Scientific Paper

Contribution of the management of grazing sows to the resilience of pig husbandry systems

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Abstract

Objective: To analyze the results of the management of grazing sows at international scale, as well as the elements of waste in field and confinement, which contribute to the resilience of pig husbandry systems.

Materials and Methods: The results of more than 80 publications about the elements of the management of grazing sows: main grazing systems, se of plant genetic resources in their feeding under different climate conditions, stocking rate, quality of the ration, breed, category, as well as waste recycling, applicable to the conditions of the tropic, were analyzed.

Results: There is innovative evidence in the management of grazing sows with the use of different plant genetic resources, in systems that go from subsistence to intensive management with electrical fence. The conditions or requisites for management, effect of stocking rate, species, importance of the nutritional value and animal category (mainly with sows), recycling in grazing and semi-confinement (deep litter), are analyzed.

Conclusions: Feeding, mainly, of pigs, based on pastures and forages, mainly, implies different management, with different solutions from the ones that are applied in conventional confined systems with concentrate feeds. The agroecological management and use of adequate plant genetic resources are the ways for resilient and sustainable production in the face of climate change, which contributes to food sovereignty.

Keywords: agroecology, recycling, grazing systems

Introduction

In the tropic there is a large diversity of plant genetic resources for food and agriculture (PGRFA), which can be utilized in feeding monogastric animals, which, managed sustainably, can become the solution to substitute imported concentrate feeds (SNICS, 2020).

Producing food and protecting the ecosystem are challenges for science. In this sense, agroecology offers a scientific and operational framework for the redesign of animal production systems, so that they can face better the next challenges, through a set of alternative practices to industrial agriculture (Dumont *et al*., 2014), which involve agricultural diversification, water regulation, creation of a favorable microclimate, soil protection and maintenance of carbon reserves (Nicholls and Altieri, 2019).

In Cuba, during more than 40 years, conventional agriculture was practiced; however, during the last 20 years an agroecological transition process has occurred (Vázquez-Moreno, 2018), in which more than one hundred thousand farmer families participate who have obtained results in this regard (Machín, 2016). Nevertheless, to withstand and recover from climate extremes that are foreseen since 2030, or earlier, as well as from the new possible pandemics, transformations are required which, if not achieved in the next ten years (threshold period of climate tolerance), the affectations to food production will have repercussions on food security and sovereignty (Vázquez-Moreno, 2020).

Among these transformations is the management of grazing pigs, which is differentiated in the type of system used. This improves recycling and soil fertility, substitutes part of the concentrate feed by pastures, forages and tubers, among others; besides decreasing the use of fossil energy and maintaining a natural behavior (exploring and rooting). All of it causes improvements regarding animal welfare and health, and contributes to the adaptation and mitigation of the climate change (Pietrosemoli, 2016).

In pig production in Cuba, pig rotational grazing is barely used, combined with semi-confinement, because in the state sector and, in a

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great part of the private sector, intensive confined systems prevail, with feeding based on energy-protein concentrate feeds, combined with the use of processed agroindustrial residues. However, there are many problems related to feeding, due to the little participation of farmers in the production of their own feedstuffs, which makes them dependent on unstable importing and on the little capacity of concentrate feed-producing plants, at local and national scale, among others (GEGAN and MINAG, 2019).

Regarding the recycling of pig waste, Cuba has innovative experiences and social technologies that can contribute to food sovereignty. In the grazing systems with semi-confinement, the deep litter (layer of different materials, such as hay, rice or coffee husk, corn leaves, sugarcane bagasse, wheat and soybean straw, and others), which is deposited in the pens of pig husbandry facilities to substitute the cement floor (Cruz-Martínez and Almaguel, 2017) could utilize the waste of the plant genetic resources used in the farm, and contribute to recycling. That is: if the principles and fundamentals of circular economy, it will be possible to reach successfully the integral sustainability of the system (Espaliat-Canu, 2019).

The purpose of this study is to analyze the results related to the management of grazing sows at international scale, as well as the elements of waste recycling in the field and confinement, which contribute to the resilience of pig husbandry systems.

Materials and Methods

The information of more than 80 publications of specialized journals, books, works in the internet, scientific events and meetings, among others, about the management of grazing pigs, under different climate conditions, was analyzed. The study included the breeds, grazing and management systems, pasture species, categories, among others. Emphasis was made on the management of plant genetic resources and waste recycling, as well as on the general requisites that must be fulfilled. Thus, principles and experiences can be extracted that contribute to the sustainability and resilience of the systems under the conditions of the tropic.

Results and Discussion

Management of grazing pigs. The difficult economic circumstances Latin America and the Caribbean go through, enhanced by the effects of the new coronavirus pandemic (CEPAL, 2020), demand actions for a more integral, local, community and family economic-social development, through sustainable models of food production and transformation, which propitiate a healthy population. In the case of pig rearing, there are innovative experiences in different countries, which contribute to food security and sovereignty, because they use social technologies, with local feedstuffs. Among these practices, is free-range pig rearing, in different management systems.

In the world, the management of pig in free range accumulates experiences and results, which have generated a set of requisites that must be fulfilled, related to the purpose of the grazing system, soil, climate, breed, animal category, nutritional quality of the ration and recycling, among others.

The main conditions for the management of grazing pigs (Bauza, 2005; Barlocco, 2011; Bell and Cracco, 2011; Campagna *et al*., 2011; Pietrosemoli, 2016; González-Martínez, 2019) are summarized below:

Grass management

- Selecting and establishing pasture species adapted to the edaphoclimatic conditions of the site, which have the nutritional value according to the conditions of a monogastric animal (low in fiber, rich in protein).
- Sufficient number of plots or paddocks, which allow the necessary resting of the grass, for its recovery after grazing, so that it is offered with availability and quality.
- Simple and easily managed structure, with emphasis on the protection of the areas where the pigs concentrate their activities (around the feeding and drinking troughs), with the placing of firm and absorbing surfaces. The facilities should be close to water sources.
- For grazing, the area should be flat, as much as possible, without drainage problems, to minimize runoff towards water courses. A minimum of 100 m distance from surface water courses and 50 m from springs, wells and other sources of drinkable water, should be respected. It is not convenient to use areas with slopes higher than 10º or a length higher than 200 m.
- The areas with slopes should be established with perennial pasture species, parallel to the level curves, whose width will increase depending on the soil, slope and climate.
- Rotational grazing in silvopastoral systems, with higher plant diversity and cover, offers better

thermal comfort, reduction of the erosion risk and carbon capture, among other benefits.
- In the sites with natural species, which do not show forage value, the area must be kept covered or with plant tapestry, to prevent erosion.

Animal management
- The global stocking rate must be estimated and applied, depending on the animal category and the instantaneous stocking rate.
- The selection of the genotype of the animals will be done according to the climate conditions (in the tropic more resistant and adapted animals should be used).
- The most recommended animal category is that of adult sows, because they can make considerable intake of pasture, compared with the younger animals.
- The nutritional requirements of the grazing animals should be calculated with 10-15 % over the requirements of those under confinement, to cover the energy expenses related to the maintenance of body temperature and exercising.
- The diet, based on pastures only, does not cover all the nutritional requirements of the animals, for which the complementation with concentrate feeds is important.
- The pigs that have not been managed under grazing conditions should be previously adapted to the intake of fibrous feedstuffs.
- As they are animals kept in free range, the aspects related to reproduction, health and parasitism should not be neglected.

As previously stated, the stocking rate, quality of the species, category and breed occupy an important place in the management of grazing pigs, aspects that are analyzed below:

a. Effect of the stocking rate

When studying different stocking rates (37, 74, 111 and 148 animals/ha) in growing-finishing pigs grazing *Cynodon dactylon* (L.) Pers., and analyzing their effect on the pasture and soil, Pietrosemoli *et al*. (2020) recommend that the stocking rates do not exceed 37 animals/ha.

In the case of pregnant sows grazing *C. dactylon,* with rotational management, Pietrosemoli and Green (2009) evaluated three stocking rates: 10, 15 and 25 sows/ha and suggested using stocking rates lower than 25 sows/ha, Pietrosemoli (2016) concluded that the stocking rate should not exceed 10 sows/ha.

González-Martínez (2019) recommends an average annual global stocking rate of 3,5 to 4,0 sows, plus all their production per hectare. He indicates that the estimated calculation is 10 kg/m^2, because with good-quality forage up to 50 % of the nutritional requirements for the maintenance of the sows can be supplied and, only approximately 5-20 % in growing-fattening pigs.

b. Pasture species

Bell and Cracco (2005) state that the first thing to be considered in the management of grazing pigs is to use species that are capable of offering quality forage (high protein content and low fiber content). The legume family appears as the most indicated one; while the family of grasses, is placed on a lower level, because in general it offers forage of lower quality than the former ones. A limitation is being able to produce quality forage throughout the year, for which in the dry season it is recommended to use cut forages or crops of other species. High importance is ascribed to persistence, to prevent soil degradation, even when the vegetation does not represent a feed resource for the animals. The management of the occupation times and stocking rate should contemplate that the natural plant cover is always present.

If the plant cover is lost, the bare soil can be rapidly eroded, runoffs, nitrogen leaching and volatilization can occur, which, in turn, would cause atmospheric contamination of underground and surface waters. All this provokes damages to the fauna which lives on the land and beneath it. The floristic evolution depends on a set of factors that cannot be determined in the short term.

c. Intensive rational management

Voisin rational management (VRM) applies a set of principles for pig grazing in free range. Due to its agroecological management, it contributes to the climate change adaptation and mitigation.

According to González-Martínez (2019), rational grazing in sows is based on management with high global and instantaneous stocking rate, short grazing periods and optimum resting. Its main characteristics are: utilization of technologies with marked participation of the human factors, that is why it is rational; economy in the use of concentrate feed, correct administration of the forage resource, simple and easily managed infrastructure, uniform distribution of dejections, docility and easy management and commercial flexibility. The rational rotational grazing in perennial species allows resting periods for the recovery of the species, with higher plant cover,

reduction of the erosion risk, better distribution of the excreta, decrease of contamination by bacteria and parasites. Nevertheless, 10-15 % more feedstuff is needed, according to the requirement tables, calculated for confinement, because of energy expenses related to the maintenance of the body temperature, and exercising. With this system, it is possible to decrease concentrate feed between 20 and 30 %, with an offer twice per day, but it is necessary to make sure that all the animals have access to the feed.

Monteverde (2018), in temperate pastures, summarizes the main results that can be reached when the laws of Voisin rational grazing are applied: improving productivity per hectare, based on pasture; increasing soil fertility and physical characteristics, decreasing the costs per unit, having a system less dependent on external inputs, increasing diversity, and thus resilience of the system; promoting health (human, animal, environmental), producing quality foodstuffs, improving the quality of life of those who work, capturing the highest quantity of energy (photosynthesis), management depending on the plant and animal physiology and on the dynamic development of the soil life.

In Cuba, Milera-Rodríguez *et al.* (2019) indicated that the rational management adjusts to the current context of climate emergency, because it applies a systemic approach, considers the soil-plant-animal relation in an integrated way (adaptation), demands a multidisciplinary work (adaptation-mitigation). It is also rational and flexible, because man is involved in decision-making, without mechanicism, without pre-fixed order in the rotation of enclosed pastures (adaptation). This system favors the biodiversity and persistence of species in the grasslands (adaptation), propitiates high availability and quality of the offered forage (mitigation), which allows higher selectiveness by the grazing animals and decreases methane emission per kilogram of consumed dry matter (mitigation). This management reduces the vulnerability and decreases the system resilience (adaptation).

d. Quality of the ration

The other aspect to be considered is the high selectiveness of pigs, which seek to consume the fresh parts of the plant, and reject the most fibrous ones. In the works with forage Sorghum bicolor (L.) Moench under grazing conditions, the utilization was close to 70 % of the offered pasture, and decreased as the plant maturity increased (Bauza, 2005). The intake values in pregnant sows grazing forage *S. bicolor,* were approximately 750 g DM per day, equivalent to almost 5 kg of green forage. In this work a substitution of 25 % of the concentrate feed was estimated.

Bauza (2005) states that the pig does not make as efficient utilization of the nutrients in pastures as ruminants, because it does not have the enzymes capable of digesting the components of the cell wall of plants (hemicellulose, cellulose and lignin) or the capacity of pre-gastric fermentation. However, GEGAN and MINAG (2019) indicate that when they were fed with fresh forages, the pigs made a utilization of the protein at small intestine level and, in the case of adults, they were able to obtain an important quantity of energy through the fermentation processes in the large intestine (cecum and colon). It is admitted that the pig is able to utilize by these fermentations, approximately, 30 % of the cellulose, and 50 % of the hemicellulose, unlike the lignin, which is indigestible.

The main contribution of the pasture consists in proteins of good biological value, which can complement the low content in lysine, tryptophan and methionine of the protein from cereal grains. The other important contribution is constituted by vitamins, especially of the B complex (hydrosoluble), which also provide provitamin A (carotene) and provitamin D (ergosterol), as well as interesting quantities of vitamin C.

The effect of the pasture on milk production and its repercussion on the initial growth of the piglets should not be missed. The objective is to stimulate to the maximum milk production, before trying to save ration, for which, in lactating sows, care must be taken in a recommendation of partial substitution of concentrate feed by pastures. Theoretically, the substitution can be in 10 % of the concentrate feed, aspect that will not necessarily cause an economic benefit, and a lower cost per kilogram of weaned piglet.

Barlocco (2011), under field conditions, used concentrate feed in a controlled way and permanent grazing of the species *Trifolium pratense* L., *Lolium multiflorum* Lam. and *Cichorium intibus* L. the main criterion that was used to determine the strip changes was based on the height of *C. intibus*, which should be 20-30 cm to determine the entrance and 5 cm in the case of the departure of the animals. There was an important difference in the utilization of the various species, with high intake of chicory, and scarce intake of ryegrass, due to season (spring), when hardening and loss of

quality and palatability occurs in this species, with the subsequent rejection by pigs, even adults, in the face of an important restriction of concentrate feed.

Thus, if the nutritional requirements, grazing forms, selectiveness, pasture management and stocking rates, are known, in addition to choosing the best cultivar for each particular zone, success in pork production in the field can be guaranteed, at a lower cost compared with classical confined systems (Faner, 2016).

Animal category. The works carried out by Barlocco *et al*. (2005) have cultivated pastures (*T. pratense*, *L. multiflorum* and *C. intibus*), offered in permanent grazing to rearing and fattening animals, with Pampa Rocha (PP) creole animals and crossing of Pampa-Rocha with Duroc (HDP). Daily supplementation of concentrate feed was always lower than the maximum intake capacity, and is expressed as a percentage of the maximum voluntary intake. The supply of concentrate feed or restrictions of 85, 70 and 50 % were identified as slight, moderate and strong restriction, respectively. In these studies, field shelters, a pacifier-type drinker and feeding trough were used for every 4 to 8 pigs. They were ringed at weaning and controlled. The studies were divided by season: I) spring-summer, II) winter spring, III) winter-spring.

The main results in rearing are summarized in a weight gain in rearing lower than that obtained in fattening, since the conversion efficiency of the concentrate feed was better with the restriction levels used. It can be stated that as the supply of the ration decreases, the conversion efficiency of this feedstuff improves. Product of crossbreeding (HDP), the pigs improve the productive indicators for any level of concentrate feed restriction, with regards to those obtained with pigs in breed purity (PP).

Regarding fattening pigs, the main results are summarized in the restriction of concentrate feed, which determines an increase in the number of days to reach a certain weight, an aspect that influences production costs. The slight restriction regime in HPD pigs (II) determines higher intake of concentrate feed than the moderate restriction regime, which allows to affirm the importance of restricting the supply of this feedstuff, when cultivated pastures are permanently available. HPD pigs in a moderate restriction regime show better utilization of the concentrate feed compared with PP (II). The lower level of concentrate feed supply determined a saving of 34,2 kg of concentrate feed per animal and per period (14 % less in III). Regarding dry matter intake and conversion efficiency, the fundamental conclusion is that grass intake evolves as the animal advances in weight and age, and depends on the level of concentrate feed supply. As the contribution of DM by pasture in the diet increases, the conversion efficiency of the total worsens, which shows that the pig is less efficient in the use of this feedstuff compared with the ration, and the effect is higher as the restriction grows stronger.

According to Bauza (2005), in the categories of females for replacement, grazing pregnant sows and lactating sows, there are several factors to take into consideration. With abundant forage supply, the pig, after entering the plot, quickly consumes a large amount of grass, until satiety. Then, it stops and dedicates itself to touring the plot, rooting or resting. The decrease in the quality of the species is proportional to its utilization and intake is notably reduced with the high temperatures.

In grazing replacement females, subject to a restriction of concentrate feed in the diet, regardless of the breed used, their puberty is delayed. This is achieved with a significantly lower weight, even though the pasture has a beneficial effect due to the contribution of vitamins, minerals, proteins, as well as the well-being and greater muscle strengthening generated by exercise.

The pregnant sow is the one that best adapts to pasture feeding, since it combines several characteristics: lower nutrient requirements, larger animals, with high intake capacity, and a high degree of development of the large intestine. The results of the conducted works indicate that it is possible to lower considerably the cost of feeding during pregnancy, replacing the balanced ration by grazing forage sorghum and supplying a mixture of grain with mineral complement.

In the category of lactating sows, Bauza (2005) pointed out that grazing has a favorable effect on milk production. The supply of nutrients for lactation of volatile fatty acids, produced in the large intestine as a result of the fermentation of hemicellulose and cellulose, is an immediate energy source, which is quickly incorporated into the lactosynthesis process. This explains the higher milk production of sows kept on pasture. However, the energy supply from this source is not enough to maintain milk production, which will be sustained from the ingested concentrate feed and the body reserves deposited during pregnancy.

In other studies with primiparous sows, from pregnancy to weaning (Gónzalez-Illescas, 2016),

there were no differences in the studied indicators (productive and health). However, the supply of concentrate feed was 50,0 % lower in the grazing treatment, hence the advantage of the system in terms of saving supplements. Similar results were found by Fajardo-Castillo (2009), related to the efficiency of the daily production cost, which was lower in grazing, when evaluating the pregnancy-weaning cycle in reproductive sows. However, this author pointed out that at this stage of the production process (lactation), the sale of the piglets did not allow to recover the costs. For such reason, it is common to carry it out only at the end of pre-fattening, with an average weight of the piglets between 20 and 25 kg.

Management of the creole breed and its crossings. Pig domestication, throughout the world, had its origin in its management in free range and continued like this, fundamentally, in subsistence economies. This species can develop in all latitudes, in all climates, and in all production systems, thanks to its breed diversity, cosmopolitanism, adaptability, and productive efficiency. Likewise, due to their omnivorous nature, pigs can take advantage of almost all food resources (Aparicio-Tovar and Vargas-Giraldo, 2011).

The traditional rearing of pigs (creole or crossbred) is the one linked to the natural environment, in which the animals are in direct contact with the land, part or full time, in paddocks or field extensions of greater or lesser extent.

In Uruguay, Carballo-Sánchez *et al*. (2021) report that they use the Pampa Rocha creole breed and its crossings and, in more than 90,0 % of the farms, the pig herd does not exceed 50 animals. The farmers use outdoor production in, at least, one stage of the production cycle, mainly in rearing.

This tenancy form is based on lower investment on facilities, easier management of pigs on pasture, especially in the pregnancy categories, and the intention of reducing the feeding cost, substituting the concentrate feed ration by an accessible and low-cost feedstuff.

In Mexico, the Mexican Pelón is used in different management systems (backyard, intensive and extensive), and it is suggested that this breed is evolving, from traditional backyard systems, to intensive and extensive entrepreneurial systems, where rusticity and adaptability are utilized (Hernández *et al*., 2020).

In Colombia, there are several types of creole pigs, but the prevailing one is Zungo. Espinosa and Ly (2015) report that, when comparing the intensive rearing of Landrace pigs with Zungo, there was no cost of fertilizers, herbicides or insecticides per ton of meat produced, in the case of Zungo pigs, and the consumed water only represented 52,0 % of that used with Landrace animals.

In Venezuela, the Demonstrative Technological Showcases program (VTD, for its initials in Spanish) is applied, with the aim of generating pig units in small family scale and transforming the existing ones, which produce in a traditional way, for animal production in accordance with the environment, without deteriorating it. In this system, feeding technologies are used, based on the use of feeding raw materials, typical of the area, such as *Ipomoea batatas* (L.) Lam, *Saccharum officinarum* L., *Manihot esculenta* Crantz, *Morus alba* L., *Trichanthera gigantea* (Bonpl.) Nees. and hydroponic or germinated green fodder, to generate a balanced, non-dependent and sustainable diet (González-Araujo, 2011).

In northeastern Brazil, management with local breeds is used extensively and for subsistence; in addition to rope management for family rearing (Silva-Filha and Barbosa, 2011).

In Italy, as well as in other European countries, different forms of extensive production were developed since the early 1990s. But, in recent years, pig farms in the field have had greater expansion, related to organic production and the exploitation of pigs of autochthonous breeds, aimed at typical quality products, with higher market prices. In Sicily, the field exploitation of the native Black Sicilian breed has been practiced for centuries, with forms of free or extensive management. This breed is of considerable interest due to the optimum characteristics of its meat, and the main advantage is represented by the modest investments, estimated between 1/5 and 1/3, with respect to those necessary for intensive farms (Grosso *et al*., 2011).

In Spain, Aparicio-Tovar and Vargas-Giraldo (2011), in a case study carried out in extensive farms, dedicated to the breeding of the Iberian pig in the Autonomous Community of Extremadura, which concentrates 50 % of the sows of this breed in the country, observed that 25 % of the farms had less than five sows, or less than 25 fattening pigs. Likewise, the average surface devoted to pig farming was 51,1 ha. The labor of these farms was of family character in 97 % of the cases.

According to Pérez-Ciria (2015), the great advantage of the extensive free-range rearing system of the Iberian pig lies on the higher degree

of well-being, since stress is minimized and allows acorn-fed pig products to have better quality than those produced by the pigs under field fattening and, these, than those of fattening, as the duration of the grazing, and the kilograms replaced with acorns and grass, increase.

In Cuba, the Creole pig comes from pigs of the Iberian breed, which in five centuries of exploitation has experienced a crossbreeding process, mainly with Hampshire and Duroc pigs. This type of pig, generally, is not exploited intensively or in total confinement, except in specialized genetic units, where the breeding stock and replacement females that are distributed to peasant pig farmers are produced. The most widespread exploitation system is extensive rearing under palm and tree plantations, or rope farming, in smaller farms, although there are farmers who confine the animals in cages for their protection. Feeding is based on waste from agriculture and the food processing industry, natural vegetation and tree fruits, as well as waste from family food, popularly called *sancocho*.

In 1995, an intensive free-range grazing system (CIAL for its initials in Spanish) was proposed in Cuba. This system made emphasis on the substitution of concentrate feeds by local feedstuffs. However, it did not take into account grass and forage plants or intensive grazing management (Ly and Rico, 2006).

In the Pinar del Río province, the creole pig is managed extensively, in mountain and pre-mountain zones, where the farms have an area between 4 and 50 ha. Feeding is based, almost exclusively, on the resources of the environment and the fallen fruits of the Cuban live oak *Quercus oleoides* spp Sagraeana C.H. Mill, a tree endemic to Cuba, play a fundamental role.

Studies carried out by Hernández *et al*. (2020) in that province confirmed the low growth and high ages at slaughter of creole pigs from Pinar del Río, as well as the inconvenience of not having controlled areas to reduce the energy expense of pigs or sufficient information regarding the intake of the fruit from the Cuban live oak. However, the traditional local perception refers that the reached weights are satisfactory.

Recycling in grazing and deep litter. The challenge of circular economy for the pig husbandry sector consists in achieving a reasonable balance between satisfying the nutritional needs of a continuously growing population, and safe and efficient production, which at the same time protects, maintains, and even improves, the natural environment (Espaliat-Canu, 2019).

Pig production waste can be used in different ways, depending on the used system. In the case of grazing animals, they are incorporated directly into the pasture, in confined or semi-confined production systems, the deep litter (Cruz-Martínez and Almaguel, 2020) or the installation of biodigesters (Martín-Martín *et al*., 2020) can also be used.

a) Grazing

In general, pigs only utilize between 50,0 and 60,0 % of the nutrients present in the feedstuffs they consume. That is why their excreta have a high content of nitrogen, phosphorus, potassium, calcium, magnesium, organic matter, among others, which are recycled in the soil. The design of the paddock or enclosed pasture is important, which allows the uniform distribution of the droppings. In grazing, recycling occurs that can improve or worsen soil and pasture conditions. Among the main factors with possible ecological risks are: the high stocking rate, the feeding type and level and the layout of the service area where the feeders and drinkers are located permanently, since in them accumulation of water and mud can occur, with the subsequent runoff of nutrients from the soil.

In Uruguay, Monteverde and Pino (2014) studied, during 12 years of grazing with pigs, the effect on the soil. The plots were rectangular and were divided into three reference areas: the service area, where feeding and drinking troughs were located (25 % of the area), followed by an intermediate one at a distance of 15 m and the grazing area (75 %), 40 m away from the above-mentioned ones. The pastures used were alfalfa and a mixture of red and white clover and chicory. The system produced important modifications in the physical, chemical and biological properties of the soil, which generated high spatial heterogeneity in the differentiated management zones. The service area (includes drinking trough, feeding trough and shelters) concentrated the greatest impacts and the grazing area with planted pastures, the lowest ones.

The system caused slight soil compaction throughout the area. Organic matter was reduced, on the surface, from 4,7 % in control soil to 3,9 % in soil with pigs, and decreased 17 % in depth, and was highly correlated with the decrease of non-particulate organic matter (<50 µm). The large surpluses of P were associated with the stocking rate, the loss

of the ration and the performance of the excretions of the animals. The excess of N was concentrated in the most compacted zone of the service area, with little accumulation in the soil, increasing the risk of water contamination.

The increases in N, K and P in the zone of the service area, without tillage, were highly correlated with the increase of electrical conductivity. The physical-chemical changes were differentially influenced by the stocking rate used.

The results suggest that producing pigs in the field can be an alternative to confined systems, but it can generate environmental problems due to inadequate management practices. In Venezuela, Rivero *et al*. (2013) obtained similar results concerning P on a soil with different characteristics from the previous one, in short-term periods (174 days).

According to Pietrosemoli (2016), management, with frequent changes in feeding areas and shade structures, would potentially allow to obtain a better distribution of nutrients in the plots. Also restricted grazing, at certain times of the day, and the use of simple buildings, with deep litter, could be an option for better recycling.

b) Deep litter

The deep litter is used in small and medium-scale production systems. In the summer months and in zones with high temperatures, shade buildings can be designed, with temporary roofs, made of dry plant materials, 30-40 cm thick, to guarantee a cool environment inside. The litter that is deposited in these facilities, in addition to saving the water and electricity that it generates, reduces odors and the presence of flies, because there is no emission of liquid waste. This influences hygiene and favors biosafety, due to the range of diseases associated with these vectors. However, it must be taken into account that, in deep litter systems, the temperature and accumulation of gases are higher, with regards to conventional systems, for which the construction principles of the facilities and the management of the animals are different (Cruz-Martínez and Almaguel, 2017).

The Demonstrative Technological Showcases program (VTD), used in Venezuela, applies deep litter technology in all facilities, and these are designed to function as a physical system (evaporation and filtration), with a litter height that allows to obtain good filtering capacity, and that the solids remain in the litter. Different materials are used: rice husks (excellent, due to the low moisture absorption capacity), coffee parchment, crop residues (corn, rice, etc.), grass hay and other available organic materials, even with low filtering capacity (González-Araujo, 2011).

In studies conducted by Cruz-Martínez and Almaguel (2020), a saving of 177 m^3 of water for cleaning the facility was observed in a rearing cycle (savings of 46,8 liters/animal/day); while the drinking water intake was similar in the different types of floors, approximately 45,4 m^3. In the winter season, the deep litter generates temperature values that favor animal welfare. However, in the summer season, it is necessary to take cooling measures to prevent animal behavior traits from being affected.

Somenzini *et al*. (2016), in a study of two pig management systems consisting in deep litter (DL) and free range (FR), observed significant differences in final weight and daily live weight gain ($p < 0, 05$), in favor of the animals on deep litter (0,95 *vs* 0,81 kg). With regards to food conversion, the animals in free range needed less feed quantity (DL: 3,13:1, FR: 3,10:1), although without significant difference compared with DL. These authors conclude that the DL system would be a good alternative to consider in the reconversion processes of farms with field production systems, or in establishments that are in growth stages, since the initial investment is lower than that of conventional intensive systems.

After the pig rearing cycle is over, the litter is removed from the facility and can be composted, as is the case with agricultural crop residues, hay or other materials, and animal excretions (Pentón-Fernández *et al*., 2020). The application of the deep litter composting technique and its application as organic fertilizer in grazing areas or agricultural crops, complies with the postulates of circular economy, which implies a contribution to the environment, through better waste management, water recovery; efficient energy management; balance of the natural environment, recovery of nutrients from the soil and management of their use; as well as the decrease of greenhouse gases and commitment to animal welfare.

Conclusions

The management of grazing pigs, mainly sows, has shown lower investment in facilities, decrease of feeding costs, due to the substitution of concentrated supplements by low-cost local feedstuffs, decrease of contamination, if recycling is adequately managed, and better welfare of the pig.

In grazing, the actual supply of nutrients will depend on the physiological status and quality of the forage species, as well as the animal category

and the breed of pigs used, depending on the season and the existing edaphoclimatic conditions.

When the management requirements are met, with recycling of excretions in the pasture, the use of agricultural crop residues in the litter and application in the field of the fertilizer that results from composting, contribution is being made to sustainability in a circular way, due to the saving of supplements, fuels, fertilizers and water, as well as the adaptation and mitigation of climate change. From a systemic point of view, this agroecological management of pigs is the path to resilient production. With it, contribution is made to food security and sovereignty, but it implies a different management, with different solutions from conventional systems.

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Conflict of interests

The author declares that there is no conflict of interests.

Authors' contribution

- Milagros de la Caridad Milera-Rodríguez. Contributed to the conception and design of the paper, wrote and revised its content.

Bibliographic references

Aparicio-Tovar, M. A. & Vargas-Giraldo, J. de D. Innovación y formación en explotaciones porcinas familiares. En: N. Barlocco y A. Vadell, eds. *Producción de cerdos a campo. Aportes para el desarrollo de tecnologías apropiadas para la producción familiar*. Montevideo: Departamento de Publicaciones de la Facultad de Agronomía, Universidad de la República Oriental del Uruguay. p. 87-91. http://www.ciap.org.ar/Sitio/Archivos/Innovacion%20y%20formacion%20en%20explotaciones%20porcinas%20familiares.pdf, 2011.

Barlocco, N. Consumo y utilización de pasturas por cerdos en la fase de recría-terminación. En: N. Barlocco y A. Vadell, eds. *Producción de cerdos a campo. Aportes para el desarrollo de tecnologías apropiadas para la producción familiar*. Montevideo: Departamento de Publicaciones de la Facultad de Agronomía, Universidad de la República Oriental del Uruguay. p. 36-38. https://www.produccion-animal.com.ar/produccion_porcina/00-produccion_porcina_general/100-pastoriles.pdf, 2011.

Bauza, R. Utilización de pasturas en la alimentación de reproductores. *Taller "Utilización de pasturas en la alimentación de cerdos"*. Montevideo: Facultad de Agronomía, Universidad de la República. http://www.ciap.org.ar/Sitio/Archivos/UTILIZACION%20DE%20PASTURAS%20EN%20LA%20ALIMENTACION%20DE%20REPRODUCTORES.pdf, 2005.

Bell, W. & Cracco, P. El uso de pasturas en la cría de cerdos a campo la experiencia de la UPC. En: En: N. Barlocco y A. Vadell, eds. *Producción de Cerdos a campo. Aportes para el desarrollo de tecnologías apropiadas para la producción familiar*. Montevideo: Departamento de Publicaciones de la Facultad de Agronomía, Universidad de la República Oriental del Uruguay. p. 39-43. http://www.ciap.org.ar/Sitio/Archivos/El%20uso%20de%20pasturas%20en%20la%20cria%20de%20cerdos%20a%20campo.pdf, 2011.

Campagna, D.; Dichio, L.; Ausilio, A.; Bessón, P. A.; Silva, P. & Spinollo, L. Efectos de la carga animal sobre el tapiz vegetal y el recurso suelo en un sistema de producción porcina al aire libre. En: N. Barlocco y A. Vadell, eds. *Producción de cerdos a campo. Aportes para el desarrollo de tecnologías apropiadas para la producción familiar*. Montevideo: Departamento de Publicaciones de la Facultad de Agronomía, Universidad de la República del Uruguay. p. 97-101. http://www.ciap.org.ar/Sitio/Archivos/Efectos%20de%20la%20carga%20animal%20sobre%20el%20tapiz%20vegetal%20y%20el%20recurso%20suelo%20en%20un%20sistema%20de%20produccion%20porcina%20al%20aire%20libre.pdf, 2011.

Carballo-Sánchez, Cecilia S.; Espino-Martínez, Nandy S. & Vodanovich-Possamai, Ana L. Producción de cerdos al aire libre como estrategia productiva a escala familia. En: J. M. Palma-García, J. F. Cruz-Uribe and coord., eds. *Tecnologías sociales en la producción pecuaria de América Latina y el Caribe*. Colima, México: Universidad de Colima. p. 175-184. http://www.ciap.org.ar/Sitio/Archivos/Produccion decerdosalairelibrecomoestrategiaproductivaaescalafamilia.pdf, 2021.

CEPAL. *Informe sobre el impacto económico en América Latina y el Caribe de la enfermedad por coronavirus (COVID-19)*. Santiago de Chile: Comisión Económica para América Latina y el Caribe, 2020. https://repositorio.cepal.org/bitstream/handle/11362/45602/1/S2000313_es.pdf, 2020.

Cruz-Martínez, Elizabeth & Almaguel, R. E. Cama profunda en el sistema de extensión y capacitación porcina. *Importancia del manejo de reproductoras porcinas en sistemas silvopastoriles con dietas no convencionales*; Matanzas, Cuba: EEPF Indio Hatuey, Universidad de Matanzas. 2020.

Cruz-Martínez, Elizabeth & Almaguel, R. E. Evaluación de la tecnología de cama profunda con cerdos en crecimiento-ceba para el sector campesino de Cuba. En: *Tecnología de cama profunda en la producción porcina cubana*. España: Editorial Academia Española, 2017.

Dumont, B.; González-García, E.; Thomas, M.; Fortun-Lamothe, L.; Ducrot, C.; Dourmad, J. Y.

et al. Forty research issues for the redesign of animal production systems in the 21st century. *Animal*. 8 (8):1382-1393, 2014. DOI: https://doi.org/10.1017/S1751731114001281.

Espaliat-Canu, M. *Economía circular y sostenibilidad en el sector agroalimentario*. Barcelona, España: Universitat Politècnica de Catalunya. https://www.prevencionintegral.com/ca/comunidad/blog/hacia-mundo-sostenible/2019/07/11/economia-circular-sostenibilidad-en-sector-agroalimentario. [05/10/2020], 2019.

Espinosa, Claudia & Ly, J. Cerdos criollos colombianos y agricultura sostenible. *RCPP*. 22 (1):1-9. [CD-ROM], 2015.

Fajardo-Castillo, Diana S. *Evaluación de dos sistemas de instalaciones y manejo para la etapa de lactancia, comparando la producción porcina tradicional vs la producción al aire libre*. Trabajo de grado como requisito para optar por el título de Zootecnista. Bogotá: Facultad de Zootecnia, Universidad de La Salle. https://ciencia.lasalle.edu.co/cgi/viewcontent.cgi?article=1063&context=zootecnia, 2009.

Faner, C. La pastura de alfalfa como fuente de alimentación para cerdos en crecimiento y terminación. *Universo Porcino*. 1-7. https://www.yumpu.com/es/document/read/19654205/la-pastura-de-alfalfa-como-fuente-de-alimentacion-para-cerdos-en-, 2016.

GEGAN & MINAG. *Ideas iniciales para reordenar e incrementar la producción de carne porcina*. La Habana: GEGAN, MINAG. 2019.

González-Araujo, C. Innovación y desarrollo de tecnologías en porcinos apropiadas para la producción familiar. En: N. Barlocco y A. Vadell, eds. *Producción de cerdos a campo. Aportes para el desarrollo de tecnologías apropiadas para la producción familiar*. Montevideo: Departamento de Publicaciones de la Facultad de Agronomía, Universidad de la República del Uruguay. p. 106-109. http://www.ciap.org.ar/Sitio/Archivos/Innovacion%20y%20desarrollo%20de%20tecnologias%20en%20porcinos%20apropiadas.pdf, 2011.

González-Illescas, R. A. *Efectos del pastoreo sobre los parámetros productivos de la gestación porcina en una granja del cantón Pasaje*. Machala, Ecuador: Unidad académica de Ciencias Agropecuarias, Universidad Técnica de Machala. http://repositorio.utmachala.edu.ec/bitstream/48000/7682/1/DE00040_TRABAJO-DETITULACION.pdf, 2016.

González-Martínez, K. *Manejo de cerdos en pastoreo. Pastoreo racional en cerdos. Una herramienta estratégica*. La porcicultura.com. https://laporcicultura.com/alimentacion-del-cerdo/cerdo-en-pastoreo/. [28/01/2021], 2019.

Grosso, L.; Barbieri, S.; Ferrante, V. & Ferrari, P. La producción porcina a campo en Italia. En: N. Barlocco and A. Vadell, eds. *Producción de cerdos a campo. Aportes para el desarrollo de tecnologías apropiadas para la producción familiar*. Montevideo: Departamento de Publicaciones de la Facultad de Agronomía, Universidad de la República Oriental del Uruguay. p. 110-115. http://www.ciap.org.ar/Sitio/Archivos/La%20produccion%20porcina%20a%20campo%20en%20Italia.pdf, 2011.

Hernández, A. Á.; García-Munguía, C. A.; García-Munguía, A. M.; Ortíz-Ortíz, J. R.; Sierra-Vásquez, Á. C. & Morales-Flores, Socorro. Sistema de producción del Cerdo Pelón Mexicano en la península de Yucatán. *Nova scientia*. 12 (1):1-21, 2020. DOI: https://doi.org/10.21640/ns.v12i24.2234.

Ly, J. & Rico, Carmen. Cría de cerdos al aire libre. El caso cubano. *RCPP*. 13 (1). [CD-ROM], 2006.

Machín, B. P. Movimiento agroecológico de campesino a campesino. En: F. Funes-Aguilar y L. L. Vázquez-Moreno, eds. *Avances de la Agroecología en Cuba*. Matanzas, Cuba: EEPF Indio Hatuey. p. 421-443, 2015.

Martín-Martín, G. J.; Milera-Rodríguez, Milagros de la C.; Suárez-Hernández, J.; Cepero-Casas, L. & Pentón-Pentón, Gertrudis. La utilización de fuentes renovables de energía. Importancia de las fincas agroenergéticas. En: Milagros de la C. Milera-Rodríguez, comp. *Manejo agroecológico de los sistemas agropecuarios. Usos del suelo con abonos y biochar*. Matanzas, Cuba: EEPF Indio Hatuey. 2020.

Milera-Rodríguez, Milagros de la C.; Machado-Martínez, R. L.; Alonso-Amaro, O.; Hernández-Chávez, Marta B. & Sánchez-Cárdenas, Saray. Pastoreo racional intensivo como alternativa para una ganadería baja en emisiones. *Pastos y Forrajes*. 42 (1):3-12. http://scielo.sld.cu/scielo.php?script=sci_arttext&pid=S0864-03942019000100003&lng=es&tlng=es, 2019.

Monteverde, S. Pastoreo Racional Voisin. Montevideo: Universidad de la Republica de Uruguay. https://www.researchgate.net/publication/328789909_Pastoreo_Racional_Voisin#fullTextFileContent, 2018.

Monteverde, S. & Pino, Amabelia del. Variabilidad espacial en las propiedades químicas del suelo en un sistema de producción con cerdos en pastoreo. *Ciencias Agronómicas. Revista de Investigaciones de la Facultad de Ciencias Agrarias UNR*. 23 (14):37-45. https://cienciasagronomicas.unr.edu.ar/journal/index.php/agronom/article/download/66/72, 2014.

Nicholls, Clara I. & Altieri, M. A. Bases agroecológicas para la adaptación de la agricultura al cambio climático. *Cuadernos de Investigación UNED*. 11 (1):S55-S61. https://revistas.uned.ac.cr/index.php/cuadernos/article/view/2322/2829, 2019.

Pentón-Fernández, Gertrudis; Schmidt, H.-P.; Milera-Rodríguez, Milagros de la C.; Martín-Martín, G. J.; Brea-Maure, Odelín & Brunet-Zulueta, J. Empleo de fertilizantes orgánicos basados en biochar, producidos a partir de residuos agropecuarios. En: Milagros de la C. Milera-Rodríguez, comp. *Manejo agroecológico de los sistemas agropecuarios. Usos del suelo con abonos y biochar*. Matanzas, Cuba: EEPF Indio Hatuey, 2020.

Pérez-Ciria, Leticia. *La alimentación del cerdo Ibérico y su impacto sobre la calidad de la carne*. Trabajo fin de grado. España: Facultad de Veterinaria, Universidad de Zaragoza. https://zaguan.unizar.es/record/31760/files/TAZ-TFG-2015-1561.pdf, 2015.

Pietrosemoli, Silvana. Porcinos a pastoreo, estrategias para reducir su potencial impacto ambiental. *Arch. Latinoam. Prod. Anim*. 24 (2):89-94. https://ojs.alpa.uy/index.php/ojs_files/article/download/2527/948/, 2016.

Pietrosemoli, Silvana & Green, J. T. Efecto de la carga animal de cerdas adultas en la cobertura vegetal de pasto bermuda (*Cynodon dactylon*) durante el invierno. *Memorias de la Asociación Latinoamericana de Producción Animal*. ALPA. p. 354, 2009.

Pietrosemoli, Silvana; Raczkowski, C.; Green J. T. & Villamide, Maria J. Effects of growing-finishing pig stocking rates on bermudagrass ground cover and soil properties. *Animals*. 10 (9):1666, 2020. DOI: https://doi.org/10.3390/ani10091666.

Rivero, Carmen; Cabrales, E.; Santana, Giovanna; Rivas, Mayra; Pulido, Mansonia; Rey, J. *et al*. Efecto del pastoreo de cerdos sobre las fracciones de nitrógeno, carbono y fósforo del suelo *Temas Agrarios*. 18 (1), 2013. DOI: https://doi.org/10.21897/rta.v18i1.706.

Silva-Filha, O. L. & Barbosa, É. J. R. Como se produz de suínos locais na região nordeste do Brasil. En: N. Barlocco y A. Vadell, eds. *Producción de cerdos a campo. Aportes para el desarrollo de tecnologías apropiadas para la producción familiar*. Montevideo: Departamento de Publicaciones de la Facultad de Agronomía, Universidad de la República del Uruguay. p. 126-128. http://www.ciap.org.ar/Sitio/Archivos/Como%20se%20produz%20suinos%20locais%20na%20regiao%20nordeste%20do%20Brasil.pdf, 2011.

SNICS. *Recursos fitogenéticos para la alimentación y la agricultura (RFAA)*. México: Servicio Nacional de Inspección y Certificación de Semillas. https://www.gob.mx/snics/acciones-y-programas/que-son-los-recursos-fitogeneticos-para-la-alimentacion-y-la-agricultura. [20/07/2021], 2020.

Somenzini, D.; Spinollo, L.; Skejich, Patricia; Abdul-Ahad, J.; D´Eletto, M.; Stoppani, C. *et al*. Rendimiento productivo de cerdos de engorde en sistema al aire libre (AL) respecto a un sistema de cama profunda (CP). *Memorias del XIII Congreso Nacional de Producción Porcina*. Chaco, Argentina. p. 181, 2016.

Vázquez-Moreno, L. L. Sostenibilidad ambiental y agricultura resiliente al cambio climático. *Congreso Internacional de Suelos*. La Habana: Instituto de Suelos, Sociedad Cubana de la Ciencia del Suelo, 2018.

Vázquez-Moreno, L. L. *La territorialización de la producción agroalimentaria sobre bases agroecológicas en Cuba*. Medellín, Colombia: Centro Latinoamericano de Investigaciones Agroecológicas-CELIA. https://www.biodiversidadla.org/Documentos/La-territorializacion-de-la-produccion-agroalimentaria-sobre-bases-agroecologicas-en-Cuba. 2020.