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Feeding leucaena to dairy cows in intensive silvopastoral systems in Colombia and Mexico

Leucaena como alimento para vacas lecheras en sistemas silvopastoriles intensivos en Colombia y México

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Abstract

The demand for milk and dairy products globally is expected to grow in future decades, leading to an increase in the global dairy cattle population. Therefore it is important to identify production options that both improve efficiency and help reduce negative effects on the environment. Intensive silvopastoral systems have been proposed as a sustainable strategy in the tropics to increase the availability and quality of forage throughout the year for milk production from cattle. This paper reports the effects of silvopastoral systems that include leucaena at the farm level on milk production and on the environment in both Colombia and Mexico. Evaluation of different milk production systems has shown that the leucaena-based systems increased milk production both per cow and per hectare, increased the production of milk solids, improved the fatty acid profile in the milk and resulted in environmental benefits when compared with conventional systems.

Keywords: Cattle, environmental benefits, grazing, milk solids, profit, tree legumes.

Resumen

Se espera que la demanda de leche y productos lácteos a nivel mundial crezca en las próximas décadas, lo que llevará a un aumento de la población de ganado lechero en todo el mundo. Debido a esto, es importante identificar opciones de producción ganadera que mejoren la eficiencia y ayuden a reducir los efectos negativos sobre el medio ambiente. En las últimas décadas, se han propuesto los sistemas silvopastoriles intensivos como una estrategia sostenible en el trópico para aumentar la disponibilidad y la calidad del forraje durante todo el año para la producción de leche bovina. Este documento informa sobre los efectos de los sistemas silvopastoriles con leucaena a nivel de finca sobre la producción de leche y cómo estos pueden ser más amigables con el medio ambiente en Colombia y México. La evaluación de diferentes sistemas de producción de leche ha demostrado que los sistemas basados en leucaena aumentan la productividad tanto por unidad animal como por unidad de área, aumentando de igual forma la producción de sólidos lácteos, mejoran el perfil de ácidos grasos en la leche y aportan beneficios ambientales en comparación con los sistemas convencionales.

Palabras clave: Beneficios ambientales, ganado bovino, leguminosas arbóreas, pastoreo, rentabilidad, sólidos en leche.

Introduction

It is projected that the world's demand for animal protein will continue to grow during future decades as a result of increases in global population, income per capita and the percentage of people living in urban areas (Alexandratos and Bruinsma 2012). In particular the demand for milk and dairy products is expected to grow by 58% between 2010 and 2030, and world milk production is projected to increase by 177 Mt (23%) by 2025 compared with the

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base years (2013–15), corresponding to an average growth rate of 1.8% per annum (OECD/FAO 2017).

To achieve these production levels an increase in world milk production of 35% or 300 Mt will be required. Therefore, it is important to identify livestock production systems that improve efficiency and reduce negative effects on the environment while fulfilling the demand for good quality food in an economically efficient manner (Thornton and Herrero 2010).

Intensive silvopastoral systems (ISPS) have been advanced as sustainable strategies in the tropics to increase the availability and quality of forage throughout the year for milk production from cattle (Chará et al. 2017). In addition, these systems are claimed to reduce or reverse the negative environmental impacts of cattle ranching, while increasing animal production and economic performance. With these systems it is also possible to certify milk and cheese as organic products (Nahed-Toral et al. 2013), thereby justifying improved prices (Solís-Méndez et al. 2013). For example, some leucaena-based systems in Colombia have been certified organic for more than 20 years, with milk products such as long-life milk without additives in either the milk or the animal diet.

This paper reports the effects of ISPS with leucaena (*Leucaena leucocephala*) on milk production and environmental outcomes at the farm level. For more than 20 years in Colombia, different systems of milk production have been evaluated. The leucaena-based systems have increased milk production per cow and per hectare, increased the production of milk solids and improved the fatty acid profile of milk, when compared with conventional systems (Rivera et al. 2009; Prieto-Manrique et al. 2018).

ISPS are a type of silvopastoral system that combines high-density cultivation of fodder shrubs (4,000–40,000 plants/ha) with: (i) improved tropical grasses; and (ii) tree or palm species at densities of 100–600 trees/ha. These systems are rotationally grazed for periods of 12–24 hours followed by 40–50 day resting periods (Chará et al. 2017) (Figures 1 and 2). On the other hand, typical traditional systems in Colombia are characterized by: low stocking rates (fewer than 0.6 AU/ha; AU = 450 kg dry animal), the use of grass monocultures, low biomass and animal production, low fodder quality and low animal reproductive performance (González et al. 2015).

Intensive silvopastoral systems with *Leucaena leucocephala* for milk production

In the Valle del Cauca department in Colombia for example (El Hatico farm), ISPS with *L. leucocephala* interspersed with highly productive improved pastures (*Megathyrsus maximus* and *Cynodon plectostachyus*), native multipurpose trees and palms (25–100 trees/ha) have been evaluated for many years (Figure 3).

Figure 1. ISPS with leucaena, *Cynodon plectostachyus* and *Megathyrsus maximus* grazed by Brahman breed animals in a dual-purpose system. El Porvenir, Cesar, Colombia. (Photo: Claudia Córdoba)

Figure 2. ISPS with leucaena with more than 20 years of continuous production. El Chaco, Tolima, Colombia. (Photo: Julián Rivera)

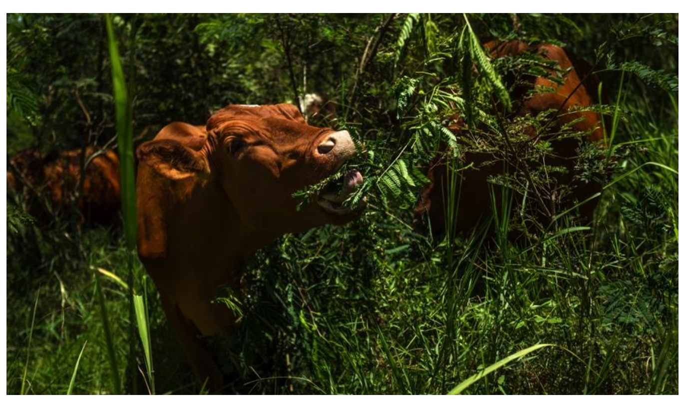

Figure 3. ISPS with leucaena and *Megathyrsus maximus* grazed by Lucerna breed animals in a tropical dairy system. El Hatico, Valle del Cauca, Colombia. (Photo: M. Kohut)

After establishing the silvopastoral system, there was an increase in both quantity and quality of forage. Forage dry matter (DM) production increased by an average of 17% compared with the initial situation (a grass monoculture with fertilizer application and irrigation, concentrate feed use and high production costs). Although leucaena shrubs planted at high density directly produced only 20% of the total DM/yr, through their N contribution, total DM production in the ISPS increased from 24 to 36 t/ha/yr. Thus, this system can produce up to 47% more biomass than treeless pastures (Calle et al. 2013; Gaviria et al. 2015). By incorporating leucaena and scattered trees on El Hatico farm, the use of chemical fertilizers was eliminated from the grazing system, which once relied on the application of 400 kg urea/ha/year (equivalent to 184 kg N). Average milk production was maintained at 12,000 L/ha/yr for more than 20 years without relying on the use of concentrate feeds (Calle et al. 2013).

Another example is Lucerna farm, where in the 1990s African star grass (*Cynodon plectostachyus*) monocultures supported a stocking rate of 3.5 cows/ha and produced 9,000 L milk/ha/yr, but required N fertilizer application (450–500 kg urea/ha/yr). Since converting to ISPS with 10,000 *L. leucocephala* shrubs/ha, the same farm now supports up to 4.5 cows per hectare, produces 15,000 L milk/ha/yr and requires no fertilizer or concentrate feeds on areas that have had 28 years of continuous production (Chará et al. 2017; Rivera-Herrera et al. 2017).

In the Colombian dry Caribe region, Rivera et al. (2009) reported production of 5,551 L milk/ha/yr in ISPS with leucaena (10,000 shrubs/ha), *C. plectostachyus* and *M. maximus* (Figure 1) but only 1,150 L milk/ha/yr in a conventional grass pasture without trees. In Brazil, Paciullo et al. (2014) reported that incorporating leucaena in *Urochloa decumbens* pasture increased milk production from 9.5 to 10.4 L/cow/d ($P<0.05$).

The concentrations of protein, fat and total solids in the milk from ISPS were significantly higher ($P<0.05$) than from pure grass pastures with yields of 0.15 vs. 0.13 kg/cow/day, 0.22 vs. 0.17 kg/cow/day and 0.59 vs. 0.51 kg/cow/day for the ISPS and conventional system, respectively (Rivera et al. 2009). Another benefit leucaena offers is the modification of the fatty acid profile of the milk. Prieto-Manrique et al. (2018) observed that cows in ISPS produced higher amounts of polyunsaturated fatty acids than cows in conventional systems fed grass plus concentrates. Unsaturated fatty acids such as c9t11 conjugated linoleic acid, t11 transvaccenic acid and some long-chain n-3 fatty acids in bovine milk are associated with human health benefits, e.g. reduced incidence of heart disease (Livingstone et al. 2012).

With the higher milk solids from ISPS, the characteristics of the milk produced allow for increased yields of dairy products and improved efficiency in the transformation of milk to cheese, when compared with milk produced by animals fed grass plus sorghum grain (Mohammed et al. 2016). In spite of using lower supplementation, the ISPS did not differ from the conventional system regarding production, according to Mohammed et al. (2016), who also indicated higher profitability in the system with leucaena. González (2013) estimated internal rates of return (IRR) of 13% in systems involving leucaena and only 0.7% in conventional systems in Mexico and Colombia. In World Animal Protection et al. (2014), it is reported that once the system is established, maintenance costs are lowered due to the reduction in external inputs such as fertilizers, mineralized salts and concentrate feeds. After the initial investment and a stabilization period, the higher productivity per hectare generates returns that ensure the economic viability of ISPS. Analyzing financial data identified that, after the 4th year, income exceeds costs resulting in a positive balance in cash flow, achieving situations of economic surplus. For this study, farm income and profitability were 56 and 72% higher, respectively, than those of the traditional system (grass monoculture with high concentrate feed use) (Reyes et al. 2016).

Finally, with respect to environmental issues, Rivera et al. (2016) found lower emissions of greenhouse gases (GHG) from ISPS involving leucaena and *C. plectostachyus* rotationally grazed (1 day grazing and 28 days rest) than from a conventional system. To produce one kg of fat-and-protein-corrected milk (FPCM), the ISPS emitted 12.3% less GHG (2.05 vs. 2.34 kg CO_2-eq). Regarding the use of non-renewable energy, the ISPS required only 63% of the energy used in the conventional system to produce one kg FPCM (3.64 vs. 5.81 MJ/kg). In the context of climate change, systems with leucaena can produce milk more consistently in times of severe drought, e.g. during periods of El Niño. The shade provided by the trees reduces soil moisture losses and soil biological activity is increased, especially dung beetle activity, allowing the resilience of the system through periods of drought (Chará et al. 2017).

The mechanisms that explain the productive responses from the ISPS include an increase in forage supply, greater intake of dry matter and improved nutritive value of the pastures. Animals grazing in ISPS including leucaena have DM intakes up to 30% higher than those grazing in conventional systems (Cuartas et al. 2015). This could be a function of higher forage on offer in the ISPS, which can be up to 330% higher than that of conventional systems based only on tropical grass monocultures, allowing higher selectivity for the animals (Broom et al. 2013; Gaviria et al. 2015).

According to Gaviria et al. (2015) and Cuartas et al. (2015), including leucaena at 25% of the diet with *M. maximus* and *C. plectostachyus* could lower neutral detergent fiber (NDF) concentration in the total ration by 15%, while the acid detergent fiber (ADF) concentration could be reduced by 20%. The low fiber concentration in the diet improves intake by allowing higher passage rates (Boval and Dixon 2012). In addition, legume particles are cubic, while grass particles are long and thin, which implies higher passage rates in such species as *L. leucocephala* (Barahona and Sánchez 2005). An added benefit is that ISPS with *L. leucocephala* provide higher thermal comfort for the animals, so they can dedicate more time to browsing and grazing, because they have possibilities of ingesting a higher biomass quantity (Broom et al. 2013). Molina et al. (2016) reported that including *L. leucocephala* at 24% of the diet of growing heifers increased DM intake from 2.02 to 2.47% of the animal live weight (P=0.01).

From a nutritional point of view, an aspect to be considered is the digestibility of the legume, which describes the quantity of truly available nutrients for the animal. Although leucaena has a lower digestibility than some forage species due to the presence of secondary metabolites such as condensed tannins, its combination with lower quality grasses increases the degradability of the total forage, which increases the availability of nutrients to be used by rumen microflora and by the animal itself. Other desirable attributes are the high protein concentration, low fiber percentages and acceptable non-structural carbohydrate values (rapidly soluble carbohydrates).

Final considerations

Intensive silvopastoral systems incorporating leucaena constitute a sustainable strategy to increase the availability and quality of forage throughout the year for milk production from cattle in the tropics. Relative to grass monocultures ISPS can: produce more edible dry matter and nutrients per hectare (more crude protein and less fiber); increase milk production due to higher diet quality while reducing the need for chemical fertilizers and concentrate feeds; improve farm profitability; increase carbon sequestration and reduce methane emissions from enteric fermentation; and contribute to improved animal welfare and biodiversity.

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(Note of the editors: All hyperlinks were verified 11 August 2019.)

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