Characterizing the seasonal pattern of milk production of Dual Purpose Cattle System farms from East El Salvador

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ABSTRACT

The objective of this research was to characterize the multiple production and the seasonal pattern of milk production of dual purpose cattle system (DPCS) farms from east zone of El Salvador. To take into account the seasonal pattern in production, the yearly operation of farms was divided into two seasons: rainy (May through October) and dry (November through April). Data were collected by interviewing of farmers from three municipalities; the statistical analyses were descriptive and comparison test. Results showed that all farms produced milk (44 ± 48 L.day^{-1}) and meat (4 ± 4.3 steers), 34% produced dairy products (103 ± 131 kg.month^{-1} white cheese), and 81% produced maize (3.3 tons) and sorghum (1.1 tons). The analysis of seasonal variation showed that there was more milk production with a pasture-based diet, more milking cows, and less labor in the rainy season than in the dry season, in which stored feeding, less milking cows, and more labor were used. Milk production, herd size, milking cows, and labor were significantly different between seasons (P<0.05). Given the annual cycle of operation, farmers rely on the practice of the seasonal pattern to optimize milk yield, to produce weaned steers, dairy products, maize and sorghum, and to match supply of abundant and inexpensive grasses, which minimize feed cost and labor.

Keywords: dry season, milk artisan, milk seasonality, rainy season,

Caracterización del patrón estacional de producción de leche en granjas Doble Propósito del oriente de El Salvador

RESUMEN

El objetivo del presente estudio fue caracterizar la producción múltiple y el patrón estacional de producción de leche en granjas del sistema doble propósito (DP) del oriente de El Salvador. Para considerar el patrón estacional de la producción, la operación anual de las granjas se dividió en dos estaciones, invierno (mayo-octubre) y verano (noviembre-abril). Los datos fueron colectados mediante una entrevista a ganaderos de tres municipios seleccionados; para el análisis se utilizaron tablas de comparación y estadística descriptiva. Los resultados mostraron que todas las granjas produjeron leche (44 ± 48 l.día^{-1}) y carne (4 ± 4,3 novillos), 34% productos lácteos (103 ± 131 kg.mes^{-1} queso) y 81% maíz (3,3 t) y sorgo (1,1 t). El análisis de la variación estacional mostró que en invierno hubo mayor producción de leche con una alimentación a base de pastos, mayor proporción de vacas en ordeño y menos mano de obra, comparada con el verano que mostró menos vacas en ordeño, más mano de obra y dependencia de alimentos almacenados. Las variables cantidad de leche, tamaño del hato, vacas en ordeño y mano de obra fueron diferentes entre las dos estaciones (P<0,05). Dado un ciclo anual de operación, los agricultores dependen de la práctica del patrón estacional para optimizar el rendimiento de leche, producir novillos destetados, productos lácteos, maíz y sorgo y coincidir con el suministro abundante de pastos, lo cual minimiza costo de alimentación y mano de obra.

Palabras clave: verano, procesadores artesanales, invierno, estacionalidad de la leche

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INTRODUCTION

Milk producers in El Salvador have been classified in three groups, based on the level of technology: traditional or subsistence (30%), semi-specialized or dual-purpose cattle system (DPCS) (67%), and specialized or dairy farms (3%) (CAMAGRO and BMI 2006). DPCS farms produce most of the milk (65%) and beef (30%) in the country (Garcia-Ramirez 2010).

The DPCS farms use crossbred cows (Bos taurus and Bos indicus) to produce milk and meat (weaned steers). In addition to these two products, DPCS and subsistence farms are also known to produce maize (staple food) and sorghum (livestock feed). Another important characteristic in the operation of this production system is the marked pattern of seasonal production of milk: milk seasonality. Seasonality refers to the variation of milk supply during the year (Oltenacu *et al.* 1989). Researchers studying the seasonality of milk production from specialized dairy farms have commonly divided the yearly production between seasons to estimate seasonal differences (Oltenacu *et al.* 1989; Allore *et al.* 1997; Sheen and Riesco 2002).

The seasonality of milk production of specialized dairy farms has been explained by the higher proportion of cows calving during the beginning of spring (grass-growing season) in New Zealand (Garcia and Holmes 1999) and the United States (Kaiser *et al.* 1988; Sun *et al*. 1995). Moreover, in the United States, other management practices such as confinement or pasture based systems, feeding type, calving date, and herd size have been found to be associated with seasonality. In tropical environments two marked seasons are observed: the rainy season (May to October) and the dry season (November to April; MAG 2003). In El Salvador DPCS farmers supply more milk in the rainy season than in the dry season (MAG 2003).

On the other hand, the characterization is a tool to evaluate production systems (Connell *et al.* 2007), and it is defined as the description of the principal characteristics and multiple interrelationship of group of farmers (Bolaños 1999). This is important because it provides basic information to policy makers and managers that allows them to implement appropriate strategies to develop and standardize the operation of farmers (Cabrera *et al.* 2004), as well as to provide the basis for future investigations (Juárez-Barrientos *et al.* 2015). The first step to obtain information of a production system is to describe aspects such as component, context, interaction and output.

El Salvador lacks characterization studies of DPCS farms. Qualitative and quantitative studies describe the DPCS as also the main system to produce milk at the continental level. The operation of this production system are found in Colombia (Salamanca *et al.* 2011; Cortés-Mora *et al.* 2012), Costa Rica (Holguín *et al.* 2003), Mexico (Vilaboa-Arroniz and Díaz-Rivera 2009; Chalate-Molina *et al.* 2010; Orantes-Zebadúa *et al.* 2014; Juárez-Barrientos e*t al.* 2015; Cuevas-Reyes *et al.* 2016), and Venezuela (Paez and Jiménez 2000; Páez *et al*. 2003; Connell *et al.* 2007; González *et al.* 2011)

The DPCS farms in these studies vary regarding size of herd and farmland, labor, farmer education, and level of technology within and among countries. However, some common features of the production system across studies are the production of milk and meat, grass-fed cows, and crossbred animals.

Researchers characterizing the DPCS have excluded two important characteristics shared by these systems, the seasonal pattern of milk production and the planting of crops, practiced by fewer farmers. This seasonal pattern of milk production developed by the DPCS of America may be the result of the interaction among environmental, technical, and socio-economic factors; while the crop-output may be a product produce by this system; both, interaction and multiple production are important aspects of the system.

Moreover, the normal protocol to describe the operation of DPCS farms is to use data of the total or average quantity of output and input in a time span (e.g., month or year). This common procedure may not account for the seasonal changes in output as well as in inputs. Therefore, the objective of this study was to characterize the multiple production and the seasonal pattern of milk production of the DPCS, traditional and

semi-specialized farmers located in three municipalities in the eastern zone of El Salvador.

MATERIALS AND METHODS

The study area was in the Department of Morazán located in the east zone of El Salvador (13°35'N latitude and 88°07'W longitude), where the highest cattle population is located. The east zone is comprised of four Departments and they accounted for 52% (30,344 farmers) of the cattle farmers and 43% of the national herd (MINEC 2007). The municipalities of Guatajiagua, Semsembra, and Yamabal (Figure 1) were selected for their location respect to the major cattle area in the country, long history in cattle farming (more than 50 years), and their economic activity is based on the production of cattle, maize, and sorghum.

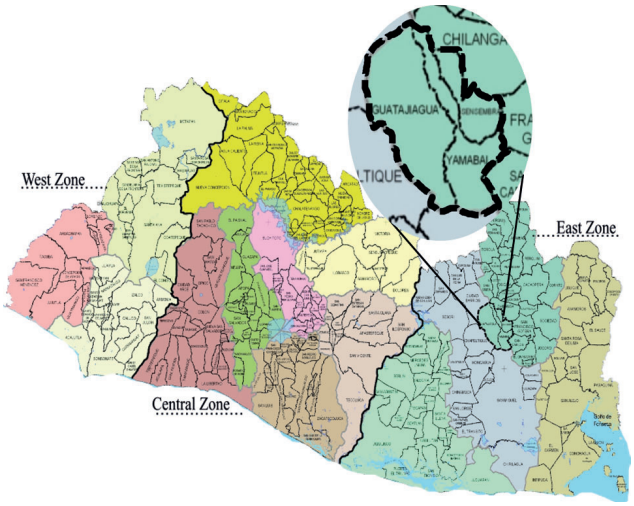

Figure 1. Location of the study, Morazán El Salvador (SNET 2012)

The specific number of cattle farms in the three Municipalities was unavailable, but based on the 2007 Agricultural Census, there are 207, 198, and 196 livestock farms in Guatajiagua, Semsembra, and Yamabal respectively.

A questionnaire was designed to elicit information readily provided by farmers regarding the farm operation (Holguín *et al.* 2003; Chalate-Molina *et al.* 2010; Campos-Ramírez and Urrutia-Vásquez 2014; Juárez-Barrientos *et al.* 2015). The information was compiled in four main aspects:

1. - Related to milk production, such as herd size, lactating cows, feedstuff, labor (family or hired), forage, daily milk produce, daily milk process, dairy products (white cheese, cream, cottage cheese), processors classification (small and large processors groups) and farmland.

2. - Related to objectives and goals, such as milk sells or process, subsistence, selling place.

3. - Related to output beef, sorghum, and maize productions, such as number of male and female calves, selling time, area planted.

4. - Related to socio-demographic characteristics.

The questionnaire survey was targeted to all farmers engaged on dairy farming in the three selected municipalities from the Department of Morazán and was applicated using a face-to-face interview to farmers, during the dry season of 2011. For describing the seasonal pattern of farm operation, the yearly production was divided into rainy season (May to October) and dry season (November to April), based on the classification of the country and as commonly done by previous studies on seasonal effect (Oltenacu *et al.* 1989; Allore *et al.* 1997; Sheen and Riesco 2002; Thuranira-McKeever *et al.* 2010). The data corresponded to the production periods of the rainy season in 2010 and the dry season in 2011 for each farmer.

Those farmers processing milk were grouped into small (less than 100 $L.day^{-1}$) and large (more than 100 $L.day^{-1}$). To estimate the forages quantity consumed per farm in each season, we report the forage supply in these seasons through the description of the forage used and the size of the farmland. To provide additional information to the seasonal variation of milk production, the calving month pattern was determined using data from a farm under study which recorded the calving period. The data included calving information of 13 cows, from 2006 to 2011.

Wilcoxon matched pair test was used to test for season-to-season change in variables

(significance was accepted at P<0.05), and descriptive statistics to describe other farm variables.

RESULTS AND DISCUSSION

A total of 126 cattle farmers were identified, from which 33 were either unreached or unwilling to answer the questionnaire. The valid responses were 89 farmers and local artisan (milk processors; there were 28 that produce their own milk for processing), which included the full population for the municipality of Sensembra (14) and Yamabal (60). All farmers fell into the category of subsistence and DPCS farms, which was needed for the analysis. Four more farmers that only bought milk for processing dairy products were added to the seasonal comparison analysis.

Of the 93 farmers interviewed, 87% were male and 13% females. The average age was 54 years but varied between 20 and 86 years. From all the respondents, 26% had zero level of education, 26% had between one and five years, 27% had between five and ten years, and 21% more than ten years of education. Most respondents owned the land (84%) and were full time employed (84%).

The farmers milk production objective revealed three categories: milk seller (56%), milk processor (34%), and milk consumer (10%). The milk sellers produced milk for selling at the farm gate to local processors (Table 1); the milk processors produced milk for processing and selling dairy products to retailers of the nearby city, San Miguel; the milk consumers produced milk for own consumption. The high variability (SD larger than the mean) of farmers' subcategories can be attributed to the quantity of milk produce by small and large groups.

Results revealed that DPCS farmers produced five types of outputs: milk, dairy products, weaned steers, maize, and sorghum (Table 2). Some farmers (milk processors) processed their milk produce into white cheese, cream, and cottage cheese, in which the former was the main item.

All farmers were selling weaned steers, since this is a common product of the dual purpose cattle system. The weaned steers (48% of total calves; n = 340) were sold at farm gate to intermediaries. Regarding the selling age of the weaned steers, 45% of the farmers responded it was 18 months old; 23%, 24 months; 17%, 12 months, and 15% said other ages.

Most of the farmers (81%) also planted maize in plots of 1.07 ha (SD = 2.34) and sorghum 1.10 ha (SD = 1.69), with an average yield of about 3.30 and 1.10 tons.ha^{-1}, respectively. Maize, the staple food in the country, and sorghum, livestock feeding, were destined for either own consumption or sale. Regarding the crop production, two types of by-products were derived and used to feed the cows for dry season: maize and sorghum stovers.

Farmers shift from pasture to stored forages to feed the cow between the rainy and dry seasons. This has been mentioned in the country as one of the main factors causing the seasonal milk supply (Garcia-Ramirez 2011). The farmers under study practiced this feeding pattern. Results showed that in the rainy season cows grazed on pastures.

The average stocking rate was 1.88 (SD = 1.80) animals per ha. Most of the grassing land (65%) was covered with native pastures such as chompipe (*Ixophorus unisetus*), jaragua (*Hiparrenia rufa*), and zaleas (*Brachiaria decumbens*). From total farmland, 475 ha (35%) were planted with improved grasses, including

Table 1. Production of milk by farmers group[1]

Group	% of farmers	Dry season		Rainy season	
		Mean (L)	SD[2]	Mean (L)	SD[2]
Milk seller	56	32.1	37.8	40.9	44.6
Milk processor	34	49.2	65.7	58.3	68.6
Milk consumers	10	5.5	4.3	5.9	5.3

[1]Milk suckled by calves is not counted.

[2]Standard deviation.

callie (*Cynodon dactylon,* var. callie), carimagua (*Andropogon gayanus*), and swazi (*Digitaria swazilandensis*). Half of the farmers reported having had jaragua (*H. rufa*), which covered 75% (359 ha) of the area with improved pasture.

The stored forages comprised the feeding of cattle in dry season. About half of the farmers, 54%, used chopped stovers from maize and sorghum, 10% used silage, 9% used cut green forage, and 27% used both chopped stover and silage. Forage stovers, is a by-product obtained from the on-farm production of maize and sorghum (81% of farmers). Silage was prepared (37% of farmers) from sorghum (*Sorghum vulgare*, var. sweet), maize (*Zea maize*), and king grass (*Pennisetum hybridum*); the area planted totaled 29 ha, in average plots of 0.51 ha (SD = 0.97). Additionally, 93% of the farmers used feed concentrate, monthly gross consumption was 103 tons, 690 kg (SD = 835) per farm.

The results of comparing the level of inputs and outputs between the dry and rainy seasons are presented in Table 3. Compared to the values presented in Table 1 and 2, less variability (SD smaller than the mean) was observed in the outputs when divided by small and large groups; for instance, the daily milk process and white cheese showed a SD smaller than the mean (lower half of Table 3). The seasonal pattern was observed in two sub categories of outputs and in the two selected inputs. Labor and herd size were significantly different between seasons. Similarly, the outputs of daily milk produce and daily milk process were statistically different between seasons (see Table 3).

Although the data used to determine the calving pattern is insufficient to represent the complete sample, it provides useful additional information. The month with the highest calving frequency was July (four calving), followed by May (three calving), June and February (two calving), and the least frequent, January and September (one calving). The average monthly rate of calving was 5.5, 9 calving out of 13 were in the first three months of the rainy season (mid-May: beginning of rainy season), when cows are grass-fed during the rainy season.

The higher milk supply from the DPCS farms could be due to a higher proportion of parturitions during this season. In specialized dairy farms, the higher proportion of cows calving during spring (grass-growing season) explains the seasonal differences on milk production (Garcia and Holmes 1999). Cows are milked at peak lactation stage, during spring-summer, and then reach the other seasons, fall-winter, at the decreasing phase.

Seasonal changes in milk quantity suggest that farmers may adjust the level of input used to that of output produced; the inputs labor and herd size results may show evidences. Labor is a

Table 2. Outputs of DPCS farmers.

Item	Dry season		Rainy season		% of farmers
	Mean	SD[2]	Mean	SD	
Milk (daily; L)[1]	36	53	44	48	100
Dairy products (monthly):					38
*- White cheese (kg)	94	103	103	131	
*- Cottage cheese (total; kg)	404		618		
*- Cream (total; L)	930		1,098		
Weaned steers (per farm)	4	4.3			100
Maize (tons.farm^{-1})			3.3		81
Sorghum (tons)			1.1		81

[1]Milk suckled by calves is not counted.

[2]Standard deviation

Table 3. Average inputs and outputs per cattle farmer between seasons in east zone of El Salvador (n = 89), (Wilcoxon Matched Pair Test).

Variable	Dry season			Rainy season			z	P-values
	Total	Mean	SD	Total	Mean	SD		
Inputs								
Labor (full time equivalent)	94.5	1.06	0.69	68.3	0.76	0.57	5.28*	<0.001
*- Family labor	47.5	0.71	0.36	36.0	0.51	0.39	2.86*	0.004
*- Hired labor	47.0	1.11	0.54	32.3	0.89	0.63	3.47*	<0.001
Herd (animal)[1]	1833	20.6	18.7	2085	23.4	23.5	2.11*	0.0
*- Lactating cow	709	7.97	7.39	774	8.69	8.61	2.01*	0.05
Farmland (ha)				1384	15.5	13.9		
Outputs								
Daily milk (L)[2]	3183	35.8	48.5	3916	44.0	53.4	3.20*	0.00136
Small processors								
Daily milk process (L)	938	34.6	24.2	1194	43.8	34.6	1.83	0.07
White cheese (kg/month)	2556	103	131	2512	94.1	103	0.42	0.67
Large group								
Daily milk process (L)	1480	247	83.4	1718	286	86.5	2.02*	0.04
White cheese (Kg/month)	4013	669	335	4054	676	332	0.66	0.50

*Level of significance at P<0.05

[1]animals older than 1.5 years

[2]Does not include the milk suckled by calves

basic input in any agriculture process and in the present study, this input was found to significantly change between the two seasons; labor input was excluded by previous studies estimating the seasonal effect on dairy farms (Ray *et al.* 1992; Thuranira-McKeever *et al.* 2010). Results showed that farmers needed more labor (including family and hired) to produce milk in the dry season than what they needed in the rainy season. The higher labor needed in the dry season (27.7%), though the average cows per worker fell 36% to 18 cows (SD = 10.5), was to feed the animals twice or three times a day, carry forage, and handle the manure.

The less labor demand for milk production during rainy season gives a surplus that could have been used for planting maize, sorghum, and preparing silage for the dry season. Despite of using more labor in the dry season production, the output per worker was lower (M = 27.5 liter of milk, SD = 19.4) than that of the rainy season (M = 51.0 liters of milk, SD = 38.5).

The number of animals kept in the rainy season was larger than those kept in the dry season. More milking cows were also kept in the rainy season than in the dry season. The decrease in herds might be explained by the sale of weaned steers before the beginning of the dry season, when animals are fed on stored forages, while the decrease in the milking cows might be related to the dry-off of cows.

The calving pattern, indeed, showed a higher proportion of cows calving at the beginning of the rainy season, and those cows may be then dried-off in the dry season, because under the pasture-based system the lactation length is shorter. Another factor justifying the decreased number of animals (herd and milking cow) in the dry season compared to rainy season could be the higher feed costs per cow and more labor needed to manage them. In this system, stored forages for milk production are the largest cost, compared with pastures (Benson 2008; Alfonso-Avila *et al.* 2012). Thus to reduce feed costs and labor, a smaller herd and less milking cows might

have been planned in the dry season, and then a greater proportion of cows may be scheduled to calve in the rainy season to fully take advantage of the low cost grasses and less labor.

On the other hand, results showed that daily milk produced in the rainy season was significantly higher, 18.7% compared to the dry season. The higher milk production may have resulted from the greater proportion of cows (65 cows) calving at the beginning of the rainy season. These cows could have been milked at peak lactation phase during the rainy season and then reached the dry season at decreasing phase or having been dry-off, overall, having more milk in the rainy season than in the dry season.

Daily milk process by small and large group in the rainy season was higher, 21.4% and 13.6%, compared to the dry season, with significant differences only for large group (small: $Z = 1.83$, $P<0.07$). The uneven milk supply of processors between seasons could have been expected since it has already explained that a greater proportion of cows at peak yield of lactation may have been planned for the rainy season.

However, the monthly productions of white cheese by the two groups were not significantly different between the two seasons (small: $Z = 0.42$, $P>0.67$; large: $z = 0.66$, $P>0.50$). In addition, the quantity produced of other dairy products, cream (dry: 1,098 liters.month^{-1}; rainy: 930 liters.month^{-1}) and cottage cheese (dry: 618 kg.month^{-1}; rainy: 404 kg.month^{-1}) was actually greater in the dry season than in the rainy season.

This greater quantity of dairy products in the dry season, though milk processed was 21.4% (small group) and 13.6% (large) less, may be attributed to changes in the milk composition through the interactive influence of lactation stage and feeding type. Tropical grasses are characterized by low quality for milk production (Aguilares-Peréz *et al.* 2009; Tinoco-Magaña *et al.* 2012).

Insufficient fiber and dry matter intake caused by the poor quality pasture, might have downwardly shifted both fat and protein content, which was in the trough at the beginning of lactation stage of cow. Whereas the forages chopped stovers, silage, and concentrate might have upwardly shifted the fat and protein content, which was in the peak at the end of lactation stage of cow. Thus, farmers may have obtained the higher quantity of milk products during the dry season compared to the rainy season.

The calving pattern seems to be synchronized with the time of sale of weaned steers. We make this statement based on the following premises: a greater proportion of the farmers (45%) reported to sell the weaned steers when they reach 18 months of age. Fixing mid-May as the calving month, the 18 months were completed in mid-October (last month of rainy season) of the next year. If calves were weaned at 12-month old, then they could be grazed during the six months of the rainy season, when forage supply is inexpensive and abundant, and sold when they reached the 18 months (mid-October). October is reported as one of the highest selling months for beef in the most important cattle traditional-market located in east zone El Salvador[1]. This situation may imply the effect of the calving pattern to the beef markets.

Seasonal pattern, through scheduling of cows calving, seems to play a profound effect on operation of DPCS farms in El Salvador. Dairy farmers from New Zealand have developed a similar pattern of seasonal production, which is highly efficient with minimal need for housing, effluence disposal, machinery, and expensive feeding system (White *et al.* 2002; Verkerk 2003). These characteristics are overall observed in the operation of DPCS farmers.

As a final consideration, important advances could be attained for farmers if research is done in the relationship and interaction between the date of calving and the lactation curve shape, milk composition, feeding strategies, lactation length, and reproduction.

CONCLUSIONS

This study characterized the operation of DPCS farms under the seasonal pattern of milk production in eastern El Salvador. From the questionnaire survey, the results showed the diversified production of farmers operating

[1]Vijil, JC. 21 julio 2009. Beef market price in San Miguel (oral communication). San Miguel, El Salvador. Centro de Agronegocios San Miguel.

DPCS. Farmers integrated production of milk, dairy products, beef, maize, and sorghum.

Integrating cattle production and crops was important for farmers, because it allowed the use of by-product as feed for animals during the dry season. Future analysis on profitability, resilience and sustainability of the seasonal and multi-output production of DPCS farms could provide valuable knowledge of this farming system.

Dividing the operation into rainy and dry seasons was more appropriate to describe the farms under the seasonal pattern of milk production. Adopting the approach of two different operation practices between seasons revealed better understanding of this production system.

For an annual operation, the seasonal pattern of milk production may be important to maximize milk yield, combine production of meat, dairy products, crops, and to match supply of low cost grasses.

For the dairy industry to be successfully developed, the government must considered constructing from the seasonal pattern of production; this pattern is farmers' response to the adaptation of dairying after combined the capital, labor, and natural endowment.

CITED LITERATURE

Aguilares-Peréz, C; Ku-Vera, J; Garnsworthy, PC. 2009. Effect of bypass fat on energy balance, milk production and reproduction in grazing crossbred cows in the tropics. Livestock Science 121(2009): 64-71.

Alfonso-Vila, AR; Wattiauz, MA; Espinosa-Ortega, A; Sanches-Vera, A; Arriaga-Jordan, CM. 2012. Local feeding strategies and milk composition in small-scale dairy production systems during the rainy season in the highland of Mexico. Tropical Animal Health and Production 44:637-644.

Allore, HG; Oltenacu, PA; N. Erb, NH. 1997. Effects of seasons, herd size, and geographic region on the composition and quality of milk in the Northeast. Journal of Dairy Science 80:3040-3049.

Benson, AG. 2008. Pasture-based and confinement dairy farming in the United States: an assessment. Journal of International Farm Management 4(2):1-16.

Bolaños, O. 1999. Caracterización y tipificación de organizaciones de productores y productoras. IX Congreso Nacional Agronómico / I Congreso Nacional de Extensión. Costa Rica: 31-39.

Cabrera, D; García-Martínez, VA; de la Cruz, RA; Castaldo, A; Perea, JM; Peinado, JM. 2004. Metodología para la caracterización y tipificación de sistemas ganaderos. Departamento de Produccion Animal Universidad de Cordoba 1(2004):1-9.

CAMAGRO (Cámara Agropecuaria y Agroindustrial); BMI (Banco Multisectorial de inversionaes). 2006. Cadena agroproductiva del subsector lácteos en El Salvador. San Salvador, El Salvador. BMI & CAMAGRO: 127 p.

Campos-Ramírez, VI; Urrutia-Vásquez, FA. 2014. Caracterización y georeferenciación de explotaciones de ganado bovino para su uso en vigilancia epidemiológica en el municipio de Sonsonate, departamento de Sonsonate. Tesis Lic. San Salvador, El Salvador, Universidad de El Salvador. 92 p.

Chalate-Molina, H; Gallardo-López, F; Pérez-Hernández, P; Lang-Ovalle, FP; Ortega-Jiménez E; Vilaboa-Arroniz, J. 2010. Características del sistema de producción bovinos de doble propósito en el estado de Morelos, México. Zootecnia Tropical 28(3):1-13.

Connell, J; Navarro, L; Torrealba, M; Rodríguez, I; Guevara, E; Ramírez, M; Alfaro, C; Tirado, H. 2007. Caracterización técnica-productiva de los sistemas ganaderos del sur del estado Anzoátegui. Manejo del recurso pastizal. Zootecnia Tropical 25(3):201-204.

Cortés-Mora, J; Cortéz-Torres A; Cortéz-Torres, J. 2012. Características estructurales del sistema de producción con bovinos de doble propósito en el trópico húmedo colombiano. Revista Colombiana de Ciencias Pecuarias 25:229-239.

Cuevas Reyes, V; Loaiza Meza, A; Espinosa García, JA; Vélez Izquierdo, A; Montoya Flores, MD. 2016. Tipología de las explotaciones ganaderas de bovinos doble propósito en Sinaloa, México. Revista Mexicana de Ciencias Pecuarias 7(1):69-83

García-Ramírez, RA. 2010. Desarrollo de la cadena de valor para los productos lacteos: modelo productivo para las MIPYME del sector lacteo de El Salvador. San Salvador, El Salvador. Ministerio de Economia. 29 p. (Serie técnica). Informe Técnico n°1.

García-Ramírez, RA. 2011. Desarrollo de la cadena de valor para los productos lácteos: Modelos productivos para las MIPYMES del Sector lácteo de El Salvador. San Salvador, El Salvador. Ministerio de Economía. 45 p. (Serie técnica). Informe Técnico n°4.

García, SC; Holmes, CW. 1999. Effects of time of calving on the productivity of pastures-based dairy systems: A review. New Zealand Journal of Agricultural Research 42:347-362.

González, B; Peña, M; Urdaneta, F; Velasco, J; Casanova, Á. 2011. Sistemas productivos ganaderos de doble propósito en el municipio Sucre, estado Zulia. Revista de la Facultad de Agronomia de la Universidad del Zulia 28(1):523-535.

Holguín, VA; Ibrahim, M; Mora, J; Rojas, A. 2003. Caracterización de sistemas de manejo nutricional en ganaderías de doble propósito de la región Pacífico Central de Costa Rica. Agroforesteria en las Américas 10(39-40):40-46

Juárez-Barrientos, JM; Herman-Lara, E; Soto-Estrada, A; Ávalos-de la Cruz, DA; Vilaboa-Arroniz, J; Díaz-Rivera, P. 2015. Tipificación de sistemas de doble propósito para producción de leche en el distrito de desarrollo rural 008, Veracruz, México. Revista Cientifica XXV(4):317-323.

Kaiser, HM; Oltenacu, PA; Smith, TR. 1988. The effect of alternative seasonal price differentials on milk production in New York. Notheastern Journal of Agricultural and Resource Economics 17(1):46-55.

MAG (Ministerio de Agricultura y Ganaderia). 2003. Plan de desarrollo ganadero de El Salvador, Santa Tecla, El Salvador, 91 p.

MINEC (Ministerio de Economía). 2007. IV Censo Agropecuario 2007-2008. El Salvador, San Salvador, Ministerio de Economía. 627 p.

Oltenacu, PA; Smith, TR; Harry, M. 1989. Factors associated with seasonality of milk production in New York State. Journal of Dairy Science 72(4):1072-1079.

Orantes-Zebadúa, MÁ; Platas-Rosado, D; Córdova-Avalos, V; Santos-Lara, M; Córdova-Avalos, A. 2014. Caracterización de la ganaderia de doble proposito en una region de Chiapas, Mexico. Ecosistemas y Recursos Agropecuarios 1(1):49-58.

Páez, L; Linares, T; Sayago, W; Pacheco, R. 2003. Caracterización estructural y funcional de fincas ganaderas de doble propósito en el municipio Páez del estado Apure, Venezuela. Zootecnia Tropical 21(3):301-323.

Paez, L; Jiménez, M. 2000. Caracterización estructural y tipologías de fincas de ganadería de doble propósito en la microregión Acequia-Socopo del estado Barinas. Zootecnia Tropical 18(2):177-196.

Ray, DE; Halbach, TJ; Armstrong, DV. 1992. Season and lactation number effect on milk production and reproduction of dairy cattle in Arizona. Journal of Dairy Science 75:2976-2983.

Sheen, SR; Riesco, AD. 2002. Factores que afectan la producción de leche en vacas de doble propósito en tropico húmedo (Pucallpa). Revista de Investigaciones Veterinarias del Perú 13(1):25-31.

SNET (Servicio Nacional de Estudios Territoriales). 2012. El Salvador División Política Administrativa. Salvador. El Salvador, San Salvador, SNET. Accessed Aug. 2016. Available at http://www.snet.gob.sv.

Sun, CH; Kaiser, HM; Forker, OD. 1995. Analysis of seasonal milk price incentive plan. Review of Agricultural Economics 17:383-393.

Thuranira-McKeever, C; Shaw, A; Machila, N; Eisler, M; Welburn, S; Maudlin, I. 2010. Seasonal influence on Livestock keeping in a sedentary crop-livestock system. Tropical Animal Health and Production 42:705-717.

Tinoco-Magaña, JC; Aguilar-Pérez, CF; Delgado-León, R; Magaña-Monforte, JG; Ku-Vera, JC; Herrera-Camacho, J. 2012. Effect of energy supplementation on productivity of dual-purpose cows grazing in a silvopastoral system in the tropics. Tropical Animal Health and Production 44:1013-1078.

Verkerk, G. 2003. Pasture-based dairying: challenges and rewards for New Zealand producers. Theriogenology 59:553-561.

Vilaboa Arroniz, J; Díaz Rivera, P. 2009. Caracterización socioeconómica y tecnológica de los sistemas ganaderos en siete municipios del estado de Veracruz, México. Zootecnia Tropical 27(4):427-436.

White, LS; Benson, GA; Washburn, SP; J. Green, JT. 2002. Milk production and economic measures in confinement or pasture systems using seasonally calved Holstein and Jersey cows. Journal of Dairy Science 85(1):95-104.

Salamanca, A; García, JC; Pinzón, HA; Vargas, E; Mosquera, H; Tovar, RA. 2011. Diagnóstico estructural y productivo de fincas del sistema doble propósito en el municipio de Arauca departamento de Arauca (en linea). Sitio Argentino de producción animal. 6p. Consultado 15 ago. 2016. Disponible en http://www.produccion-animal.com.ar/empresa_agropecuaria/empresa_agropecuaria/100-arauca-2.pdf