

## PRODUCTION COST STRUCTURE OF *OPUNTIA FICUS-INDICA* (L.) MILL. IN MEXICO, ITALY AND SPAIN

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Keywords: Opuntia, production, costs, Mexico, Italy, Spain

### 1. Introduction

*Opuntia* is a genus of plants in Cactaceae present in the natural environment and agricultural systems of arid areas. It is native to America. It is cultivated throughout the world (America, Asia, Europe, Africa and Oceania) as it grows in arid and semi-arid pedoclimatic zones. *Opuntia ficus-indica* (L.) Mill. is the most important economic cactus species in the world. (Casas and Barbera, 2002). According to the Foundation for Agrarian Innovation (FIA, 2010) and ISTAT Data Bank (2013), Mexico is the world's largest producer (45% of world production). Other important producing countries are Italy (12.2%) and South Africa (3.7%). Although *Opuntias* have been used as an important subsistence crop in many communities around the world, consumption remains limited to local ethnic markets with little export. Only Mexico, Italy, Chile, South Africa and Argentina produce it commercially and it benefits from good marketing strategies in Italy, Mexico, the United States and South Africa.

Regarding Mexico, cactus pear creates employment and income in areas where few other crops can be produced. Available figures illustrate its importance: the planted area covers currently around 50,000–70,000 ha and the gross annual production is in the range 300,000–500,000 t. It is the 5th fruit crop in the country. In this way, about 20,000 families obtain income from cactus pear cultivation. Vegetable production, featured by small plots of land cultivation, supposes an additional 12,000 ha of cultivated area (Timpanaro et al., 2015).

The 2nd world producer (and leading world exporter of cactus pear) is Italy, mostly concentrated (96 %) in Sicily with 7,000–8,300 ha producing about 78,000–87,000 t per year (ISTAT Data Bank, 2013; Timpanaro et al., 2015). Sicily is the main Italian producer (90 %), while Apulia recorded 2013 production of 2,650 t from 320 ha, mainly grown in the province of Foggia (North Apulia) with selected (spineless) cultivars. Intensive orchards mainly grow the yellow variety (which is spineless). In Apulia, particularly in the Salento peninsula (South Apulia), there is an equal distribution of the two-coloured fruits, from spiny genotypes, often growing wild or in private gardens.

South Africa's 1,500 ha produces about 15,000 t. Chile's specialised area is about 1,100 ha and gives a production of over 8,000 t. Smaller areas are located in Argentina (800 hectares and 7,500 tonnes) and the USA (200 hectares and 4,000 tonnes, of which more than 50 % is in California). Brazil, Peru, Colombia, Jordan, Egypt, Tunisia, Algeria, Morocco, Turkey, Spain, and Greece are other countries where cactus pear is cultivated (Inglese et al., 2017).

However, the limits of statistics collection do not allow to get an accurate image of cactus pear production in these countries. Furthermore, the fruit relatively low economic and social importance makes difficult that world organisations (EU, FAO, OECD, World Bank, etc.) supply consistent economic data about world cactus pear production (areas, production, employment, gross sales, export figures, etc.) (Inglese et al., 2017).

The objective of this research is the economic evaluation of the structure and production costs of *Opuntia ficus-indica* (L.) Mill. in Mexico, Italy and Spain. These three specific countries have been chosen to compare the main world producer (Mexico) with the main world exporter (Italy) and to establish the main economic and market characteristics that impede the development of this crop in the arid rural Spanish areas.

### 2. Material and Methods

First, a comparison among the production environment for each area (Mexico, Italy and Spain) has been made. Then, cost accounting has been used to make the economic evaluation of the cactus pear production structure (Romero et al., 2006). All operations have been considered self-financing to avoid introducing financial variables. Economic assessment does not include fixed costs because these costs can introduce bias that do not affect the production process. Data from other countries were obtained through published research (Basile et al., 2002; Losada et al., 2017).

An average value of 1.0 € equal to 1.129 US \$ is considered during 2017 (European Central Bank, 2018) for comparisons with Losada et al. (2017) and 1.259 for comparisons with Timpanaro and Foti (2014). Information was updated using inflation information from European Central Bank (2018).

Spanish production information was obtained by carrying out *in situ* interviews in three steps: (i) open interviews with farmers; (ii) questionnaires sent by post and, (iii) audits and validations of the information with specific questions directed to interviewees. Analysts made observations for 3 years at full production in Spain, including data from collaborating companies.

Total variable production cost was established, which is included in the cost of the working assets. Opportunity costs (Samuelson and Nordhaus, 1995) have been calculated as the next-best alternative use of working capital in risk-free financial assets. An interest rate of 2.0% was assumed, depending on the current cost of money and the inflation adjustment.

The production variables obtained from secondary data and interviews (**Table 2**) have been used to calculate costs and incomes. Differences in categories are due to the different processes undertaken for getting information and the differences of cultivation techniques in the three countries. The gross income and total variable costs can be calculated by using the contribution margin (CM), which is the margin used before considering depreciation and fixed costs. CM is calculated by taking the difference between the gross incomes (GI) and the incremental costs or variable costs (IC).

### 3. Results and discussion

#### 3.1 Characterization of the productive environment of the fruit

##### a) Mexico

In the last two decades there have been significant changes in cactus pear production in Mexico, including adoption of drip irrigation in semi-arid areas, cultivation in less arid areas (central highlands and some subtropical regions in the central south and western part of the country), use of mechanical fruit-cleaning technologies, improved packing materials, and modern commercial presentations. According to Losada et al. (2017), the orchard size in Mexico ranges between 1 and 20 ha, with the predominant size being 1-3 ha. Sixty-four percent of producers own orchards from 1 to 3 ha in area in contrast to the 23 % with 4 to 8 ha. Only about 9 % of the farmers have areas of 12 to 20 ha. The main variety produced is the pale green Alfayuca (*Opuntia amyclaea*). Distance between prickly pear plants goes from 4 to 6 m between plants and rows. The productive period of the prickly pear fruit orchards varies from 20 to 70 years. Production cycle in a commercial orchard starts in March (once frosts cannot hamper the crop). Tender cladodes (humans can consume them) are produced. They grow and are pruned later when they reach a height of 1.5 to 2.0 m (to facilitate fruit picking); the pruning season starts in February and ends in April. Fertilization is mainly with triple 17 (17 N - 17 P<sub>2</sub>O<sub>5</sub> - 17 K<sub>2</sub>O) and urea (46 N), without a clear period for inorganic fertilizer use. Organic material is used once or twice per year mainly as manure because it is free and only a transport cost applies; the amount used depends on the availability of the excreta and the age of the prickly pear orchard varying from 15 to 60 kg of dry manure *per plant* (500 t ha<sup>-1</sup>). Prickly pear is very prone to pests and diseases; Mexican producers are constantly watching to avoid them especially during the post-harvest. Fruit production starts in March, increases in April and rises significantly during June, while in September, October and November production falls. The yield *per ha* is 10 to 15 t of fruit (Inglese et al., 2017).

##### b) Italy

Italy represents an atypical example of the appreciation of *Opuntia ficus-indica*. Cactus pear has been exploited since the 18<sup>th</sup> century, when its multiple uses included fences in farming systems and emergency fodder.

In Italy, cactus pear is spontaneous and cultivated mainly in southern regions, Sicily, Sardinia, Calabria and Apulia. However, cultivation concentrates on the island of Sicily, which accounts for 90 % of total production (3,500 ha of specialized area, 15,000 ha in total). There are 4 important regions within this island: San Cono, Mount Etna, Roccapalumba and Santa Margherita Belice.

Sicilian cactus pear production was exported to the continent. This economic success was reinforced by the *scozzolatura* technique. This ancient practice, developed by Italians at the beginning of the 18<sup>th</sup> century, consists of cutting off the first flowering that normally the prickly pear plant produces in May. The plant is forced into a second more abundant flowering that takes place during the full summer period (July/August). It also delays its fructification, allowing to harvest in autumn, producing better quality fruit than in the regular August season. In 1975, modern plantations were established for the fruit industry. Cactus pear production is situated in areas that are environmentally too poor for other crops (Inglese et al., 2017). The cultivars “*Gialla*”, “*Rossa*” and “*Bianca*” are grown. The “yellow” varieties are the most common (about 75 % of the plants on average), followed by the “Red” ones and, then, the “White” ones. Summer fruits account for 10 % of production, while the autumn harvest (August-November) accounts for the remaining 90 %. Rainfall is 600 mm *per year*. Under irrigation, yield can reach 25 t *per ha*. The production units in Sicily (Italy) have an average size of less than 3 ha (Basile et al., 2002).

Plantation density is highly variable with a number of plants *per* ha which goes from 300 to a maximum of 900 plants depending on farm layout. Traditional use of simple and complex (binary and ternary) mineral fertilizers is common and countered by a generalized use of stable manure or other types of organic manure. Weeding with mainly glyphosate and fighting the fruit fly and scabious rust with products based on dimethoate in conventional cultivation are also frequent. Mechanical weeding, the use of traps (organic auxiliaries) and natural insecticides in organic cultivation are other techniques.

As regards the use of labor, running a cactus pear plot is characterized by the need to utilize a relatively high number of labor hours, although technical progress has come in the last few years to determine a partial reduction in the overall number of phases of work to be done compared to the past. The specific nature of some of the cultivation operations, such as pruning, *scozzolatura* and thinning, are entirely carried out by hand, because no systems have been invented to mechanize these farming operations and, thus, take up high levels of labor.

### c) Spain

In Spain (Andalusia, Murcia, Almeria and the Balearic Islands) cactus pear is only found on few family plantations. Lanzarote (Canary Islands) has a small production of red dye. (Inglese et al., 2017). Regular crops of *O. ficus-indica* covers an extension of approximately 185 ha. There are 131,360 disseminated plants. Official Spanish production is around 720 t *per* year (MAPA, 2018), being difficult to quantify the real production. The average size of the crops is 15 ha, with a plantation framework of  $2 \times 7$  (between plants and between streets, respectively) and a plant density of 714 plants *per* ha. As a cultivated plant, the prickly pear plant life is approximately 20 years.

Regarding irrigation, the water used to irrigate *O. ficus-indica* crops is of residual origin (municipal-treated wastewater). If the year is drought, orchards are irrigated 4 times a week (2-3 h *per* ha) during May and June through drip irrigation. If it rains, irrigation is only done in June. The practices of pruning, weeding, thinning and harvesting of the fruits are done manually. The pruning is only for renewal purpose (daily, for 15-30 min *per* ha) and the weeding is only made in the streets (once a year); thus, these labors do not require many working hours. Thinning requires more work, being done during a full month for 5-6 h *per* ha daily. By contrast, harvesting fruits requires more time, because it is a very delicate labor due to the numerous prickles that the fruit presents and, moreover, in this type of crops, few operators usually work. To facilitate this labor, long-arm tongs are used. Moreover, it is usual to pick the fruits with a piece of cladode, with what is achieved to increase the conservation period. This labor is usually done early in the morning because the dew prevents the prickles from causing hurts; thus, the hottest hours of the day are avoided. In addition, the removal of prickles and packaging is also done manually, usually in boxes of 13-14 kg. Each person can pack between 30 and 75 kg of fruit *per* h, considering the labors of removal of prickles, accommodation and weighing of fruits.

No fertilizers nor organic matter are used for this crop. About phytosanitary products, the active substance mainly used is dimethoate (1.5 %) and chlorpyrifos (2 %) for the treatment of Mediterranean fruit fly (*Ceratitidis capitata*) and cochineal (*Dactylopius coccus*), respectively. The treatment with chlorpyrifos is done approximately once a month but not during the harvest period (August and September). In contrast, the treatment with dimethoate is carried out every two weeks from the second half of July to the end of September.

### 3.2 Cost analysis

**Table 1** shows the information of the compared cactus pear production cost analysis for the 3 studied production countries: Mexico, Italy and Spain.

**Table 1.** Cactus pear production cost structure (euros/ha)

Item	Mexico <sup>1</sup> (€ ha <sup>-1</sup> )	Italy <sup>2</sup> (€ ha <sup>-1</sup> )	Spain (€ ha <sup>-1</sup> )
Tools	198.40		
Weeding	163.86		77.37
Pruning	54.91		55.26
Fertilization	55.80	383.4	
Fumigation (pests)	69.08	142.35	389.47
Others		25.8	
Pruning, <i>scozzolatura</i> , fruit thinning		1,330.65	
Other cultivation operations		393	
Harvest	326.83		442.11
Transport	181.57		

Mechanized operations		394.5	
Brooms	4.42		
Straw	51.37		
Gloves	8.85		
Cost of crates	2.65		
Watering		309.45	344.24
Thinning			221.05
Insurances and taxes		383.25	260.52
Wages and salaries		326.7	7663,42
<b>TOTAL</b>	<b>939.77</b>	<b>4,055.1</b>	<b>9,453.77</b>

<sup>1</sup>Adapted from Losada et al. (2017); <sup>2</sup>adapted from Basile et al. (2002) and Timpanaro and Foti (2014).

### 3.3 Analysis of the gross economic profit margin

In Mexico, according to Losada et al. (2017), average production *per ha* was approximately 12.8 t ha<sup>-1</sup> (400 crates), which were sold at an average price of 3.2 € each crate. This gives a total of 1,280 € *per ha* planted. The profit *per ha* is ~340 €.

According to Basile et al. (2002), average production *per ha* in Italy was approximately 15.1 t ha<sup>-1</sup>. Timpanaro and Foti (2014) calculate farm incomes considering fruit market value in 2013 at different producing areas. By combining average yields and prices, average farm incomes vary from 4,756 € ha<sup>-1</sup> for the “Belice Valley” to 6,672 € ha<sup>-1</sup> for the “San Cono Hills” (+40 % of the minimum). This means an average income of 5,714 € *per ha*. The average profit per hectare is 1,659 € *per ha*.

In Spain, average production *per ha* is 234 t ha<sup>-1</sup> (from 195 up to 273). Prices depend on the moment of the season and go from 1.8 € *per kg* down to 1.05 €. This implies an average income 555,255 € *per ha*. Thus, average profit is 545,801 € *per ha*.

### 4. Conclusions

Production structure are different in each producing country. Spain does not present a real productive sector but isolated farms. The high price that the product reaches (and the profitability) is because the production is very small. On the other hand, Italy presents a developed cactus pear producing sector. Spanish producers should look at Italy before growing to avoid problems derived of increasing production without real distribution and effective channels and mature demand.

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