ORIGINAL ARTICLE

Evaluation of Biols in Star Grass (*Cynodon nlemfluensis*) for the Livestock Subsector. Fusagasugá-Colombia Case

https://cu-id.com/2177/v31n4e02

Evaluación de bioles en pasto estrella (*Cynodon nlemfluensis*), para el subsector ganadero. Caso Fusagasugá-Colombia

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ABSTRACT: In order to evaluate the nutritional contribution of two types of biols (from the biodigestion of excreta from pig and bovine animal production systems in their liquid fraction) in three concentrations 50, 75 and 100 % (V/V) to grasses of Bermudagrass *(Cynodon nlemfluensis)* in the city of Fusagasugá, Colombia. The zootechnical variables of interest considered in the analysis were crude protein (CP%), Net Energy of Lactation NEL, NDF, ADF (%) and green forage production GF (kg/m^2). The results were analyzed by applying the RGB Algorithm of the TaurusWebs® Software to establish the level of significance, the free statistical software InfoStat was used through the Duncan Multiple Range Test. According to the results obtained, the contribution of bioles to the improvement in the parameters evaluated and their contribution to the circular economy of the Bovine Production Systems of the Municipality of Fusagasugá is evident.

Keywords: biols, evaluate, nutrition, Cynodon nlemfluensis.

RESUMEN: Con el objetivo de evaluar el aporte nutricional de dos tipos de bioles (procedentes de la biodigestión de excretas de sistemas de producción animal porcino y bovino en su fracción líquida) en tres concentraciones 50, 75 y 100 %(V/V) a pasturas de *estrella (Cynodon nlemfluensis)* en el Municipio de Fusagasugá-Colombia. Las variables de interés zootécnico contempladas en el análisis fueron proteína cruda (%PC), Energía Neta de Lactancia ENL (Mjul), FDN (%), FDA (%) y productividad de forraje verde FV (kg/m^2). Los resultados se analizaron mediante la aplicación del Algoritmo RGB del Software TaurusWebs® para establecer el nivel de significancia se utilizó el software estadístico libre InfoStat mediante la prueba de medias de Duncan. De acuerdo con los resultados obtenidos se hace evidente el aporte de los bioles al mejoramiento en los parámetros evaluados y la contribución de los mismos a la economía circular de los Sistemas de Producción Bovina del Municipio de Fusagasugá.

Palabras clave **:** biodigestión, producción animal, nutrición, Cynodon nlemfluensis.

INTRODUCTION

According to FAO (2022), the global demand and production of livestock products are increasing rapidly, due to population growth, rising incomes, and changes in lifestyle and diets. At the same time, livestock systems have a significant impact on the environment, including air, land, soil, water and biodiversity. This growth of the sector needs to be addressed in the context of finite natural resources, contribution to long-term livelihoods and food security, and responses to climate change.

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Received: 09/05/2022
Accepted: 14/09/2022

The large amounts of biodegradable waste produced by intensive livestock production systems can have a negative impact on the environment, if not properly managed according to Alburquerque *et al.* (2012); likewise, intensive agriculture has promoted soil degradation and loss of organic matter and fertility, increased production costs (to maintain productivity) and contributed to CO2 emissions (European Environment Agency, 2009). According to FAO (2022), agriculture, livestock and deforestation generate a third of greenhouse gases worldwide. Much of these emissions derive from the fermentation of manure and the use of fertilizers.

As an alternative to the negative impacts that livestock farming has on the environment, alternatives are required that aim to achieve the Sustainable Development Goals (SDG), especially Goal 7-Renewable and Non-polluting Energy; 11-Sustainable Cities and Communities and 13-Climate Action. That is why biodigesters appear as a viable alternative since they allow biogas to be produced in livestock production systems, which can be used as fuel, minimizing the use of non-renewable fuels within them. With the biodigestion of organic waste that, in a systemic and sustainable conception, would cease to be a waste and would feed back into the system in the form of fertilizer, both in its liquid and solid fractions. With the technological adoption of biodigesters, sustainable development is promoted, avoiding the emission of greenhouse gases (biodigesters reduce the emission of methane into the atmosphere); on the other hand, the use of this technology allows improving sanitary conditions, by avoiding bad odors, insects and control microorganisms capable of generating diseases.

Within the energy production carried out in biodigestion and the conversion of methane gas into energy, it can be obtained, as in the case of this project, that from the excreta coming from pig and bovine production systems, bioliquids are generated in the biodigestion process, which can be used as a source of nutrients for different crops, a fact that constitutes an important contribution in the generation of alternative value to the initial idea that is, energy generation.

The biodigestate is a product obtained by the process of consumption of organic matter by the bacteria present in the anaerobic biodigester; this favors lower odor emissions due to the degradation of volatile organic compounds, a higher concentration of rapidly assimilated nitrogen. This complex of easily assimilated nutrients favors, in addition to plants, the micro and macrobiota of the soil. In studies by Aparcana 82005) and Siura (2008) the presence of phytoregulators is related: indole acetic acid, gibberellins, purines, thiamin (Vit B1), riboflavin (Vit B2), folic acid, pantothenic acid, tryptophan, cyanocobalamin (Vit B12), pyridoxine (Vit B6)

This is how biodigestates, when used in livestock production systems, also contribute to the SDGs, in reducing poverty (the purchase of fossil fuels and chemically synthesized fertilizers is reduced and generates new economic income) and hunger; since they point to food security, increased harvest and soil remediation in coherence with the paradigm of Sustainable Development and with the concept of Circular Economy.

The European Parlament (2021) defines the Circular Economy in the following terms: "The circular economy is a model of production and consumption that involves sharing, renting, reusing, repairing, renewing and recycling existing materials and products as many times as possible to create added value. In this way, the life cycle of the products is extended"

The circular economy is a model of production and consumption that contemplates feedback from a systemic approach as an essential component to guarantee sustainable and multidimensional growth. With the circular economy, a correct optimization of resources originates, the reduction in the consumption of raw materials and the use of waste, as is the case of products obtained from biodigestion, recycling them or giving them a new life to turn them into new products, in this case, organic fertilizers for the improvement of meadows.

As stated by Zacarías (2018) in the UN, in practice, the circular economy is achieved through repairing, recycling, reusing and remanufacturing of products, something not as new as it seems, "What was a contaminant waste and went to the drains, now it is collected and is an input for another production process and thus the cycles begin to close".

In the star grass meadows (*Cynodon nlemfluensis*) implemented in the Municipality of Fusagasugá, variability is generated both in yield and forage composition, which is reflected in its consumption and digestibility. It is undeniable that the yield, botanical composition and forage quality have a direct relationship with the integrated management of the meadow, the technological level of the system, the periodicity and moment in which it is consumed, which limits the technical and financial results for cattle production.

According to Castro *et al.* (2017)), the effect of cutting on the forage plant depends on the amount and type of tissue removed, its phenological state and meteorological conditions at the time of obtaining the green material. In addition, the intensity and frequency of cutting that affects the growth rate of the forage, and its nutritional accumulation, depend on the duration of regrowth.

For this reason, it is essential for bovine production systems to have complementary tools that provide information in real time for decision making, while laboratory analyzes by their nature are delayed.

The technology of the RGB image analysis algorithm for calculating the %PC consists of a statistical and mathematical process, carried out on the images of the meadows (taken by a drone with an HD camera), which identifies the wavelengths captured by photosynthesis of the pastures. From these, the solar energy that enters the plant is calculated and the %CP that the grass would be able to synthesize is estimated. These results would be comparable with those generated by methodologies such as near infrared spectroscopy technology - NIRS (Molano *et al.*, 2016).

Nutritional requirements of star grass (*Cynodon nlemfluensis*): For Martínez (2019), this grass of tropical development and commonly used as grazing forage, requires soils with a high degree of fertilization and responds very well to the addition of nitrogen sources, especially in wet conditions. It has been reported by the same author, as recommendations for fertilization/hectare: N: 70 kilograms, K2O: 24 kilograms, P2O5: 57.25 kilograms, SO4: 59.8 kilograms and MgO: 33 kilograms.

Cynodon grass species have a C4 photosynthetic metabolism, so they can accumulate more dry matter in relation to C3 grasses, they are widely cultivated in tropical and subtropical zones, and respond to nitrogen fertilization to increase yield and nutritional quality (Yong *et al.*, 2012).

According to Del Pozo *et al.* (2002) studies reveal that nitrogenous compounds greatly influence the metabolic activity and quality of pastures, contributing to morphological traits that increase profits in the use of pastures for cattle. Complementing this information, investigations in star grass (*Cynodon nlemfuensis*) with the application of nitrogenous compounds, show that there is an increase in the formation and functioning of its structures.

In studies carried out in tropical and subtropical zones, it has been found that star grass has good potential for growth, yield and nutritional quality for dairy production, by managing adequate days of rotation and recovery in conjunction with fertilization, to optimize its yield, quality and persistence. Vendramini *et al.* (2010); Pineda *et al.* (2016); Arteaga *et al.* (2019), report for star grass, values of 71.7% and 40.5% for FND and FDA, respectively.

MATERIALS AND METHODS

Location

The experiment was carried out between October and December 2021, at La Esperanza Agro-Environmental Unit, of the University of Cundinamarca; which is located in the municipality of Fusagasugá-Colombia, Guavio Bajo village, at coordinates (4.276072N; -74.386612W), at an altitude of 1,530 meters above sea level.

The study area in the cultivation of star grass (*Cynodon nlefuensis*) was 480 m^2 and plots of 6 m^2 per treatment were proposed, distributed for four types of biols (three from pigs and one from bovine), all coming from different animal production systems. (Santa Barbara-pig, La Saucita-pig, La Plateau-bovine, El Mirador-pig). Each biol was subjected to concentrations of 25, 50 and 75% (V/V), with two applications (15 and 30 days post-grazing) as shown in Table 1. The incorporation of the biol in the plots was carried out by Sprinkling with a 20 L backpack pump, graduated with a solid cone nozzle to reach humidity in the entire developed foliar area of the forage, applying 1.5 L/m^2. To avoid the edge effect, a strip of the same size as the plots was left between each treatment.

The biols were obtained from biodigester schemes aimed at obtaining gas as an alternative energy through the Call 829 Project "Strategic innovation for the sustainable energy-productive use of agricultural waste in the generation and use of renewable energy in the rural area of Fusagasugá" financed by the Ministry of Science, Technology and Innovation of Colombia and executed by the University of Cundinamarca-Colombia and the Agrarian University of Havana-Cuba.

After completing 40 days of recovery of the meadow, aerial images were taken through a DJISpark drone and a 12Mpx HD camera, at a height of 15 m to be processed through the TaurusWebs® V20121 Software, which has an RGB Image Analysis algorithm (Red-green-Blue) named -AAIRGB-. This software, by analyzing the wavelengths of the digital image, generated algorithmic spectra, in which it is represented with scales of Crude Protein (% PC), Net Energy of Lactation (ENL), Neutral Detergent Fiber (NDF) and Acid Detergent Fiber (FDA), which has the prairie, in this case star grass, based on dry matter. It should be clarified that this analysis system is capable of identifying inert objects, soil and light from the sky and has achieved 93% accuracy in its calibration compared to reference laboratories through the use of NIRS technology (Ospina *et al.*, 2020).

Consistent with the above, the present experiment contemplates the variables: PC (%), ENL (Mjul), FDN (%), FDA (%) and Green forage production (kg/m2). Each experimental area or plot was subjected to several spectral detections through the Software, on the same image; achieving at the end, minimum 7 repetitions of analysis/variable/plot.

To obtain the basis for analysis and statistical decision, a two-way experimental model was carried out using the InfoStat free software, assuming the systems (type of biol) as a condition and the concentration percentages as treatments. Duncan's Multiple Ranges posthoc test was applied to the ANAVA result for averages and, in order to determine differences between biol of pigs with bovines and

these with the control, analyzes by contrasts were assumed.

Comparison Information

In addition to the comparison of the treatments in the results of the nutritional composition of the forage, the result of the soil analysis prior to the experiment (Table 2 and Table 3) was used as a reference indicator for the entire experiment.

These preliminary analyzes allow inferring, under the Soil-Plant-Animal systemic approach, that the star grass pasture (*Cynodon nlemfluensis*) of the present investigation has low nutrient contents in terms of nitrogen N and phosphorus P, essential elements in protein synthesis. Therefore, an addition of these minerals through the use of biols would contribute to the improvement of the bromatological characteristics and nutritional content of the forage to be offered to cattle.

RESULTS AND DISCUSSION

As a result of the study of effects by productive system from which the biol was taken (type of biol) and its concentrations (0, 25, 50 and 75% V/V), it was

TABLE 1. Distribution of treatments, taking into account the type of biol and application concentration

Type of biol	System name	Concentration (%V/V)
Porcine	Santa Barbara	25 50 75
Porcine	La Saucita	25 50 75
Bovine	La Meseta	25 50 75
Porcine	El Mirador	25 50 75
Control		0

TABLE 2. Result of soil analysis of plot N.13 - La Esperanza Agro-Environmental Unit - University of Cundinamarca

Nutrients	Measurement parameter	Measurement	Interpretation
Potassium	meq/100	0,35	Medium
Calcium	meq/100	4,17	Medium
Magnesium	meq/100	1,44	Medium
Sodium	meq/L	1,18	Medium
Aluminum	meq/100	N.A.	--
C.I.C.	meq/100	20,31	High
Phosphorus	Ppm	13	Deficient
N-NH4	Ppm	5	Deficient
N-NO3	Ppm	5	Deficient
Sulfur	Ppm	2	Deficient
Iron	Ppm	1615	High
Manganese	Ppm	25	Medium
Copper	Ppm	0,60	Medium
Zinc	Ppm	11,80	High
Boron	Ppm	0,29	Medium

TABLE 3. Physicochemical characteristics of the soil of plot N.13 - La Esperanza Agro-Environmental Unit - University of Cundinamarca

Property	Measurement parameter	Measurement	Interpretation
pH	%	5,99	Medium
EC.	%	0,23	Bass
Sand	%	1	
Silt	%	81	
Clay	%	18	
Texture		Silt-Loam	
Organic M.	%	5,09	
CO.	%	2,95	Bass
Sat Humidity	%	52	High
Sat Bases	%	30,40	
Density app.	g/cc	1,01	

TABLE 4. Determination of effects by type of biol and application concentration

Variable	R^2 of the model	CV (%) of the model	Productive system	Treatment
PC (%)	0,67	8,25	P<0,01	P<0,01
ENL (MJul)	0,67	2,53	P<0,01	P<0,01
FDN (%)	0,67	1,66	P<0,01	P<0,01
FDA (%)	0,67	2,05	P<0,01	P<0,01
FV (Kg/m^2)	0,85	14,5	P<0,01	P<0.01

P<0,01 indicates highly significant differences (**).

determined through the two-way analysis of variance that for all the variables (PC, ENL, FDN, FDA and green forage production), at least one of the biols and one of the concentrations generate highly significant differences (P<0.01), as it can be seen in Table 4. This allows deducing that the type of biol has a different composition of nutritional or mineral contributions and therefore, its effect causes variation in the conditions of PV production (kg/m2) and nutritional composition of the forage.

Analysis of Crude Protein (%) in the Forage

According to INTAGRI-México (2018), the crude protein of forages is divided into true protein and non-protein nitrogen (NNP); the true protein of the forages constitutes 60% to 80% of the total nitrogen, the rest is made up of the soluble NNP and small amounts of lignified nitrogen. Crude protein is one of the most variable components in pastures, the factors that affect the nutritional value will notoriously modify the protein content. Leaf proteins are mainly concentrated in chloroplasts, in turn 40% of these chloroplast proteins are mostly made up of fraction 1 or ribulose 1-5 diphosphate carboxylase. Non-protein constituents represent 20 to 35% of the total nitrogen.

From the result of the Multiple Range test by Duncan, it is determined that the farms "Santa Barbara" and "La Saucita" with pig production, have biol with statistically equal effects on the percentage of protein (P>0.05). Up to this criterion, it cannot be affirmed that this effect corresponds to the biol derived from pig production, because in "El Mirador" farm, with the same animal species, highly significant differences are obtained (P<0.01), as with the control treatment. In addition, it is the fact that the biol from “La plateau” farm, that comes from bovine production, is statistically different from the others and a level of 10.5% protein is reported for the use of this biol (Figure 1a). Thus, it can be determined that the differences by type of biol really depend more on the productive conditions, the feeding scheme the animals receive, raw materials used and the differences that may occur in the mechanism and fermentation process to obtain the biol. This argument agrees with what was stated by Bernal *et al.* (2022), who affirm that each Biol is "unique" since the conditions of a production system are very particular

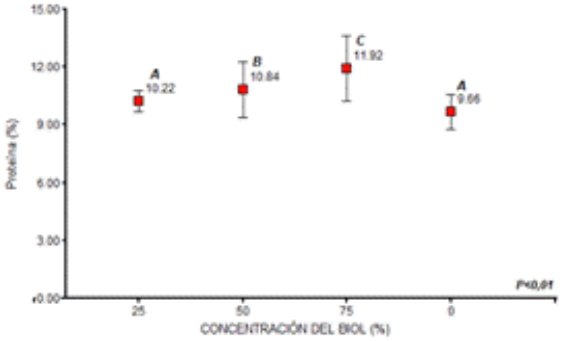

FIGURE 1A. pc levels by type of biol.

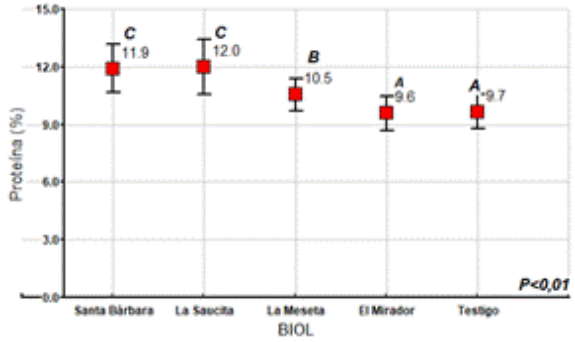

FIGURE 1b. CP levels by biol concentration.

and dependent on different productive economic aspects, therefore, it can have different food sources over time.

In the same analysis, but comparing by percentage of biol concentration, it is determined that the control plot and those that contemplate 25% inclusion of biol, are statistically equal (P>0.05) and from there, as represented in Figure 1b, as the concentration of the biol is increased, the formation of protein in the forage would be significantly increased (P<0.01).

Forage Energy analysis

The behavior of energy in the forage through Duncan's analysis was similar to that determined in protein (%), where the control group is statistically equal (P>0.05) to that from pigs (El Mirador), but this last farm has differences with other biols from the same species and with the biol from bovines (P<0.01), as it can be detailed in Figure 2. This corroborates the importance of taking into account, in addition to the animal species that provides the organic material to be

fermented, other aspects that influence the nutritional contributions that bioles can make. The energy behavior is also similar to that of protein, when the effects by biol concentration are analyzed, determining that when exceeding 50% biol inclusion, highly significant differences (P<0.01) are reached for energy production in the forage (Figure 2b).

Analysis of FDN and FDA in Forage

Fiber analyses (FDN and FDA) that denote the nutritional content of the forage, are contrary to the protein and energy behaviors described so far. It has been determined that the types of biol with the highest level of protein and energy are the ones that show the lowest percentage of NDF and FDA, as shown in Figure 3a, maintaining statistical equality between the control group and the porcine biol of "El Mirador" and highly significant differences between the other types of biol (P<0.01).

Regarding the concentrations of biol (%V/V), the lowest production of fiber (FDN and FDA) is found for 75%, with significant differences over the other dilutions. It confirms, that the increase in the amount of biol, has an effect on the nutritional composition of the forage, favoring greatly the formation of structures of greater use and limiting the conformation of structural carbohydrates. This corroborates what was proposed Aparcana (2005); Siura (2008), who indicate that the use of biol occurs mainly as a promoter and strengthener of the growth of the plant, roots and fruits, thanks to the production of plant hormones and that Bernal *et al.* (2022), assume it as a biofertilization alternative, because in its composition, elements (macro and microelements) have valuable contributions to the soil and plants, with the possibility of even providing hormones (auxins) that help in the recovery of plant tissues after grazing and green forage production; constituting it then, in an opportunity of sustainability with a high degree of benefit, contributing to the soil and to the crop (in the case of meadow).

Green Forage Production Analysis (kg/m2)

As an indicator of the effectiveness of the process, the green forage production variable (kg/m2) is analyzed, obtaining within the indicators to be highlighted (Figure 4a) that, the pig biol from "La Saucita" system and bovine biol from "El mirador" system are statistically equal (P>0.05) and among the other production systems there are highly significant differences (P<0.01). In the same way, in concentration percentages, significant differences were found in each group (P<0.01), being the control, the one with the lowest production and increasing as the biol concentration increased (Figure 4b). According to these results and their significant differences, it is corroborated that biol as an organic

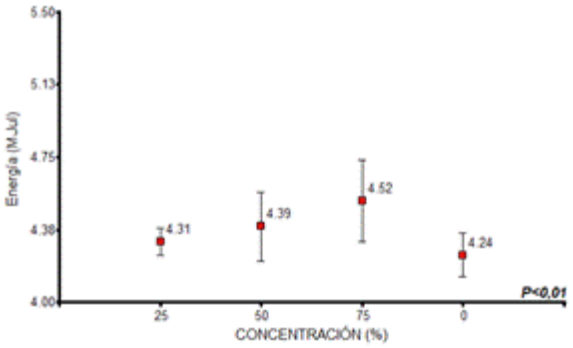

FIGURE 2a. ENL levels per type of biol.

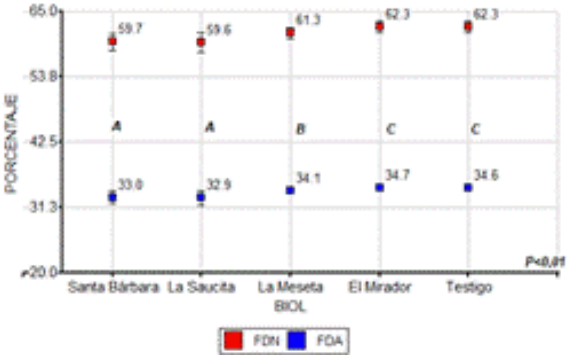

FIGURE 2b. ENL levels per biol concentration.

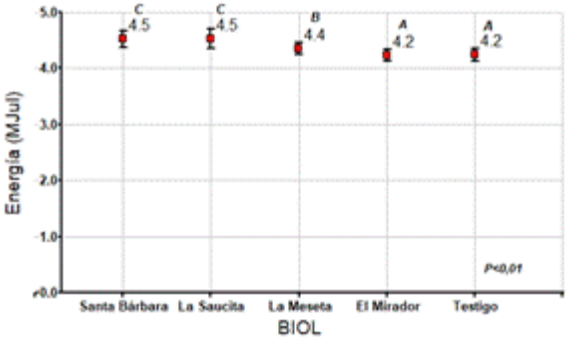

FIGURE 3a. FDN and FDA levels per type of biol.

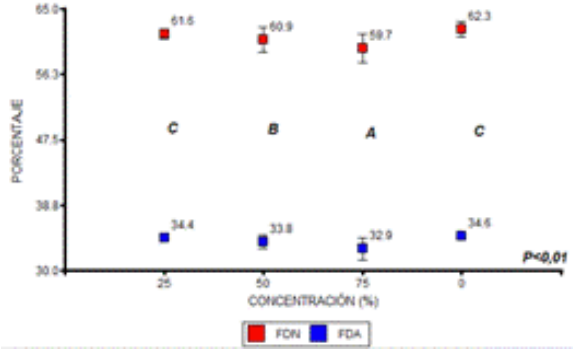

FIGURE 3b. FDN and FDA levels per biol concentration

fertilizer has a positive effect on the production of green forage (quantity), in the case of star grass (*Cynodon nlemfuensis*), derived from the opportunity

of contributing nutrients, minerals and hormones that intervene favorably in the production of green biomass, as stated by Aparcana (2005); Siura (2008) and Bernal *et al.* (2022).

Contrast Effects

When analyzing the information through data groups (contrasts) as shown in Table 5, it was determined:

1. The species that originates the organic material from which the biol came from (porcine and bovine), causes highly significant differences (P<0.01) for all the variables measured in the study.
2. The biols derived from organic material from pigs generate highly significant differences with the control group (P<0.01) for all the variables measured in the study.
3. The biol derived from bovine organic material generates highly significant differences with the control group (P<0.01) for all the variables measured in the study.

The foregoing corroborates that, although there are differences in the effect due to the origin of the biol or the concentration used (%V/V) in the application, any type of biol is beneficial to improve nutritional levels and forage production in star grass (*Cynodon nlemfuensis*).

CONCLUSIONS

- According to the results obtained through the RGB Algorithm, highly significant differences (p<0.01) are observed in the means for the variables PC (%), ENL (MJul), FDN, FDA and forage productivity (kg/m2) in the experimental units intervened, due to the effect of the type of biol and its concentration from a 50/50 ratio (%V/V).
- It is determined that all types of biols generate a positive effect on the nutritional improvement of forage regardless of whether they are derived from bovine or porcine excreta, however, the scope of this depends on the technical-productive conditions of the animal system from which the organic material to ferment is derived and the characteristics of the biodigestion process, that in this case, used continuous flow plastic biodigesters.

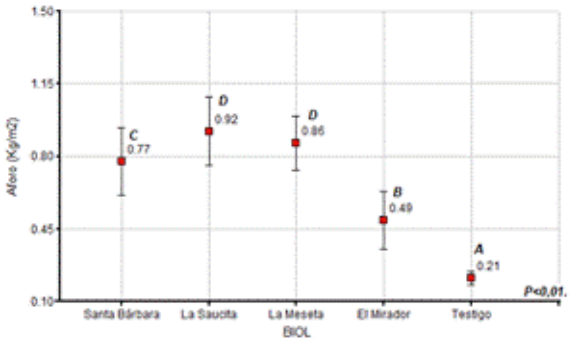

FIGURE 4a. FV production per biol type.

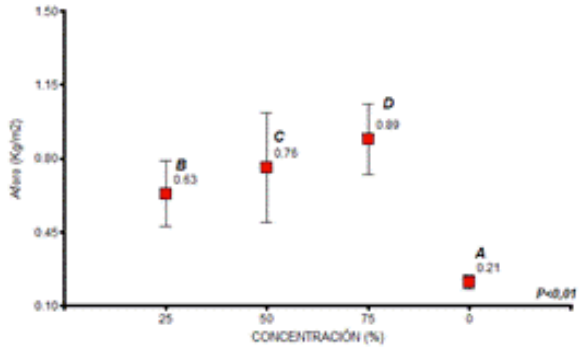

FIGURE 4b. FV production per biol concentration

- The improvement obtained in the protein content in *Cynodon nlemfluensis* forage is related to the contribution made by biol, of the elements nitrogen, phosphorus, sulfur (deficient in the preliminary analysis of the soil-Table 2 and 3), as metabolic precursors for the synthesis of amino acids and conformation of vegetable protein, deducing from this, the favoring of the spray application protocol on the foliar area of the plant at 15 and 30 days, highlighting a direct relationship between the increase in the biol concentration and the protein formation.
- According to the results and their significance, the rational use of biols (in this case, liquid fraction) obtained from the anaerobic fermentation of organic materials derived from animal production (bovine or pigs excreta) is proposed as a potential contribution to the circular economy), subjected to biodigestion for biogas production. Thus, there is not only the opportunity for energy use to subsidize agricultural production schemes with a source of

TABLE 5. Comparison results by contrast groups

Variable	Pig Biol (3 farms) vs Bovine Biol (1 farm)	Pig Biol (3 farms) vs Control	Bovine Biol vs. Control
PC (%)	P<0,01	P<0,01	P<0,01
ENL (MJul)	P<0,01	P<0,01	P<0,01
FDN (%)	P<0,01	P<0,01	P<0,01
FDA (%)	P<0,01	P<0,01	P<0,01
FV (Kg/m^2)	P>0.01	P<0,01	P<0,01

P<0.01 indicates highly significant differences (**).

energy derived from said materials that are apparently waste and that, depending on their disposal route, can generate large environmental impacts; but also, a maximum use of nutrients and their availability is made to be reincorporated into the arable soil for fodder production.

ACKNOWLEDGMENT

The authors express special thanks to the Faculty of Agricultural Sciences, the Center for Agricultural Studies and the PROSAFIS, SISPROS and GRIPEZ research groups of the University of Cundinamarca-Colombia. To Dr. Yanoy Morejón from the Agrarian University of Havana-Cuba.

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The authors of this work declare no conflict of interest.