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REGULAR ARTICLES

Evaluation of comparative advantages in the profitability and competitiveness of the small-scale dairy system of Tulancingo Valley, Mexico

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Abstract
This article combines a Policy Analysis Matrix with a sensitivity and poverty line analysis with the objective of evaluating the economic contribution of comparative advantages to the private profitability and competitiveness of small-scale dairy systems. For 1 year, socioeconomic data were collected from 82 farms selected from four strata via statistical sampling. Two scenarios were established to determine the quantitative contribution of comparative advantages: (1) a simulated scenario, which accounted for the cost of purchasing the total food and the opportunity cost of the family labour force (FLF), and (2) an actual production scenario, which accounted for the cost of producing food and eliminating the payment of the FLF and included other income. The E3 and E4 producers were the most profitable and competitive in the simulated scenario and actual production scenario. Of the four scales evaluated, the E2 and E1 producers were the most efficient in taking advantage of the economic contribution provided by the comparative advantages in their own production of food and employment of the FLF, in addition to accounting for other income, a condition that increased their profitability by 171 and 144% and competitiveness by 346 and 273%, respectively. The poverty results indicated that only E3 and E4 producers were non-vulnerable in the simulated scenario and actual production scenario. The purchase of food was the comparative advantage with the greatest sensitivity to cost increases in the two scenarios analysed, which exacerbated the effect on the E1 and E2 producers.

Keywords Small-scale dairy systems · Sensitivity analysis · Poverty · Production costs · Policy analysis matrix

Introduction

In Mexico, small-scale dairy production systems (SSDPSs) are considered to be of great importance because of their contribution to cushioning poverty and generating employment (Salas-Reyes et al. 2015; Sainz-Sanchez et al. 2017). At the national level, this system accounts for 20% of the total economic value of agriculture, 35% of milk production and more than 78% of the country's dairy farms (SAGARPA 2016; Martínez-García et al. 2015a; Celis-Álvarez et al. 2016).

The state of Hidalgo is the tenth largest milk producer of the 32 states of Mexico, whereby the Tulancingo municipalities (study region) contribute 17% of the agricultural value and represent the third largest producer at state level (SIAP 2017). Hidalgo is the fourth poorest state in Mexico, with a *per capita* income below the minimum wage (CONEVAL 2017), a condition that can favour the development of small-scale dairy systems because small-scale dairy farming is an activity that generates higher income than the minimum wage paid in Mexico (Posadas-Domínguez et al. 2014a).

Recent research has shown that Mexican SSDPSs generate employment in rural areas (Espinoza-Ortega et al. 2007), in addition to income and food (Posadas-Domínguez et al. 2014a), by exploiting comparative advantages such as employment of the family labour force (FLF) and production of

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their own farm inputs (Albarrán-Portillo et al. 2015; Salas-Reyes et al. 2015). Small-scale dairy systems use comparative advantages as strategies to increase the economic benefit and their profitability (Posadas-Domínguez et al. 2014b).

With current scenarios, evaluating the profitability and competitiveness of the SSDPSs of Tulancingo Valley, Mexico, is not an easy task. Quantifying the comparative advantages of this system when accounting for the cost of using the FLF and producing their own food is a difficult empirical question. Such an analysis requires a systematic form of evaluation, and for this purpose, a Policy Analysis Matrix (PAM) is a simple tool that can be used.

Therefore, the objective of this work was to quantitatively evaluate the increase in the private profitability and competitiveness of the SSDPSs of the Valley of Tulancingo, Mexico, resulting from the comparative advantages associated with production of their own inputs and employment of the FLF, in addition to the economic contribution in accounting for other income (OI). Two scenarios were evaluated to meet this objective: (1) a simulated scenario, which determined the profitability and competitiveness when accounting for the opportunity cost of the FLF and the cost of buying all food in the regional market, and (2) an actual production scenario, which determined the profitability and competitiveness when accounting for the cost of the producers to produce their own food, eliminating the cost of payment of the FLF and accounting for OI.

In Mexico, the first scenario is the subject of a significant number of studies, representing a relevant topic in the sustainability and profitability of the SSDPSs (Albarrán-Portillo et al. 2015; Martínez-García et al. 2015a; Pincay-Figueroa et al. 2016). However, with the increasing acceleration of urban sprawl and its fight for land and crop space, it is necessary to ask what the economic impacts on the private profitability and competitiveness of the SSDPSs of the Valley of Tulancingo, Mexico, would be if they were subjected to regional price parameters in the purchase of food and payment of wages.

The second scenario in particular, accounting for OI, has been rarely studied in Mexican research (Posadas-Domínguez et al. 2016). A possible explanation for this fact may be because the research that accounts for OI generates few arguments in decision-making at the farm level, but its importance has been reported in the context of net benefits and profitability increases (Val-Arreola et al. 2004; Espinoza-Ortega et al. 2005; Fadul-Pacheco et al. 2013; Albarrán-Portillo et al. 2015).

Materials and methods

Study area

The study was performed in the localities of Palma, Cebolletas and Huapalcalco in the municipality of Tulancingo, Hidalgo, Mexico. The coordinates are latitude 20° north and longitude 98° west, and the altitude is 2180 m.a.s.l. The annual rainfall is 500 to 553 mm, the climate is temperate, the average temperature is 14 °C and the rainy season is between May and October (INEGI 2017).

Statistical sampling

A statistical sample with a Neyman distribution was used to select a sample from a population of 800 dairy systems registered in the Dirección General de Fomento Lechero de Tulancingo (Directorate General of the Dairy Development of Tulancingo). The precision used was 10% of the mean with a $P < 0.05$.

$$n = \frac{\left(\sum_i^L N_i S_{Ni}\right)^2}{N^2 D^2 + \sum_i^L N_i S_{Ni}^2} \tag{1}$$

where n is the final sample size, N is the population size, N_i is the number of producers of the i-th stratum, ${S_{Ni}}^2$ is the estimated variance of stratum (i), S_i is the standard deviation of the i-th stratum, and D^2 is the precision, which is defined as:

$$D^2 = \frac{d^2}{t^2_{\alpha/2}} \tag{2}$$

In the above equation, d^2 is the precision of the estimator and $t^2_{\alpha/2}$ is the value obtained from the Student's t distribution tables with t, 0.25, n degrees of freedom; a value of 10% ( ) was used for d.

The stratification was performed taking into account the number of cows in production; E1 ni = 28 (3–9 cows), E2 ni = 25 (10–19 cows), E3 ni = 16 (20–29 cows) y E4 ni = 13 (30–40 cows).

$$n_1 = \frac{N_i S_{Ni}}{\sum_i^L N_i S_{Ni}} .n \tag{3}$$

where n_i is the number of producers per stratum, N_i is the number of producers of the stratum (i), n is the sample size per stratum and S_{Ni} is the variance of stratum (i). The sample obtained represented 10% of the population, with 82 selected production systems divided into four productive strata (Table 1).

Table 1 Stratified sample for producers of the Tulancingo Valley

Stratum	N_i	S_i^2	S_i	N_iS_i	$N_iS_i^2$	W_i	n_i
E1	385.00	22.19	4.71	1813.77	8544.83	0.48	28.00
E2	240.00	44.30	6.66	1597.48	10,633.05	0.30	25.00
E3	95.00	124.91	11.18	1061.74	11,866.12	0.12	16.00
E4	80.00	106.29	10.31	824.76	8502.86	0.10	13.00
Total	800.00	297.69	32.85	5297.74	39,546.86	1.00	82.00

N_i population, S_i^2 variance, S_i standard deviation, W_i weighting per stratum, n_i sample size

Data collection

The socioeconomic information was obtained from biweekly visits. At each visit to the 82 production systems, a survey concerning production costs, investment in fixed assets, product marketing, credit accounting, tenure, schooling, infrastructure, number of deliveries, number of animals born and weaned and litres of milk produced per cow and herd was administered. The information obtained was complemented by monitoring and updating indicators every 2 weeks for the year between February 2016 and February 2017.

Model used

The method used to evaluate the quantitative contribution of comparative advantages to private profitability and competitiveness was a PAM (Monke and Pearson 1989). A PAM is an accounting matrix with two identities: (1) private prices, which measure profitability and competitiveness as the difference between income and production costs measured at market prices, and (2) social or economic prices, which measure profitability and competitiveness and reflect the levels of scarcity measured by government policy effects and market distortions (Lara-Covarrubias et al. 2003; IFIPRI 2008; Barrera-Rodríguez et al. 2011; Katic et al. 2013; Posadas-Domínguez et al. 2014a).

The structure of the PAM enables evaluating the comparative advantages of a productive system (first line) and competitive advantages (second line); it is possible to perform the analysis using only the first line as a criterion or using both lines jointly. In this study, only the first line of the PAM was evaluated.

To evaluate the profitability and competitiveness, accounting matrices that related the cost of production, the sale price of the product and other income derived from the activity with the net profits per litre of milk were constructed. The matrix information was used to construct five efficiency indicators that enabled quantifying whether the FLF, their own input production and OI accounting provide quantitative comparative advantages to the SSDPSs evaluated. The indicators derived from the PAM are included in Table 2.

Sensitivity analysis

The PAM is a static model that cannot capture possible changes due to increased costs, prices or productivity. To address this limitation, a sensitivity analysis was performed by increasing the cost of the food purchased, the price of the inputs for the production of food and the payment of the FLF. The objective of the sensitivity analysis was to determine the limit at which the SSDPSs evaluated becomes no longer profitable and competitive at private prices.

Table 2 Indicators derived from the PAM used to evaluate profitability and competitiveness at private prices

Relationship of private cost (RPC). This indicator determines the competitiveness of the system: if the producer's RPC < 1, the producer is competitive and receives extraordinary profits, whereas if RPC = 1, the producer does not generate extraordinary gains and is located at the equilibrium point of the system. If the producer's RPC > 1, the producer is not competitive because it does not generate the economic benefits necessary to cover the payment for the factors of production.
Coefficient of private profitability (CPP). This indicator determines the profitability. It can be expressed in percentage or in absolute terms, and it measures the income received by the producer for each weight invested.
Value added to private prices (VAP). This indicator determines the income the producer receives after having paid the cost of tradable and non-tradable inputs without accounting for the cost of internal factors.
Intermediate consumption in total income (ICTI). This indicator determines the payment of the activity to the rest of the economic sectors that have a direct relationship with the activity as suppliers and customers.
Value added in total income (VATI). This indicator determines the payment of the internal factors of production such as the either contracted or family labour.

The names and acronyms of the profitability and competitiveness indicators are shown in bold

Comparison of net benefits with poverty lines in Mexico

To analyse the poverty level, the results obtained in *per capita* income of the four producer scales evaluated with the poverty lines reported by the Consejo Nacional de Evaluación de la Política de Desarrollo Social (National Council for Evaluation of Social Development Policy) (CONEVAL) were compared. This method was proposed by Espinoza-Ortega et al. (2005) and consists of multiplying the net benefit per litre of milk by production per cow, number of cows in production and days of the month and then dividing this product by the average number of family members, which for this study was 4.1 people for the four strata evaluated.

The CONEVAL measures the level of poverty in rural regions (such as the study area) according to the *per capita* monthly income, dividing it into two groups: (1) poverty, defined as a monthly income less than 101.48 USD, which covers the purchase of the basic food basket and social rights such as health, education, transportation, housing and recreation among others, and (2) extreme poverty, defined as a monthly per capita income of less than 54.93 USD, which is insufficient to acquire the basic food basket.

The monetary values were obtained in Mexican pesos and were converted to their equivalent in USD at a peso exchange rate of 17.87:1 (Bank of Mexico data from June 26, 2017).

Results

Socioeconomic indicators

Producers in the strata E1, E3 and E4 exceeded 6000 litres per cow per year, with yields between 19 and 21 L/day; the lowest production was obtained by the E2 stratum, with an annual average of 4819.00 ± 1139.49 L per cow (L/C). The E3 producers were the oldest, with a mean age of 55.25 ± 12.94 years, and had the longest experience, 40.50 ± 13.38 years (Table 3). The highest degree of education was obtained by the E4 producers, with 33% having completed a bachelor's degree. The producers in the E3 stratum had the largest area of land for cultivation, followed by the producers in the E4, E2 and E1 strata (Table 3).

Costs of production and net profits

The cost analysis showed that under the conditions of the actual production scenario, the producers of E1, E2, E3 and E4 decreased the cost per litre of milk compared with that obtained in the simulated scenario (Table 4).

By accounting for their own production of inputs in the actual scenario of production, the producers of E2 exhibited the greatest decrease in cost per litre of milk, which was similar to that of the producers in the E1 stratum and inferior to those in the rest of the strata (Table 4).

In the actual scenario of production, differences between strata were observed when the cost of payment to the FLF was eliminated: the E1 producers obtained the greatest cost reduction, which was similar to that obtained by the producers of E2 and greater than that of the E3 and E4 producers (Table 4).

Indirectly tradable inputs had the lowest cost of production in the two scenarios analysed (Table 4), without any differences between strata for this item because neither the comparative advantages nor the contribution of IO influenced their accounting.

In the actual production scenario, the net profits doubled for the E1 and E2 producers but only increased by 58 and 52% for the E4 and E3 producers, respectively (Table 4).

Comparison of net benefits with poverty lines in Mexico

The poverty lines calculated by CONEVAL for rural regions, which define a person as in extreme poverty or poverty if their monthly *per capita* income is less than 54.93 or 101.48 dollars, respectively, are compared with the income obtained in this research. It is demonstrated in Table 5 that only the E3 and E4 producers were not vulnerable to poverty in the simulated and actual production scenarios, whereas the E1 producers were classified as in extreme poverty or poverty in the two scenarios evaluated, and the E2 producers were only non-vulnerable in the actual production scenario.

PAM indicators

Coefficient of private profitability

Table 6 indicates that in the actual production scenario, the profitability increased mainly for the E2 (171%) and E1 (144%) producers and was less for the E3 producers (81%) and E4 producers (66%).

Relationship of private cost

The competitiveness of the E2 and E1 producers in the actual production scenario was 346 and 273% greater than in the simulated scenario; the rest of the strata exhibited smaller increases (Table 6).

Value added at private prices

In the actual production scenario, the E1 and E2 producers obtained the largest increases in income when paying the

Table 3 Principal socioeconomic characteristics of the SSDPSs of the Tulancingo Valley, Mexico

	Stratum 1		Stratum 2		Stratum 3		Stratum 4	
	Average	SD	Average	SD	Average	SD	Average	SD
Annual milk production/cow	6012.86	2280.66	4819.00	1139.49	6405.00	1910.82	6290.63	1303.60
Age (years)	47.67	14.84	46.75	13.52	55.25	12.94	50.33	12.20
Education (years)	6.00	5.20	8.90	4.68	7.13	4.52	11.89	5.13
Years in activity	25.33	17.88	25.90	15.11	40.50	13.38	25.44	17.21
Size of the farm (ha)	1.12	0.82	2.28	1.74	9.38	7.38	7.56	7.60

SD standard deviation

Table 4 Disaggregation of production costs per litre of milk at private prices (USD/L)

	Stratum 1		Stratum 2		Stratum 3		Stratum 4	
	SS	APS	SS	APS	SS	APS	SS	APS
Tradeable inputs								
Food produced	0.193	0.170	0.211	0.190	0.179	0.158	0.178	0.157
Purchased food	0.022	0.022	0.019	0.019	0.024	0.024	0.024	0.024
Medicines	0.009	0.009	0.010	0.010	0.005	0.005	0.006	0.006
Fuels	0.002	0.002	0.005	0.005	0.003	0.003	0.003	0.003
Fertility service	0.002	0.002	0.003	0.003	0.003	0.003	0.002	0.002
Total	0.227	0.205	0.248	0.226	0.215	0.195	0.213	0.193
Internal factors								
Family labour force	0.013	0.000	0.015	0.000	0.012	0.000	0.008	0.000
Hired labour	0.001	0.001	0.001	0.001	0.001	0.001	0.003	0.003
Electricity	0.004	0.004	0.005	0.005	0.004	0.004	0.003	0.003
Water quota	0.002	0.002	0.001	0.001	0.005	0.005	0.001	0.001
Land (property)	0.001	0.001	0.000	0.000	0.001	0.001	0.000	0.000
Total	0.021	0.008	0.021	0.007	0.022	0.010	0.015	0.007
Indirectly tradable inputs								
Depreciation of producers	0.011	0.011	0.014	0.014	0.010	0.010	0.011	0.011
Depreciation of constructions	0.004	0.004	0.007	0.007	0.004	0.004	0.004	0.004
Total	0.015	0.015	0.021	0.021	0.015	0.015	0.015	0.015
Cost per litre	0.263	0.228	0.290	0.254	0.252	0.219	0.243	0.214
Income per litre of milk	0.307	0.307	0.327	0.327	0.324	0.324	0.319	0.319
Net benefits	0.043	0.090	0.037	0.087	0.072	0.115	0.076	0.116
Other income (sale of calves)	0.000	0.011	0.000	0.014	0.000	0.011	0.000	0.011

SS simulated scenario, *APS* actual production scenario

cost of food and depreciation with respect to the rest of the strata, a fact indicated by the lower amount of hired labour (Table 6).

Intermediate consumption in total income

On average, 70% of the income obtained in the simulated scenario by the four strata evaluated was used to pay customers and suppliers. In the actual production scenario, this percentage was 11% less as a result of the savings obtained by producers when growing their own food (Table 6).

Value added in total income

The producers of the E4 and E3 strata in the two scenarios evaluated generated the highest employment both for family members and other people in the region. However, under actual production conditions, the E1 and E2 producers were the ones with the highest added value in the total income (7 and 6%), which was obtained by having a comparative advantage in terms of the FLF (Table 6).

Sensitivity analysis

The four strata evaluated in the simulated scenario were sensitive to the increase in the price of food purchase and inputs for their production, an effect that was more pronounced for the E1 and E2 producers. In the actual production scenario, the sensitivity was less, but the E1 and E2 producers still had the greatest vulnerability in terms of profitability and competitiveness (Table 7).

Profitability and competitiveness were more sensitive in the E2 and E1 producers when simulating an increase in the FLF payment in the simulated scenario and actual production scenario (Table 8).

Table 5 Monthly *per capita* income of producers of the Tulancingo Valley, Mexico

Income	Stratum 1	Stratum 2	Stratum 3	Stratum 4
Simulated scenario (USD)	38.77	57.22	280.01	450.01
Actual production scenario (USD)	80.57	133.94	446.91	683.89

Table 6 Indicators for assessing private competitiveness in small-scale dairy systems in the Tulancingo Valley, Mexico

	Stratum 1		Stratum 2		Stratum 3		Stratum 4	
	SS	APS	SS	APS	SS	APS	SS	APS
Coefficient of private profitability (USD/L)	0.009	0.022	0.007	0.019	0.016	0.029	0.018	0.030
Relationship of private cost	0.325	0.087	0.364	0.082	0.231	0.087	0.164	0.061
Value added at private prices (USD/L)	0.064	0.087	0.059	0.080	0.094	0.114	0.091	0.112
Intermediate consumption in total income (%)	79.040	71.627	82.065	75.591	71.079	64.682	71.436	64.917
Value added in total income (%)	20.960	28.373	17.935	24.409	28.421	35.318	28.564	35.083

SS simulated scenario, *APS* actual production scenario

Discussion

Socioeconomic indicators

The average daily milk yield per cow in the four evaluated scales (E1 = 19.71 L/C, E2 = 15.5 L/C, E3 = 21 L/C and E4 = 20.63 L/C) was less than that reported by Armagan and Nizam (2012), with yields of 24 and 29 L/C for 11 and 25 cows in the production line. Similar results were reported by Meul et al. (2012) and Fariña et al. (2013), with annual production that exceeded 8000 L/C. In this study, only the producers of the E1, E3 and E4 strata managed to exceed the quota of 6000 L/C per year. In México, Martínez-García et al. (2015a) and Celis-Álvarez et al. (2016) reported yields of 15 and 16 L/C per day, lower than those found in this study, although the average production per cow reached in this study is congruent with the national average. If it is possible to increase yields to closer to the international average and Mexican small-scale dairy systems are able to replicate this, these small-scale dairy systems may be an option in Mexico, and the state of Hidalgo in particular, to reduce imports and poverty and to generate employment.

In this study, the average age of the youngest producers was 46.75 ± 13.52 years (E2) and that of the oldest was 55.25 ± 12.94 years (E3). Filson et al. (2003), Armagan and Nizam (2012), Alvez et al. (2014) and Martínez-García et al. (2015b) report similar results, with ages 47, 46, 45 and 54 years. Age is a preponderant factor in the permanence of the SSDPSs of the Tulancingo Valley in Mexico. The results of this study revealed adult producers in E3 and young adults in E1, E2 and E4. It is important to mention that in the four scales evaluated, there is a generational replacement by the children of the owners of the farms, such that the permanence of the system can be guaranteed for at least one more generation.

The producers with the largest herd size (E4) had the highest education, with 33% having completed a bachelor's degree, whereas the smallest producers (E1) only finished their basic education; similar results were reported by Martínez-García et al. (2015b) and Albarrán-Portillo et al. (2015). Traditionally, the level of education in small-scale dairy systems has been linked to specialisation and increased production (Albarrán-Portillo et al. 2015). The work presented here shows that the level of education is not always an influential factor in the production strata because E2 producers had more education than E1 producers yet obtained a lower annual milk quota.

The average land tenure in this work was 1.12 ± 0.82, and the average cultivated area was 9.38 ± 7.38 ha; similar results were reported by Fadul-Pacheco et al. (2013) and Srairi et al. (2009), who reported 8.8 and 5.7 ha, respectively. In contrast, Bebe et al. (2003) and Rekhis et al. (2007) reported a smaller

Table 7 Sensitivity analysis regarding increases in the cost of food purchased and the price of the inputs for its production

Strata	Increased cost		CPP		RPC	
	Simulated scenario	Actual production scenario	Simulated scenario	Actual production scenario	Simulated scenario	Actual production scenario
E1	23%	60%	−0.003	−0.036	1.04	−0.50
E2	18%	46%	−0.002	−0.001	1.03	−0.85
E3	41%	73%	−0.004	−0.002	1.07	−7.66
E4	43%	74%	−0.001	−0.002	1.02	−1.52

CPP coefficient of private profitability, *RPC* relationship of private cost

Table 8 Sensitivity analysis regarding cost increases in the FLF

Strata	Increased cost		CPP		RPC	
	Simulated scenario	Actual production scenario	Simulated scenario	Actual production scenario	Simulated scenario	Actual production scenario
E1	450%	710%	−0.004	−0.004	1.02	1.14
E2	360%	580%	−0.004	−0.001	1.02	1.17
E3	730%	990%	−0.003	−0.004	1.01	1.10
E4	1040%	1390%	−0.002	−0.003	1.01	1.10

CPP coefficient of private profitability, *RPC* relationship of private cost

amount of land for cultivation than the one found in this work. Land tenure represents a challenge to small-scale dairy systems to meet food needs (Kawonga et al. 2012). In this study, it was found that when food production was insufficient, the producers of the four scales leased land and grew the food necessary to meet the needs of their herds. According to the field data obtained in the analysed area, the availability of arable land is not yet compromised by urban sprawl, so this area is expected to continue to maintain this comparative advantage.

Costs of production and net profits

Martínez-García et al. (2015a) found that the lower dependence on the purchase of food decreases the cost of production per litre of milk. In this study, similar results were obtained in the actual production scenario, observing a reduction in cost per litre of milk mainly in E1 and E2 producers when they grew their own food, demonstrating that as the size of herds grows, the comparative advantage of growing one's own food decreases their economic contribution, as indicated by the fact that 95 and 90% of the food inputs were grown by the E1 and E2 producers, respectively, and only 86 and 80% were grown by the E3 and E4 producers, respectively.

Posadas-Domínguez et al. (2016) simulated a scenario in which 100% of the food demand was purchased, finding that under these conditions, the net income was negative. In our study, it was found that by simulating the purchase of food, the income per litre of milk decreased mainly for E1 and E2 producers, but no negative benefits were found in any of the scales evaluated in the simulated scenario.

Salas-Reyes et al. (2015) reported that by including the opportunity cost (OC) of the FLF, the total cost of production increased by 44% and was 25% greater than the sales price per litre of milk. In contrast, in the present study, when accounting for OC, the FLF increased the cost of production mainly for the E1 and E2 producers, but there were no costs greater than the sale price per litre of milk in any of the four scales evaluated. The cost increase in the FLF for the E1 and E2 producers in the simulated scenario can be explained by the fact that 98 and 95%, respectively, of the workforce of these producers is family labour, whereas for the E3 and E4 producers, family labour accounts for only 90 and 85% of the labour force, respectively.

The lower cost of production in the indirectly tradable inputs in the simulated scenario and actual production scenario was mainly attributed to its low participation in the cost per litre of milk (between 4 and 6% for the four scales evaluated). Similar results were reported by Posadas-Domínguez et al. (2014b) for the region of Texcoco, Mexico.

Comparison of net benefits with poverty lines in Mexico

Espinoza-Ortega et al. (2005) reported that herd size and productivity resulted in higher *per capita* income in small-scale dairy systems in the Mexican Altiplano. Similar results were found in the present work, which revealed that the producers with the highest productivity and herd size (E4 and E3) obtained the highest *per capita* income of the four scales evaluated, a condition that allowed them to overcome the poverty lines established in Mexico.

The monthly *per capita* income obtained by the producers of the E2, E3 and E4 strata in the actual production scenario was sufficient to cover food and social services of the families. However, the producers in the E1 stratum in this scenario did not obtain this condition, and the situation worsened in the simulated scenario because the producers in the E1 and E2 strata would fall between the lines of extreme poverty and poverty, and only the E3 and E4 producers would be non-vulnerable. These results indicate that the SSDPSs of the Tulancingo Valley, Mexico, can be considered as an option to mitigate poverty in the state of Hidalgo, the fourth poorest state in Mexico, as long as it is valued under its actual conditions of production and the herd size is greater than 10 cows.

PAM indicators

The results of this study indicated that the four strata evaluated optimised their profitability through the use of the comparative advantage in their own production of inputs. Nevertheless, the most efficient producers were those with smaller herd sizes (E1 and E2). Similar results were reported by Ndambi and Hemme

(2009), Funes-Monzote et al. (2009), Meul et al. (2012) and Posadas-Domínguez et al. (2016), who concluded that profitability and competitiveness were greater when the food was grown rather than purchased, a condition that was best exploited by the smaller strata. The previous results are consistent with the hypothesis that a possible explanation for the permanence of Mexican small-scale dairy systems is due to the production of inputs (Posadas-Domínguez et al. 2016).

The economic literature indicates that large companies have natural advantages over smaller companies in terms of profitability and competitiveness. The explanation is based on different points that range from market power and production volume to the generation of economies of scale. The results of this work are similar to this approach when reporting greater competitiveness (0.06) at the scale of the largest producers (E4) compared with the competitiveness (0.33) obtained by the smallest producers (E1). Similar results were reported by Espinoza-Ortega et al. (2005) and Posadas-Domínguez et al. (2014b), who concluded that herd size and productivity are strategies that small-scale dairy systems use to gain income and competitiveness.

In socioeconomic terms, the producers of the four strata evaluated efficiently exploited the comparative advantage in the FLF, and as a result, profitability and competitiveness increased mainly for the E2 and E1 producers. These results are consistent with the reports of Salas-Reyes et al. (2015) and Posadas-Domínguez et al. (2014a).

Compared with the simulated scenario, the quantitative contribution of comparative advantages in self-production of inputs and the use of the FLF, in addition to OI accounting, increased profitability by 144 and 171% and competitiveness by 273 and 346% for the E1 and E2 producers, respectively, whereas the profitability of the E3 and E4 producers only increased by 66 and 81%, respectively, and their competitiveness increased by only 165 and 168%.

The higher value of the value added at private price (VAP) obtained in the actual scenario of production by E1 and E2 producers was a result of their having the lowest labour cost of the four scales evaluated and by the direct contribution of accounting for the contribution of OI to the income per litre of milk. These results are consistent with the report of Cortez-Arriola et al. (2016), which indicates that milk sales revenues were complemented and increased with the inclusion of OI, such as the sale of fodder and maize. In this study, it was found that the APV increased by 11, 10, 8 and 8% for the E1, E2, E3 and E4 producers, respectively, when the OI was accounted for.

In the simulated and actual production scenarios, the producers of the four strata evaluated allocated more than 70% of their income (ICTI) to the payment of customers and suppliers, which meant a high participation in the economy of other productive sectors of the region. Posadas-Domínguez et al. (2014a) reported lower ICTI values (between 46 and 56%) in small-scale dairy systems in the Texcoco region, Mexico. The high value of ICTI found in this study can be explained by OI accounting, which contributed 12, 16, 9 and 9% of net benefits per litre of milk to the E1, E2, E3 and E4 producers, respectively. Albarrán-Portillo et al. (2015) reported higher incomes yielded by accounting for OI (between 30 and 50%) than those reported in this study. The E3 and E4 producers in the two scenarios evaluated contributed the largest amount of both wage and family employment, whereas the E1 and E2 producers contributed little to the generation of jobs, and their herd size allowed only the use of the FLF. Similar results were reported by Posadas-Domínguez et al. (2014b) for dairy systems in the Texcoco region, Mexico.

Sensitivity analysis

Of the two comparative advantages evaluated in this study, input production was the most sensitive in both the simulated scenario and actual production scenario. This effect was most notable for the E2 and E1 producers. These results can be used by farm owners with the objective of ensuring that the cost of food (the main component of the cost of production) does not increase more than 50% because an oversight in this area can cause financial unfeasibility and risk of bankruptcy. Similar results were reported by Zimmermann and Heckelei (2012), Valvekar et al. (2010) and Posadas-Domínguez et al. (2016), who concluded that price volatility in the purchase of food increases the likelihood of dairy systems becoming unviable.

Conclusions

The E3 and E4 producers were the most profitable and competitive in both the simulated scenario and the actual production scenario, with yields of just over 20 L/C per day and larger herd sizes. Of the four strata evaluated, the E2 and E1 producers were the most efficient at taking advantage of the economic contribution provided by the comparative advantages in producing their own food and employing the FLF, in addition to when accounting for OI. The poverty results indicated that only the E3 and E4 producers were non-vulnerable in the simulated scenario and actual production scenario. The purchase of food was the comparative advantage with the greatest sensitivity to cost increases in the two scenarios analysed, and the effect was most severe for the E1 and E2 producers.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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