between reciprocal pairs were estimated, as well as the general and specific combining capacities, reciprocal and maternal effects. In addition, genetic parameters of crossbreeding (heterosis, maternal additive and direct additive effects) were determined. The greater relative importance of parental*maternal breed interaction was demonstrated, regarding paternal and maternal breed. The F1 SN, CHS, CS, NS and CCH crossings were identified as the best. The estimated genetic parameters demonstrated the superiority of maternal effects in Semi-giant and New Zealand, and the

superiority of direct effects of California and Chinchilla. Three crossings coincided among the first in the orders of importance, in diallelic crosses and F1 reproducers. There were advantages in the evaluation of crossings per productivity and reproductive traits. Publications on the evidence of the best crossings, which are ratified by the current policy of the National Plan of Genetic Improvement, were available for Cuban rabbit breeders. In addition, methods for including new crossings have been proposed.

Another important study was that of Ponce de León *et al.* (1999), who described the weaning characteristics of a new synthetic breed of rabbits, called Caoba, conceived as paternal breed of the hybrid female. Also Ponce de León *et al.* (2002) studied growth and food efficiency of different rabbit breeds. These studies confirmed that Chinchilla is one of the most productive rabbit breeds in the post-weaning stage, of great interest to rabbit breeding in Cuba.

CONCLUSIONS

An outstanding work has been developed in the field of animal genetics with different species of economic interest. These researches, carried out together with other institutions, have been published in the Cuban Journal of Agricultural Science. Several

Master and Doctoral thesis have also been presented during these 50 years, since the foundation of the Instituto de Ciencia Animal. There are many other results that were not been included in this review, but equally represent important scientific results. Future

generations should use this knowledge as a tool for achieving a more efficient and productive animal production, which will represent a deserved honor

to those who have given their lives and best efforts during these fifty years.

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