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REVIEW

Blanco Orejinegro cattle (BON) a zoogenetic resource available for efficient livestock farming in Colombia

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Aditional keywords

Creole cattle.
Weight gain.
Maternal ability.
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SUMMARY

Livestock activity in Colombia is of great economic importance, but its productive indices are not optimal, due in part to the fact that most of the animals used are of foreign breeds insufficiently adapted to local environmental conditions, which prevents them from fully developing their genetic potential. This situation is favored by the adverse environmental conditions typical of the tropics, such as the high temperatures that imply situations of thermal stress, and the low quality of forages with a marked fluctuation in their nutritional content, which conditions low energy and protein levels in them. All of the above ends up generating deficiencies in the nutrients offered with respect to the requirements of the animals, which imply imbalances or negative interactions between minerals, proteins and energy, and which end up being expressed with low productive parameters. In such unfavorable conditions, the Blanco Orejinegro Cattle (BON) is one of the Creole cattle breeds of Colombia, which have naturally adapted to the environment of the area, and which is being widely used in tropical regions of America for its reproductive and productive capacity, resistance to diseases, and for its good ability expressed in crosses with specialized meat and dairy breeds. This article reviews these aspects.

Ganado Blanco Orejinegro (BON) un recurso zoogenético disponible para una ganadería eficiente en Colombia

Palabras Clave

Bovinos criollos.
Ganancia de peso.
Habilidad materna.
Lactancia.
Inmunorresistencia.

RESUMEN

La actividad ganadera en Colombia tiene gran importancia económica, pero sus índices productivos no son óptimos, debido en parte, a que la mayoría de los animales usados son de razas foráneas insuficientemente adaptadas a las condiciones ambientales locales lo cual les impide desarrollar a plenitud su potencial genético. Esta situación es favorecida por las condiciones ambientales adversas propias del trópico, tales como las altas temperaturas que implican situaciones de estrés térmico, y la baja calidad de los forrajes con una marcada fluctuación en su contenido nutricional, que condiciona bajos niveles energéticos y proteicos en los mismos. Todo lo anterior termina generando deficiencias en los nutrientes ofertados con respecto a los requerimientos de los animales, que implican desequilibrios o interacciones negativas entre los minerales, proteínas y energía, y que terminan expresándose con bajos parámetros productivos. En tales condiciones poco favorables, el ganado Blanco Orejinegro (BON), es una de las razas de bovinos criollos de Colombia, que naturalmente se han adaptado al ambiente propio de la zona, y que está siendo ampliamente utilizada en regiones tropicales de América por su capacidad reproductiva, productiva, resistencia a enfermedades, y por su buena habilidad expresada en cruces con razas cárnicas y lácteas especializadas. En este artículo se hace una revisión de dichos aspectos.

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INTRODUCTION

Livestock in Colombia contributes 1.4% of the national gross domestic product (GDP), which in turn represents 21.8% of agricultural GDP (6.9% of national GDP) and 48.7% of animal GDP, and supplies most of the domestic demand for meat and milk in the country, whose industry moves around 16.8 billion COP (4.762 million USD) per year (FEDEGAN, 2021). The Blanco Orejinegro (BON) cattle are part of the so-called Colombian creole breeds, of the *Bos taurus* species, which are descendants of taurines breeds that were brought to Colombia during colonization. They are animals adapted to the tropics, resistant to parasitosis and infections, and thanks to their reproductive capacity, and due to their good productive ability expressed in crosses with other breeds (Ramírez *et al*., 2019; Rincón and Quintero, 2015, p. 31-37), it is currently the most used; this makes it a genetic resource of great importance for livestock activity in the tropical region, for which there is commercial availability of seminal material and

embryos to expand the use of this genetic base in the current livestock production systems of the country.

Situation of the livestock sector in Colombia

More than 500,000 families are dedicated to the production of the livestock sector in Colombia, since it generates employment for 1.1 million people, which represents 6% of national employment and 19% of agricultural employment. Currently, there are 30 million hectares occupied in livestock activities, that is, 75% of the agricultural area of the country, with a carrying capacity that can vary between 0.3 and 1 animal/ha, which shows a low performance of this activity economical. Likewise, there is an inventory of 29,622,094 head of cattle (FEDEGAN, 2021), of which less than 0.1% are pure creoles and less than 1% have some degree of miscegenation (AGROSAVIA, 2019, p. 35) distributed in 632,097 productive systems where 80 to 100 national, regional and departmental guild organizations are involved. Colombian livestock supplies the domestic demand for bovine meat by 98%, that of cow milk by 95% and produces 888,000 tons of meat and 7,393 liters per year respectively; per capita consumption of milk is 156 liters per year, while that of meat is 17.1 kilos (FEDEGAN, 2021).

The national agricultural survey (ENA) recorded that in 2019 in Colombia 77.9% of the land was used in livestock activities (39,017,179 ha), while in forests, agricultural activities and other uses they represented 10.3, 9.2 and 2.6% respectively, which denotes the importance of livestock production in the country. The bovine inventory of the Orinoquia region (**Figure 1**) for this same year was the third at the national level, with 5,927,531 head of cattle, surpassing the Pacific and Amazon, in turn the department of Meta registered 2,140,194 head of cattle, that is, 7.9% of the total of the country and 36.1% of the Orinoquia; while dairy production in the region was the lowest at the national level with 772,774 liters, which represents a national share of 3.5% (DANE, 2020a).

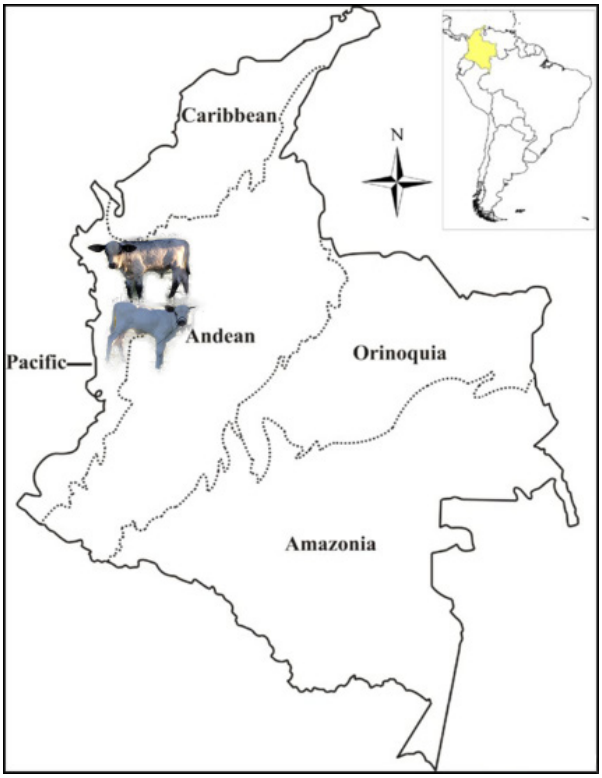

Figure 1. Natural regions of Colombia and location of the zone where the BON naturally evolved (Regiones naturales de Colombia y ubicación de la zona donde naturalmente evolucionó el BON).

Likewise, the cattle slaughter survey recorded that during the April-June 2020 quarter, the slaughter of cattle (703,734 head) decreased by 15.2% compared to the same quarter of 2019, although there were some variations within its classification, for example, the greatest increase in slaughter (24.8%) was observed in cattle destined for export, going from 25,690 to 32,058 heads. Similarly, the slaughter of calves grew 19.5%, while that of females and males decreased 22.2 and 13.1% respectively (DANE, 2020b), behavior that could possibly be influenced by the current health situation caused by SARS-CoV-2 (COVID-19).

On the other hand, in the meat industry, the products of the beef link during the 2001-2003 period were outlined as those with the greatest export vocation by presenting the highest export opening rate (18.8%); furthermore, with 52.5% they registered the highest level of participation in exports of the entire meat chain (DANE, 2020c). Likewise, dairy farming contributes 3.18% of total national employment, equivalent to 13.92% of the jobs generated by the agricultural sector. Most of the milk producers are medium and small, and combine agricultural and livestock production. In the agro-industrial activity, the dairy chain generates an annual average of 13 thousand direct jobs with an average share of 2% of total employment and 4% in industrial production (DANE, 2020d).

Although it is clear that livestock activity is of great economic importance in the country, it is not consistent with its efficiency. For example, animal production in the lowland foothills of Colombia is characterized by marked fluctuations in the quantity and quality of forages, which result in low productivity (Rincón *et al.*, 2010, p. 1-251). For this reason, the low productive parameters obtained in the breeding system whose nutritional base is *Brachiaria spp* meadows, which in most cases are in a state of degradation, are similar to those of the native savannas, with the difference that in the former, the load is 0.8 animal/ha, while in the latter it is 0.3 animal/ha. Low weaning weights (160 kg at 9 months of age) negatively influence meat production per cow exposed to bull (79.2 kg/cow/year), age at slaughter in males (39 months) and first parturition in females (60 months). The low birth rate (55%) and mortality in young people (10%) make the system inefficient (only 49.5% of live calves at weaning), and does not generate any impact on the long-awaited increase in the livestock inventory of the region and the country in general (FEDEGAN, 2014, p 1-54).

Cattle fattening is carried out in introduced *Brachiaria spp* meadows, which in most cases have been managed without fertilization during their establishment or later for their maintenance. In addition, the animal load used

has been inadequate, contributing to its degradation, which is manifested with low vigor in the regrowth of the pasture, soil compaction, and low production and nutritional quality. Consequently, the weight gain does not exceed 350 g/animal/day, the stocking density is only 0.8 animal/ha, and the age at slaughter reaches 45 months (FEDEGAN, 2006, p. 1-272). Likewise, the indicators of the dual-purpose system show how the averages of productive yields in both meat and milk are well below the production possibilities of the area.

In addition to this, bovine production is questioned because in most cases inadequate management is carried out, developing activities such as felling and burning of forests, genetic uniformity by favoring the monoculture of grasses, the desiccation of wetlands, the construction of penetration routes, the growing demand for wood for construction, the deposition of organic and inorganic waste in water and soil (Murgueitio, 2003), the emission of greenhouse gases (Carmona *et al*., 2005, p. 49-63), among other aspects, that generate a high impact of special consideration on natural resources and the environment, which can lead to natural imbalances of considerable importance (Mahecha *et al*., 2002, p. 213-225).

Against this background, works carried out by AGROSAVIA (Colombian Agricultural Research Corporation) trying to reverse this situation have shown that with annual renewal and fertilization of pastures, rotational grazing, supplementation with forage shrubs, silage, mineralized salts and performing good reproductive management, it would be possible to increase the carrying capacity above 2 animals/ha (Rincón *et al*., 2010, p. 1-251; Rincón *et al*., 2012, p. 1-164), achieve milk productions of 2,700 L/ha/lactation, and bring meat productivity to an average of 550 kg/ha/year, which shows that the potential of the area has not been fully developed.

On the other hand, the Colombian creole cattle population today is minimal compared to the large number of animals of foreign breeds such as the Brahman, despite the fact that after nearly 500 years of natural selection the former show a high degree of adaptation to the region, and to tropical environments in general, but unfortunately the genetic dilution caused by the introgression of exotic genes has contributed to the loss of such adaptation (Sánchez *et al*., 2008, p. 131-141), a situation that has already been demonstrated in bovine breeds such as N'Dama. Therefore, it is necessary to promote the use of these creole bovine breeds, to contribute to the maintenance and conservation of these local animal genetic resources.

GENERALITIES OF THE BREED

Source

The BON are descendants of the Spanish cattle brought to Latin America during the second travel of Colón (1493). These Spanish cattle were taken from Gomera (Island of the Canary archipelago) and taken to Santo Domingo, and from there they migrated to North, Central and South America, which explains the similarity of the racial characteristics of all the creole cattle of the American continent (Stonaker, 1971, p. 1-6).

Characteristics

The name of the BON breed derives from one of its main zootechnical characteristics: white fur on black skin all over the body (**Figure 2**), with the exception of the ears and the lower third of the limbs, which is black (Rincón and Quintero, 2015, p. 31-37). This cattle has its natural habitat in the foothills of the central and western mountain range (branches of the Andes mountain range), at altitudes between 800 and 1800 m, with temperatures that range between 18 and 24°C and an annual rainfall greater than 1800 mm, mainly in the coffee zone or middle zone of Colombia (**Figure 1)**, which represents 122,000 km^2 of the territory. Ecologically, it corresponds to a transitional zone between humid forest and very humid tropical forest, with quite steep, irregular and erodible topography, and soils characterized by low fertility due to its acidity, calcium and phosphorus deficiency and high iron and magnesium content. Therefore, the forages in this area are a reflection of the poor quality of the soil (Beltrán, 2012, p. 1-64). Consequently, the BON is an animal that, like other Colombian creole cattle, has naturally adapted to the environment of the tropics, showing high levels of phenotypic variability, a successful reproduction in extensive conditions despite grazing in soils with deficiencies, and therefore, grasses with insufficient usable nutritional content, and without management or sanitary practices (Sánchez *et al*., 2008, p. 131-141).

It is important to highlight that single nucleotide polymorphisms (SNP) have been identified in the breed that have been associated with weight gain characteristics such as the so-called SBTA1 related to the expression of triiodothyronine (T3), a hormone that is involved in various processes physiological including body growth and development. The genes: LNX1 which is associated with marbling, RWY1 associated with food intake, PIK3R1 associated with the production of milk, fat and protein in dairy cattle, and in Brahman cattle it is associated with the insulin-like growth factor metabolic pathway type 1 (IGF1) in turn associated with age at the onset of puberty. It was found that other SNPs and genes are related to embryonic death, and with the weight and fatty acid composition of the carcass in the breed (Londoño *et al*., 2021).

Productive parameters

Figure 2. BON heifers in grazing in conditions of the Colombian Orinoquia (Novillas BON en pastoreo en condiciones de la Orinoquia colombiana).

The BON are animals that are born with an average weight of 27.54 ± 3.72 kg (León *et al*., 2006, p. 16-24), they are weaned weighing 196.3 ± 31.4 kg at an age of 271.8 ± 13.5 days (Cañas *et al*., 2008, p. 1138-1145), give birth at first time at 1,104 ± 141 days, and the calving interval (IEP) is 487 ± 147 days, with fertility percentages that vary between 66 and 80%, values that are much higher than 52% of the national livestock average (Rocha *et al*., 2012, p. 220-228), and because the IEP is highly influenced by the environment, there are authors who for this index report between 366 and 472 days (Gutiérrez, 2003, p. 58-73).

Regarding milk production in conditions of the Colombian Orinoquia, nursing a calf and performing one milking, under rotational grazing in *Brachiaria decumbens*, *dyctioneura* and *humidicola* meadows with constant mineral supplementation, an average of 3.6 L of milk per cow with a total per lactation average of 829 L, and a maximum projected value of 1,439 L per lactation corrected to 270 days with a fat content of 4.39%, protein 3.92% and 14.08% of total solids, therefore their milk in terms of nutritional quality is much higher than that of Holstein cows (3.2 and 2.8% respectively for fat and protein) (Onofre *et al*., 2012, p. 205-210), which indicates that from this perspective the benefit of using of this breed is in the quality rather than the quantity of milk production, taking into account that lactation is carried out while delivering a wean calf of around 200 kg in weight. It is important to mention that BON cattle have a good productive capacity allowing to obtain a growth comparable to or higher than that of cattle and commercial crosses used to produce meat under tropical conditions, which allows it to be postulated as an important genetic resource to be used in the production of bovine meat (Rincón and Quintero, 2015, p. 31-37).

CHARACTERISTICS OF ADAPTATION TO THE TROPICAL ENVIRONMENT

Among the characteristics of BON that have ensured its adaptability, its docility stands out, a character influenced by the adrenal system, which is heritable and has been associated with the bovine DBH (dopamine beta hydroxylase) gene, which is located on chromosome 11 and encodes for DBH, an essential enzyme for the synthesis of dopamine; aspect that contrasts with the zebu and that turns out to be fundamental in the biological and manifest regulation of animal welfare, which directly affects the productivity of the animal, since the decrease in production related to temperament has been estimated to cause annual losses of 120 and 31 million USD in the United States and Mexico, respectively (Arredondo *et al*., 2017, p. 32-43), and taking advantage of this characteristic it has been used as a source of labor force, for loading and plowing.

These cattle have the ability to take advantage of coarse forages rich in cellulose, since they have been raised in soils that present deficient levels of some mineral elements such as phosphorus (P), copper (Cu), zinc (Zn), in such a way that the forages produced under these conditions are of low nutritional value, and despite this they have shown a great biological response that has allowed them to survive (López *et al*., 2001a, p. 121-128). BON females obtain a higher birth rate, a lower age at first service and parturition, and a greater number of days in lactation when they are supplemented with mixtures that include mineral elements that are deficient in a given region (Martínez and Ladero, 1983, p. 3-4). This ability to take advantage of coarse grasses has motivated the comparative study of the physiological and digestive capacities of BON cattle with other breeds, especially the interactions with tropical forages in good and bad quality conditions, which are closely related to the ruminal ecosystem in parameters as pH and production of volatile fatty acids (Gil and Quiroz, 1999, p. 1-87).

Several studies have shown that creole breeds, given their adaptation process to the tropical environment, have better reproductive behavior than the more recently introduced *Bos taurus* and the same *Bos indicus* (Góngora and Hernández, 2010, p. 141-151), so it is not a surprise that the fertility of BON cows turns out to be high compared to specialized dairy breeds; due to its pelvic capacity, it is easier to give birth, in addition, they have intervals between births close to 12 months and it is considered very long-lived, because they can produce young regularly up to 15 years. Likewise, cows have great maternal ability, since, during milking in the absence of the calf, the female retains up to 65% of her residual milk, ensuring the feeding of her calf. Although calves are small at birth, they are very strong and their mortality is very low (López *et al*., 2001a, p. 121-128). For their part, BON males are more precocious than females, finding an age of onset of puberty between 14 and 16 months, with weights between 206 and 234 kg, it has even been observed that BON bulls can serve a number greater number of females than Zebu and Holstein bulls (Tobón *et al*., 2012, p.75-87).

Rusticity and resistance in the breed

One of the major attributes that has contributed to the maintenance of the BON breed is the marked resistance to ectoparasites, especially to nuche (Derr *et al*., 1995, p. 307-313). It has been shown that BON show low inflammation in response to the mechanical, spoliate and inoculating action of the nuche (*Dermatobia hominis* larva), perhaps due to a set of different characteristics of this breed, such as color, length (3 -15 mm) and the fineness of the coat, the thickness of the skin (8.84 to 12.11 mm), the great pigmentation of the skin and a genetically transmitted protective humoral immunity, additionally it has been determined that the susceptibility to nuche is lower than in other creole breeds. Likewise, BON resistance to nuche has been confirmed as a hereditary trait transmitted by dominant factors, classifying it as moderately resistant compared to resistant zebu cattle and susceptible Holstein cattle (Colmenares, 1961, p. 40-73). There are also some studies that indicate resistance in the breed to tick parasites (Rocha *et al*., 2019, p. 220-228).

Resistance to viral diseases has also been demonstrated, Rodríguez and Ariza, (2006, p. 156) found evidence of natural genetic resistance to the foot-and-mouth disease virus (FMD) related to mutations in the cellular receptors (integrins) responsible for the

adhesion of the virus. Likewise, López *et al*., (2000, p. 91) in a study of *in vitro* cell cultures of BON bovines (cutaneous fibroblasts) found that 93.2% of the animals were resistant to the FA virus subtype A24 Cruzeiro and 56% to subtype O1 This, according to the authors, related to mechanisms mediated by interferon and the relative absence of the α_v-β_3 integrin. In other contributions in this regard, Ruiz *et al*., (2015, p. 1-6), also working with *in vitro* cultures of BON bovine fibroblasts infected with FMD, found that *in vitro* cells with high resistance effectively showed a low level of expression of integrin α_v-β_3, a protein that has been postulated as a cell receptor for the FMD virus, in addition, the cell culture supernatants with high antiviral activity (to control the replication of the vesicular stomatitis virus), belonged to fibroblast cultures that under *in vitro* conditions, were highly resistant to the FMD A24 subtype or highly to moderately resistant to the FMD O1 subtype. These findings show the resistance of the breed to diseases of high economic impact for livestock activity such as foot-and-mouth disease, however, it is known that it is necessary to expand research on other diseases of viral origin that affect cattle, For this reason, other *in vitro* studies have shown that in BON animals there is a phenotypic polymorphism of resistance/susceptibility against FMD and vesicular stomatitis viruses (López *et al*., 2001b, p. 280; López *et al*., 2002, p. 100-106), whose form of clinical presentation (vesicles on the tongue, nose, udder and around the crown of the hooves) can be confused with foot-and-mouth disease; possibly related to a mechanism that could be mediated by interferon, since it has an RNA as its genome, and during its replication in the cytoplasm of the infected cell it passes through double-stranded RNA, which is the major biological inducer of interferon (Fields *et al*., 1996, p. 1122-1140), although other mechanisms such as apoptosis could also be involved, since some cells infected with vesicular stomatitis virus rapidly enter apoptosis, which decreases its dissemination (Koyama *et al*., 1998, p.179-182).

On the other hand, Saldarriaga *et al*., (2020, p. 1385-1398) describing the explanatory model of growth in this breed, found that a seropositivity for bovine viral diarrhea and bovine viral leukosis has no effect on the growth parameters in BON cattle, since a viral seropositivity does not necessarily mean the development of the disease and therefore, important effects on characteristics such as those related to fertility in females and males, a decrease in milk production, a higher risk of contracting other diseases and a lower increase in weight, as has been demonstrated under different circumstances in research related to seropositivity and disease development (Yarnall and Thrusfield, 2017, p. 1-8). Additionally, it has been shown that this resistance is heritable in F1 dairy crosses with specialized European breeds (Holstein), while maintaining the high productive capacity of the latter (Cañas *et al*., 2009, p. 1138-1145).

In other contributions in this regard, Úsuga *et al*., (2018, p. 130-139) found that the molecular prevalence against bovine leukosis virus (BVL) in an evaluated herd of 124 animals was 33%, with a significant difference for the infection among the three racial groups evaluated ($p<0.05$), which were Holstein, BON and the crossing of these two, since the infection percentage was 55.9, 5 and 24% respectively for these groups, highlighting the BON x Holstein cross for presenting a reduction in the infection percentage of 32% with respect to pure Holstein, this can be attributed to the presence of resistance genes in the BON breed, such as the alleles associated with resistance to infection by the bovine leukosis virus (BoLA DRB 3.2*21, BoLA DRB 3.2*24 and BoLA DRB 3.2*37) fully identified by Hernández *et al*., (2014, p. 319-326), which is indicative of the presence of genetic factors innate to the animal that help control the infection by BVL. On the other hand, Hernández *et al*., (2011, p. 312-318) found an absence of this virus in the BON, unlike other Colombian creole breeds such as Hartón del Valle, Chino Santandereano, Velázquez, Lucerna, Casanareño, Costeño Con Cuernos and Caqueteño, and foreigners such as Holstein and Brahman, which confirms the natural resistance of BON, even above other creole breeds.

Likewise, against bacterial pathogens the BON are highlighted, in this regard Martínez *et al*., (2005, p. 333-340) genetically evaluating the resistance against brucellosis, by *in vitro* infection of bovine macrophages with *Brucella abortus* pathogenic strain Cumbal 1, determined that the breed can be classified as resistant since in these animals there seems to be a greater capacity to control intraphagosomal bacterial replication; additionally, this natural resistance against *B. abortus* in bovines is heritable and its frequency can be increased in one generation of selection, an important aspect to take into account to include reproducers of this breed in bovine herds. In this same sense, Cerquera *et al*., (2009, p. 43-50) also found genetic evidence of the particular resistance of the breed to infection, since these animals present a high frequency of the homozygous genotype BB, of the Nramp1 gene, which in various mammals is related to susceptibility and/or resistance to this intracellular pathogen (*Brucella abortus*), as well as others such as *Mycobacterium bovis*, *Mycobacterium paratuberculosis*, *Salmonella enterica* and *Leishmania donovani* (Bellamy, 1999, p. 23-27; Vidal *et al*., 1995, p. 382-390).

The foregoing is indicative that the use of creole breeds such as BON in specialized dairy herds can improve their health, reduce susceptibility to infection, reduce the discard of positive animals and the costs of using diagnostic tests and medications for the treatment of secondary infections (Úsuga *et al*., 2018, p. 130-139).

Last but not least, high temperatures and variations in the relative humidity of the environment, in situations such as those that occur in the lower Colombian tropics, exceed the ability of the normal mechanisms of animals to dissipate the heat generated, causing stress conditions that affect their physiology and homeostasis, and their reproduction, and although the economic losses due to this cause have not been quantified, it is known that follicular development, heat, implantation, early embryonic development, gestation, childbirth and return to heat during the postpartum among other aspects are altered (Góngora and Hernández, 2010, p. 141-151), conditions against which BON cattle have shown greater tolerance and therefore less heat

stress (Regino and Rodríguez, 2019, p. 68), in fact, various genes expressed in the breed have been found responsible for the codification of this adaptability to the tropical environment, for which the BON has a high coefficient of tolerance to heat, thanks to the gene for short hair (slick) present in the breed, and its pigmented dermis, which allows them to be exposed for several hours to the sun without having thermoregulation problems or thermal stress (Silva, 2018, p. 1-104), capacity that may even be higher than that of other creole bovine breeds, this related to a greater number of genomic areas responsible for the expression of factors that influence said index (De León *et al*., 2019, p. 1-13), and in turn with the deposition of intramuscular fat (marbling) and milk fat content, since they present the desirable genotype for the variant of the DGAT1 gene (Martínez *et al*., 2012a, p. 36-45) related to such factors.

BON VS. OTHER COLOMBIAN CREOLE BREEDS

Within the creole cattle of Colombia, currently the BON is the breed with the most abundant population, around 8,000 specimens (Ocampo *et al*., 2020, p. 69-77), and comparatively with Romosinuano for example, Martínez *et al*., (2012a, p. 36-45), under grazing conditions in the Colombian tropics, observed a higher consumption and better productive performance, reaching a slaughter weight in less time and consequently a greater gain (650-833 vs 499-711 g/day). The bulls considered superior, in the performance test presented weight gain values greater than 1,000 g/animal/day in BON, while in Romosinuano they reached 890 g/animal/day; in fact, these high weight gains are not surprising, since, depending on the handling, feeding and climatic season, BON bulls can show weight gain peaks of up to 1,392 g/day (Quiceno *et al*., 2012, p. 2891-2899).

BON and Sanmartinero are those with the greatest genetic variability within all Colombian creole breeds (Moreno *et al*., 2001, p. 17-23), even when comparing BON with other populations of creole cattle in South America, it stands out for its greater allelic richness, which confers great potential for the selection of individuals with superior genetics (Leal *et al*., 2014, p. 409-418). Likewise, the BON presents a lower percentage of inbreeding compared to the rest of Colombian creole bovine breeds (Martínez *et al*., 2008, p. 545-552), and likewise the trend of direct genetic values for weaning weight in the breed shows genetic progress (annual increase of 263 g/year), higher than that observed in Romosinuano and Sanmartinero (116.4 and 113 g/year respectively) (Martínez *et al*., 2009, p. 196-204), ratifying once again, the genetic-productive potential of BON (Martínez *et al*., 2014, p. 6420-6432; Martínez *et al*., 2016, p. 1-16).

On the other hand, Campos *et al*., (2004, p. 32-41) evaluating the metabolic profile of cows found higher glycemic levels in BON (3.16 ± 0.47 mmol/L) than in the Casanareño, Chino Santandereano, Costeño Con Cuernos, Hartón del Valle breeds, Lucerna, Romosinuano and Sanmartinero, an aspect that is possibly related to their milk capacity.

The average generational interval in the BON breed (4.59 years) (Ocampo *et al*., 2020, p. 69-77) is lower than that found for other Colombian creole breeds such as Sanmartinero, Romosinuano and Costeño Con Cuernos of 6.7, 5.7 and 5.4 years, respectively (Martínez *et al*., 2012b, p. 1-214), and it is even lower than that found in zebu breeds such as Brahman, Guzerá, Nellore and Gyr in which they range between 6.95 and 8.93 years (Ocampo *et al*., 2020, p. 69-77) which may be an indication of their high precocity.

Regarding studies at the molecular level, it is known that the alleles of genes that are physically close on a chromosome are inherited in an interconnected way, and these are not transmitted to the offspring independently, but as blocks of alleles or haplotypes provided by each parent (Pérez *et al*., 2014, p. 1-14); this condition creates a level of correlation between alleles known as linkage disequilibrium (LD), and this concept can be extended to any nucleotide in the genome, as well as to any type of genetic molecular marker, such as SNP. In the creole breeds BON and Romosinuano, Bejarano *et al*., (2018, p. 426-433) found a high proportion of SNP (45%) with high values of minor allele frequencies (0.3), which may be related to high levels of LD found in these populations. It is noteworthy that these values are higher than those reported in other taurine breeds and reach optimal levels of LD (r2 0.3) at a distance of up to 70 kb for the BON breed and 100 kb for Romosinuano, which is possibly associated with its condition of closed population, which has a small effective population size and is subject to a limited occurrence of recent events of genetic introgression. In this same sense, but at the reproductive level, Sánchez *et al*., (2006, p. 75-85) by identifying the t(1; 29) chromosome using the chromosomal banding technique found animals carrying the Robertsonian translocation (1:29) in Casanareño, Chino Santandereano and Romosinuano breeds, while BON stood out for the absence of this relatively frequent genetic disorder in cattle, which does not produce any phenotypic alteration, and which is related to subfertility problems due to the production of non-functional gametes and increased embryonic mortality.

On the other hand, Rocha *et al.*, (2019, p. 1-11), characterizing the tick load in four Colombian bovine breeds and relating it to heat stress in tropical conditions, found that the parasite load is higher in cattle with less adaptability to the heat stress and therefore it is highly affected ($p<0.01$) by the genetic traits of adaptation in the breeds, for which they observed that the tick load was lower in BON compared to Costeño Con Cuernos and Sanmartinero.

PERFORMANCE IN CROSSINGS WITH SPECIALIZED BREEDS

With the first crosses of zebu breeds (*Bos indicus*-Brahman) by creole, a type of animal superior to its parents was obtained (**Figure 3**), but unfortunately the greater productive potential expressed in the first generations of these crosses was exclusively attributed to the zebu and for this reason an absorbent crossing began, especially towards Brahman, which resulted in the near extinction of creole cattle and a decrease in milk produc-

tion and rusticity, as the *indicus* percentage increased in the crossing. Nowadays, the productive and reproductive capacity of the half-blood animal (F1), product of the crossing of creole cattle with specialized breeds, either meat or milk, is widely demonstrated, since this F1 has a great hybrid vigor, due to the fact that when the parents are of different breeds, it is more likely that the two genes for a certain characteristic are different, which increases the opportunities of the individual to face the different environmental circumstances that cover them in their embryonic, fetal and post-natal development; this explains the better performance in characteristics related to adaptation, fertility, survival, milk production and weight gain that is observed in these crossed animals (Cerón *et al*., 2009, p. 371-381), since they are favored by the adaptability and resistance of the creole cattle added to the high production of specialized cattle (Medina, 2005, p. 581-588).

Regarding the productive performance Madrigal *et al*., (1998, p. 72-80) found a lower mortality ($p<0.05$) in BON x zebu calves (5.4%) than in commercial zebu calves (19.6%) at 240 days of lactation on average, whose main cause was the weakness of the calf, demonstrating the rusticity and adaptation of the BON cattle. Argüello *et al*., (2020, p. 48-59) in heifers of 15.81 ± 2.05 months and 183.95 ± 33.45 kg of weight, also BON x zebu, in silvopastoral system of *Tithonia diversifolia* and *Urochloa brizantha* cv. Toledo associated with *Urochloa humidicola* found weight gains of 0.743 ± 0.37 kg/animal/day in the department of Antioquia, while in conditions of foot of mount of Orinoquia, Velásquez and Navas, (2021, p. 67-76) reported weight gains in Brahman x BON steers of 625 ± 35 g/day during the rainy season.

In this same sense, the benefits of BON have also been evident in crosses with specialized milk breeds, since milk production increases due to the better adaptation of F1 to the environment, although as the proportion of dairy genes increases the resistance of the animals to the conditions of the hot and humid climates of the tropics decreases, due to the difficulty of adaptation, evidenced by the low tolerance to heat (López *et al*., 2001a, p. 121-128). In this way, in crosses with the Holstein breed, among many other benefits, the prevalence of clinical mastitis is reduced proportionally to the percentage of BON blood, since the latter provides a protective genetic factor (Vidales *et al*., 2017, p. 23-30), which is favorable both health and economic, since bovine mastitis is considered the most expensive disease in the dairy industry, its negative effect being due to the decrease in milk production, the alteration in the quality of milk, treatment costs and risks to human health (Trujillo *et al*., 2011, p. 11-18). Additionally, the interval between parturitions presents better indices in favor of the BON x Holstein cross with respect to pure Holstein due to the high fertility provided by creole cattle and the adaptation of this type of animals to tropical conditions (Cañas *et al*., 2009, p. 35-42).

Finally, from the genetic point of view, Cerón *et al*., (2009, p. 371-381) carrying out studies in cattle crossed of BON and Romosinuano with Angus and Cebu, found 4 alleles for the SNP BM1500, 14 for WD and the 3 genotypes for the SNP of the gene. leptin (CC, CT, TT), they also found an association of the TT genotype with greater thickness of hip fat and greater weight at one year of age, and the allele 183 of the microsatellite WD with greater weight between 18 and 24 months ($p<0.05$), which have their maximum expression in certain stages

Figure. 3. Trihybrid calves: 50% BON, 25% Charolais and 25% Brahman (2-5 months old) in grazing conditions in the Colombian Orinoquia (Terneros trihíbridos: BON 50%, 25% Charolais y 25% Brahman (2-5 meses de edad) en condiciones de pastoreo en la Orinoquia).

of development of the animal, and that ratify the benefits of the crosses of specialized breeds with creole cattle such as the BON.

CONCLUSION

Bovine livestock in Colombia faces production efficiency problems related to adverse environmental conditions such as the low quality of forages used as the basis of the animals' diet, added to the lack of high-value nutritional sources that can replace the deficiencies that occur in such a situation and that lead to imbalances or negative interactions between nutrients, circumstances before which, the animals of the Colombian creole breeds such as the BON, which have naturally adapted to the tropical environment, show successful reproduction despite these adversities, therefore, they should be the genetic base of the livestock of the country, since the reproductive component represents a determining factor in production costs and in turn, in the same economic profitability of the livestock company, because it depends mainly on the period of female reproduction.

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