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**Assessment of Local Knowledge of cactus pear and the value chain
of cactus oil in the governorates of Kairouan and Kasserine, Tunisia**

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For any errors or inadequacies that may remain in this work, of course, the responsibility is entirely my own.

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1. Introduction

There is a strong consensus that climate change presents a fundamental challenge to the well-being of all countries, with potential of being more severe on countries already suffering from arid conditions, water scarcity and land degradation. Ecosystems, particularly forest, pastoral and agricultural lands, are at risk. As the land degradation takes place, the landscapes may progress through different stages and continuously transform in appearance. Desertification can create increasingly larger empty spaces over a large strip of land. Some research results suggest an optimal planting strategy for agriculture in arid environments (Hartman, 2008), e.g. the integration and consolidation of species with high potential of adaptation to changes and tolerance to vulnerable conditions. Cactus reduces the impact of desertification. It shows adaptive responses to the expected global increase of Carbon dioxide. Due to its efficient water use, cactus pear genus (*Opuntia*), native of Mexico (Barbera, 1992), is abundantly distributed in the arid and semi-arid regions of many countries (Saenz *et al.*, 2004). Thanks also to its domestication, it can be found in the wild in several countries including South and North America, South Africa and across the Mediterranean region, in Spain, Italy, Palestine, Morocco and Tunisia.

In Tunisia, cactus pear species grows in the plateaus of Kasserine and the Northwest of the country, in the plains and valleys of Cap Bon and Kairouan. In the region of Thala (Kasserine), and particularly Zelfene, it thrives notably. It has a wide potential of expansion, but the exact geographic distribution is not bounded. It can be found in the best agricultural lands as it can occupy pastoral land or in the hill area. It does exist in the mountains, in sloped terrains, in lowland and by the riversides. Simply, it is a part of the agro-silvo-pastoral system. It is used as a way of rehabilitating degraded areas and protecting forests. Some intergovernmental organizations, such as FAO, have been and are still implementing fruitful projects to promote cactus crop as food, feed and income diversification options. *Opuntia* species have multiple uses and active compounds, indicating its importance for forage, food, medicinal, cosmetic and pharmaceutical uses, and its demand is likely to increase in the future.

The relationship between people and plants is constantly changing. The knowledge of people toward a certain crop is dynamic. In this context, assessing local knowledge (LK) seems to be essential. There has been growing international recognition that local knowledge can be useful

source of information to complement scientific approaches to resource management (Gilchrist *et al.*, 2005). It reflects a community's interests and indicates places, plants and practices important to locals. As cactus pear is a part of people's traditions and daily life in Kasserine and Kairouan governorates, it is important to assess local knowledge of this plant starting from its cultivation till the processing of its by-products. Several studies suggest that supplementing scientific data with local and traditional knowledge can broaden the information base needed for better decision making (Berkes *et al.*, 2000, Olsson and Folke, 2001). Indeed, investigating local knowledge may enhance consideration of needs of rural population.

For several decades, the cultivation of prickly pear has been made for traditional uses. It is in this last decade that industrialization of cactus pear has emerged. Some companies started to specialize in producing mucilage, juice, powder and oil. There is a growing demand and consciousness in small and large-scale for cactus by-products especially cactus oil. Cactus pear oil is obtained by pressing the seeds of the prickly pear. This oil is used particularly in cosmetology as an anti-wrinkle and moisturizer. Some companies, in the studied areas, build up and are seeking to expand an international business on cactus oil industry and marketing. There is a lack of information concerning the traceability of this product since the raw material till it reaches the final consumers. This product has a commercial interest and is intended for export to international market particularly Europe where it is used in the manufacture of numerous cosmetic products such as cream, shampoo, etc. There are different destinations of this product. Studying the value chain of cactus oil is considered interesting in terms of knowing the various stakeholders, prices and added values, factors influencing its marketing, etc.

There is a delicate situation in the governorates of Kasserine and Kairouan. They are ranked as regions of development priority and they have suffered from marginalization (Ministry of Regional Development and Planning, 2012). At the same time, Kasserine and Kairouan are potential regions of *Opuntia* species; they have large estimated areas of cultivated cactus and long distances of fences along the roads and around farms. In this context, promoting alternative economic activities, related to cactus production and processing, may be important. The valuation of various prickly pear by-products and specially cactus oil industrial development could be a good initiative for improving the livelihood income of local people.

To the best of our knowledge, there are not many researches dealing with local knowledge of *Opuntia* and its value chain in Tunisia. Moreover, there are no studies on cactus oil value chain. This study investigates the local knowledge of people toward *Opuntia* and cactus oil. It highlights the marketing path of this product and the factors which may affect the progress of the sector. Actually, it is a challenging subject, but if properly studied and invested in, it may be a way of improving the potential of rural areas with promotion of a better socio-economic situation.

1.1 Objectives and research questions

The overall objective of the study is to investigate the local knowledge of people about cactus pear and the value chain of cactus oil as an interesting by-product. In order to achieve this, the following specific objectives have been defined:

1. To review the cactus pear research in Tunisia.
2. To identify local people's existing local knowledge of cactus and cactus oil: uses, practices, traditions.
3. To describe the value chain of cactus oil with the aim of identifying different stakeholders and factors influencing the market.
4. To find the strengths and weaknesses of the sector of cactus oil production.

1.2 Structure of the thesis

In this Chapter 1 we have set out the research problems based on the background information on the importance of *Opuntia* species.

Chapter 2 represents a description of the plant, its repartition, taxonomy, multiple uses and by-products. Then, a special attention is paid to cactus oil.

The research methodology is presented in Chapter 3. The definitions of the value chain and the local knowledge are explained in this chapter in order to understand the framework and aim of the study. There is also a description of the samples and the methods of data collection and analysis. The reliability of data collection is discussed. Chapter 4 presents the results and discussions of the practical findings. In Chapter 5, the recommendation for future is presented. Finally, Chapter 6 presents the conclusion and perspectives.

2. State of the art of the knowledge on *Opuntia* spp.

2.1 General information

Opuntia is the most widespread of all genera in the cactus family. The *Opuntia* cactus is a xerophyte of about 200 to 300 species. They are distributed mainly in Africa, Mediterranean countries, south western United States, northern Mexico and other areas (Hegwood, 1990; Abdel-Hameed *et al.*, 2014). This species can now be found world-wide where it has escaped cultivation and become naturalized even to the point of being classified as a noxious weed. Due to its responding to global environmental changes, *Opuntia* spp. are some of the best plants for the reforestation of arid and semi-arid areas. Due to their remarkable genetic variability, *Opuntia* plants show a high ecological adaptability and can, therefore, be encountered in places of virtually all climatic conditions (Stintzing and Carle, 2005, Moßhammer *et al.*, 2006). *Opuntia* spp. have an asynchronous development of various plant organs, so that even under the worst conditions some part of the plant is not affected. Their root characteristics avoid wind and rain erosion, encouraging their growth in degraded areas which are inadequate for other crops. The establishment of sustainable systems of production based on *Opuntia* spp. may contribute to the food security of populations in agriculturally marginalized areas and to the improvement of the soil.

The genus *Opuntia* includes many species. Some of the most known ones are:

- *Opuntia ficus-indica* (Sweet Prickly Pear)
- *Opuntia monacantha* (Drooping Prickly Pear)
- *Opuntia exaltata* (Long-spine Cactus)
- *Opuntia stricta* (Common Prickly Pear)
- *Opuntia engelmannii* (Prickly Pear Cactus)

Some of the common English names for the plant are Indian fig, barbary fig, cactus pear, spineless cactus, and prickly pear, although this last name has also been applied to other less common *Opuntia* species. In Mexican Spanish, it is well known as nopal, and the fruit is called tuna. These names are also used in American English as culinary terms. In Arab language, many names are used such as Tyne Shawki (التين الشوكي), Karmous Nasara (كرموس النصارى), el Bels (البلس)... In Tunisia, it is called Hindi (هندي). It is known as "Sultan of fruits" or "the Queen of fruits".

The cactus pear is a succulent shrub or tree ranging on average from 1.5-3 m in height. The branches (cladodes or “paddles”) are flattened and are grey-green in color. Cladodes grow one on top of the other. The edge and flat surfaces of these cladodes are covered with areoles that have tiny, easily detached spines called glochids. Many *Opuntia* species have large spines. The flowers are yellow and the fruits range in color from yellow to red and purple and contain small seeds that are usually consumed along with the flesh of the fruit.

They spread by vegetative propagation near the cultivated fields. It is relatively easily from detached cladodes. The propagation may be via seed to more distant areas, through birds feeding on the fruits (Barbera *et al.*, 1992).

Opuntia ficus-indica is a species of cactus that has long been a domesticated crop plant important in agricultural economies throughout arid and semiarid parts of the world. (El Kharrassi *et al.*, 2016). *Opuntia ficus-indica* Mill commonly known as cactus pear is the most agronomically important *Cactaceae* species producing edible fruits and cladodes used as a vegetable or forage. Harvesting of fruits is spread over a period of seven months; since June until December. Prickly pears are thus available on the markets from June-July until December to January. The prickly pear is exported mainly fresh, dried or preserved.

Uses. Cactus pear is an economically important crop with numerous uses. *Opuntia* spp. present various alternatives to its exploitation:

- **Fruit.** Authors have studied the nutritional significance of *Opuntia* sp. (Stintzing and Carle, 2005; Ennouri *et al.*, 2004). The fruits are typically consumed fresh. It is considered a refreshing fruit for that season. The potential market for this product is extensive but little exploited, so better marketing strategies are required.
- **Forage.** Paddles are used as forage for livestock as either fresh forage or stored as silage. It is available during critical dry months of the year. It reduces the need for supplying water to animals and it reduces the cost of animal feeding which is the heaviest expense and represent 50 to 60% of production costs. It has nutritional characteristics (Andrade-Montemayor *et al.*, 2011; Costa *et al.*, 2013, El Kharrassi *et al.*, 2016); they are rich in carbohydrates and calcium however, they must be combined with other foods to complete the daily diet, because they are poor in proteins.

- **Vegetable.** Pads are cleaned and cooked as a vegetable in stews and salads. They are consumed fresh mainly in Mexico and by Mexicans living in the United States of America. Mexican exports to Europe and Asia are increasing, which shows an expanded demand in non traditional markets.

Dye production. Cochineal dye is a sessile parasite of *Opuntia*, feeding on moisture and nutrients in the cactus sap. The carminic acid can be extracted from the insect's body and eggs to make the red dye. Cochineal is used primarily as a red food colouring and for cosmetics. It is a natural red dye accepted by health authorities worldwide. Cochineal constitutes a significant alternative of artificial dyes. Cactus fruits contains betalains (Nefzaoui *et al.*, 2007), which can be used in agri-food.

Economic interest. Cactus pear has an importance for small scale farmers manifested on its contribution in times of drought to both human and animal diets. It can be used in agro-forestry systems, intercropping with legumes and annual crops (Abdel-Hameed *et al.*, 2014). Cactus plant has high potential as commercial crop that it can be processed easily and it has potential international market to be source of foreign currency such as the experience of Latin America countries including Mexico (Nefzaoui *et al.*, 2009). Projects of cactus pear bring additional benefits and generation of employment. It has a interesting industrial potential.

Industrialization. It is feasible to industrialize cladodes and fruit. This potential market deals mainly with semi-processed and processed vegetables, food supplements, juices, jam, liquors. *Opuntia* spp. can be used as an ingredient to flavor foods, and is processed into beverages including wine (Yahia and Mondragon-Jacobo, 2011; Abdel-Hameed *et al.*, 2014; El Kharrassi *et al.*, 2016). The juice of cactus pear was reported to have a potent antioxidant activity and to be rich in glucose and fructose (Abdel- Hameed *et al.*, 2014). In addition, some researchers reported the production of cocoa butter equivalents from prickly pear juice fermentation by an unsaturated fatty acid auxotroph (Ennouri *et al.*, 2004).

The cosmetic industry. Cactus pear is also used for pharmaceutical and cosmetic purposes (Piga, 2004; El Kharrassi *et al.*, 2016). It has been shown to have anti-cancer, anti-viral, and anti-diabetic properties (Feugang *et al.*, 2006; El Kharrassi *et al.*, 2016). It has antioxidant properties,

which are important for preventing degenerative diseases in humans (Abdel-Hameed *et al.*, 2014).

The following table (Table 2-1) presents a summary of the multiple uses of cactus pear submitted by Inglese *et al.* in 1995.

Table 2-1. Actual and potential uses of *Opuntia ficus-indica*

Commercial area	Specific use (actual or potential)
Food production	Fruits Nopalitos Fruit juice Oil extracted from seeds Miel de tuna Queso de tuna Jellies and marmalades
Energy production	Alcohol Fresh biomass
Cattle feeding	Forage Fodder Fruit wastes
Medical uses	Flowers for diuretic purposes Cladodes for diabetes Mucilages
Agronomical uses	Soil fixation Soil mulching Soil water supply Hedges Wind breaks
Colorant uses	Betanins in fruits Carminic acid (red cochinilla dye)

Source: Inglese *et al.*, 1995

2.2 Distribution

World. The cactus pear genus (*Opuntia*) is native to arid and semi-arid regions of Mexico (Abdel-Hameed, *et al.* 2014; El Kharrassi *et al.*, 2016) which is the center of origin and domestication. Due to its efficient water use, this crop is abundantly distributed in the arid and semi-arid regions of many countries (Russel and Felker,1987; Mohamed-Yasseen *et al.*, 1996; Saenzet *al.*,2004). Cactus pear species are grown in temperate, subtropical, and cold regions (Feugang *et al.* 2006; El Kharrassi et *al.*, 2016) and are distributed in different countries including those of central and south America, the Mediterranean and South Africa (Gurrieri *et al.*,

2000; El Kharrassi *et al.*, 2016). In North Africa, prickly cactus was, for years, used as hedges of rural homes while spineless cultivars were used around sheep barns.

Tunisia. In Tunisia, as in other North African countries, the most widespread species of cactus are: *Opuntia Ficus indica*, *Opuntia dillenii*, *Opuntia vulgaris* and *Opuntia compressa* (El Kharrassi *et al.*, 2016). Cactus in Tunisia is mostly localized in areas characterized by low quality soils and water scarcity. *Opuntia ficus indica* grows in the plateaus of Kasserine and the Northwest of the country, in the plains and valleys of Cap Bon and Kairouan. In the region of Thala (Kasserine), and particularly Zelfene, it thrives notably. In Tunisia 400 000 to 500 000 ha are cultivated with the prickly pear. 5730 ha are certified organic (DGAB, 2014). Its area is widely dispersed in the country. Official statistics and information on the surface area of *Opuntia*, quantities and uses are either absent or unreliable. Densities vary from one region to another: the highest concentrations are found in central of the country (52%) and South zones (39%).

It is considered as the most important feed source for cattle during the dry season. Spineless cultivars, in particular, are the most preferred for forage production since they are easier to handle and process (Ben Salem-Fnayoua *et al.*, 2013). It has also been useful in controlling desertification and improving depleted natural rangelands by preventing long-term degradation (Vignon *et al.*, 2004; Ben Salem-Fnayoua *et al.*, 2013) of ecologically weak environments (Ben Salem-Fnayoua *et al.*, 2013). Tunisia was a pioneer in the domain of cactus. It was used from the late 80s to expand the forage and to fight against erosion and desertification of the territory. It followed countries that have better experience in this field, such as Italy, Mexico and Chile, creating partnerships and sharing expertise (TREKASS, 2013).

In the framework of the national strategy of pasture improvement started in 1990, cactus was planted in a systematic manner, particularly, in different regions. The government tried to create pilot farms and to encourage small farmers to practice production of late season and production of organic products. Organic agriculture started in the 80s by private initiatives and had a slow development until the years 1997-1998. Then a national strategy in this area has been established and is based on several components: regulation, research, training and extension, organization, structure and encouragement. This contributed to a good development of the sector.

According to official statistics, the total area of cactus in Tunisia has doubled in the past two decades. Nearly 85% of the area is planted by farmers in rural areas and 15% by the Ministry of Agriculture. Different administrations are involved; CRDA (Regional Offices of Agricultural Development) which deals with farmers, private and public agricultural lands, OEP (Office of Livestock and Pasture) which operate in private lands with stockbreeders, and DGF (General Directorate of Forests) which acts on the public territory mainly of forests. There are different kinds of subsidies and encouragements but still not so effective.

Kasserine. Land use data in Kasserine are presented in Table 2-2.

Table 2-2. Main production areas district (ha)

	Agriculturalland	Irrigated areas	Forests	Pastoral	Olive	Arboriculture
Surface (ha)	360 000	27 700	151 000	80 000	78 600	140 000

Source: Regional Directorate of Kasserine

The forest vegetation consists mainly on rosemary, Aleppo pine, oak and juniper. These forests comprise approximately 104000 hectares of dense forests, 17000 ha of moderately dense forests and 30,000 ha of degraded areas. The forests are used for wood production, pasture, pine and extraction of essential oils.

In the region of Kasserine, cultivation of prickly pear is well structured and occupies 82 775 ha. In Kasserine, the prickly pear is grown mainly for the production of fruit and fodder. The cultivation of prickly pear is currently practiced intensively, fruit production remains the most wanted and most developed. The Delegation of Zelfene alone has 20000 hectares of commercial plantations dedicated to the production of prickly pear fruit. The production of fruit of prickly pear reached 162500 tons; a large part of it is not harvested.

In the governorate of Kasserine, the spineless varieties represent 80.5% of the total area of cactus pear (CRDA-Kasserine, 2014) with 66000 ha of plantations. They are mainly used for the production of fruit and fodder, while the thorny varieties representing 20% of the area and are used primarily for the protection of parcels.

The total production of prickly pear fruit is estimated at 160 000 tons. The spineless variety represents 100 000 tons or 62.5% of the annual production of the governorate.

The main production areas are reported in table 2-3.

Table 2-3. Main production areas per district (ha)

District	Thala	Foussana	Hassi El Ferid	Majel bel- Abbas	Zone de Zelfene	Thala
Superficies (ha)	5 700	2 300	9 000	5 000	20 000	5 700

Source: TREKASS (2013)

Thus, the most productive and structured region is Zelfene (20 000 ha representing 47% of the main production area in the governorate); plantations are either irrigated or benefit from supplemental irrigation. Fruit yields vary from 1.5 to 3.5 t / ha for the spineless varieties and from 3 to 6 t / ha for spiny varieties. Production of Zelfene region represents 32.5% of the fruits of Kasserine, most of this production (87.2%) is sold outside the governorate because of the good quality of the fruit (source: CRDA Kasserine).

Kairouan. The governorate covers an area of 6712 km² and has an interesting geographical position as it represents a crossroads between North, South, East and West of the country. There are limitations with seven governorates. The regional economy is based on agriculture as a source of revenue to 70% of the population. It accounts for 26% of employment and contributes with 8% of the national production. Agricultural production is diversified. It consists of 590000 ha of agricultural land, 172000 hectares of natural vegetation. With 52504 ha of irrigated perimeter, Kairouan has 14% of the irrigated areas in the country and occupies the first spot. This allows the region to ensure an important contribution to the production of fruits, vegetables and livestock products; in fact, Kairouan is the producer for apricot and peppers. The intervention of OEP for cactus planting areas in the last five years is represented in table 2-4. The forest areas planted by prickly pear in presented in table 2-5.

Table 2-4. Intervention of OEP for cactus planting areas in the last five years in the governorate of Kairouan (ha)

District	El Alaa	Hafouz	Nasr Allah	Hajeb El Ayoun	Chbika	Weslatiya	Zaafrana
Superficies (ha)	80	90	100	10	30	50	20

Source: OEP (2014)

Table 2-5. Distribution of estimated cactus plantings in the public domain (DGF)

District	KairouanSud (Rwabdhiya)	Chbika	El Alaa	Nasr Allah
Superficies (ha)	100	260	200	200

Source: DGF (2009)

In Kairouan, the prickly pear is grown mainly for the production of fruit and fodder. In this region, cultivation of prickly pear is not well structured and most of cactus pear is used as fences for farms and along roads. A large part of it is not harvested. Total areas of spineless cactus are estimated at 4600 ha mainly in El Alaa district, and spiny pear is around 7100 ha mainly in Weslatiya (CRDA). Official data are still limited, not precise nor updated. Yet there is a cactus nursery in the district of Chbika which comprises 44 varieties of cactus cultivated since the '80s coming from different countries such as Mexico, Italy, Morocco, Algeria, etc. Most of these varieties are well adapted to Tunisian climate and soil texture.

2.3 Prickly pear seed oil

Generalities. Prickly Pear seed oil is called also Barbary Fig oil and Cactus oil. It is one of the most expensive beauty oils in the world. It is a competitor of Argan oil. The prickly pear oil has anti-free radical and anti-aging properties. This oil could be used for cosmetic purposes including the preparation of creams, lotions, gels and shampoos. Seeds are separated from the pulp, then washed carefully, dried and afterwards stored in a cool and dry place. On demand, they will be cold-pressed to obtain very rich and precious oil. The price of one liter is between 700 and 1000 Euros.

Oil composition and benefits. Depending on the variety and maturity of the fruit, the period of harvest, climate and soil conditions, figs pear contain varying amounts of seeds (10-15 g / [100 g]) which is equivalent to 3 - 4% of the fruit and about 50% of juice. The seeds contain from 5 to 7% of rare and precious oil, it is possible to extract about half of existing oil, which leads to a yield of about 3% by seeds' weight. We must therefore treat about 800 kg of figs for 1 liter of oil. It depends on the above parameters but also to the performance of equipment used and the treatment reserved for seeds. Analysis showed that this oil is rich in unsaturated fatty acid (85% with more than 60% of Linoleic Acid). These substances help to fight against the skin dryness and help to ameliorate the hydration. Its high concentration of omega-6 confers regenerating

properties. It slows down the skin oldness it has a high concentration of Sterol. It contains more tocopherol (Vitamin E) than any other oil available in the beauty care market (almost 150% more tocopherol than Argan oil). Tocopherols are molecules with strong antioxidant and free radical scavenging properties. These substances protect the skin against free radicals and prevent from the rides formation. Made as cream, it allows the treatment of wrinkles, crevices and dark circles (Guillaume and Charrouf, 2011). It can be used pure or in creams for the face, eye and body care.

Industrialization. The extraction of seeds' oil can be implemented at lower cost with a mechanical sieve to separate the seeds from the pulp and single-head screw press, the other materials are optional. Traditionally, the seeds are dried by sun exposure on tarpaulins placed on the ground, which is not an ideal solution in terms of reproducibility, neither as regards to hygiene conditions and multiple risk contamination.

The processing includes the steps described in Figure 2-1.

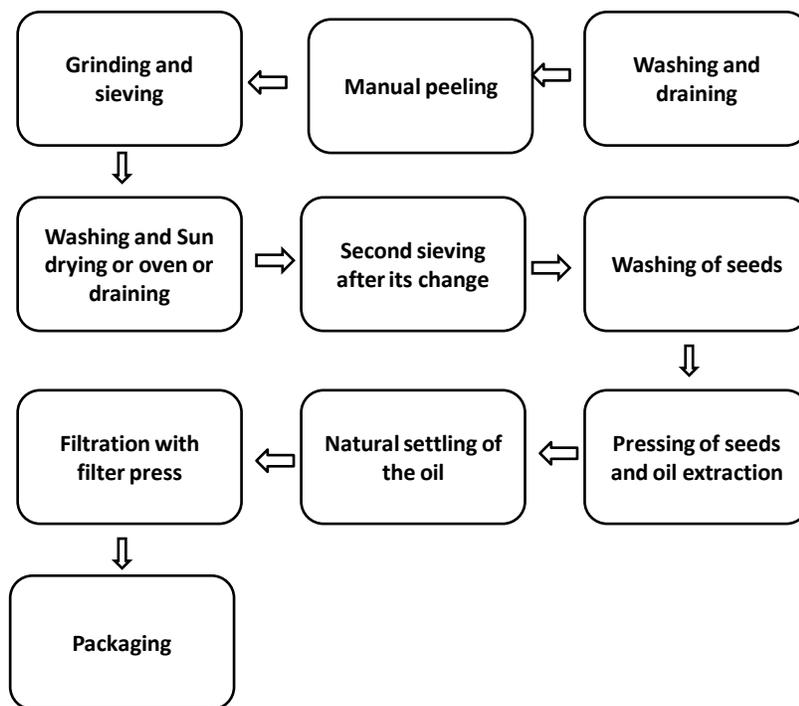


Figure 2-1. Diagram of cactus oil production (PNUD, 2015)

Cactus oil companies. Concerning companies specialized in extracting oil in the study areas, we mention a unique company called Nopal Tunisia localised in Thala-Kasserine which was created

in 2007. In Kairouan, there are two companies; Nopal- Zaafrana and Flore de la Tunisie. For the drying method, processing remains in most of cases traditional under the sun or in shade. These technologies have the advantage of being inexpensive and technically easy to handle, but they suffer from several weaknesses such as long duration of extraction oil, low yield of oil compared to the modern units. Notwithstanding their simple technology for oil extraction and drying, their product is exported.

Market. There is a national market, which still modest, presented by the shops of parapharmaceuticals, large areas in health product sections, in big malls and shops. The international market is important and presented mainly by large areas and fine grocery stores in European countries such as France, Italy, Switzerland, Russia and Germany which are characterized by affluent customers requiring a responsible values, nutritional qualities and health extrinsic products. Cactus oil is destined also to large areas of Asian countries (China, Japan, and Korea) and Gulf countries (Saudi Arabia, etc.).

The market of cactus oil is expected to increase notably in the future, and the forecast of income from manufacturing expects an increase from 2380000 Tunisian Dinar (1052138 euro) in 2019 to 6 689 200 Tunisian Dinar (2955008 euro) in 2022 (TREKASS, 2013).

3. Research methodology

The study was carried out during the months of May and June 2015 in the governorates of Kairouan and Kasserine, Central Tunisia. This research aims to assess the local knowledge (LK) of *Opuntia* species and to describe the value chain of cactus oil because there is a lack of information concerning these issues. The definitions of local knowledge, value chain and mapping a value chain are firstly presented in this chapter. Then the research plan is explained. The research is designed as a case study with a mixed methodology approach: qualitative and quantitative. A simple statistical analysis is carried out to analyze data collected through questionnaires. The two approaches have provided a basic understanding of the *Opuntia* potentialities. A SWOT analysis has been done for the oil production industry.

3.1 Definitions

Local Knowledge (LK). LK can be defined as a cumulative body of knowledge, practices, and beliefs (Gadgil *et al.* 1993; Tengö and Belfrage, 2004). It is based on experience. Local knowledge is held by individuals or communities and adapted to the local culture and environment (Warburton and Martin, 1999). It is dynamic and changing. LK is not confined to tribal groups or to the original inhabitants of an area. It includes all communities possessing local knowledge; rural and urban, settled and nomadic, original inhabitants and migrants. It embraces a larger body of knowledge systems including those classified as traditional and indigenous. Considering local residents, is required because it provides information about uses, benefits and practices in a closer way. Usually there is variation among people with regard to their knowledge as well as to their management goals and interests depending on factors such as gender, social position, etc (Nazarea, 1999; Byg *et al.*, 2012). LK is perceived as a way of linking social dimension to different branches of sciences such as ecological or economical sciences. Thereby, it can help to empower local people and improve management outcomes (Byg *et al.*2012).

Because cactus is a worldwide domesticated crop, practices and uses of communities in and nearby its area, may be similar in some cases as they may be different in other cases. Its products have always been very popular among the rural populations of arid and semi-arid areas in its native region of Mexico and in the Mediterranean basin (Barbera and Inglese, 1993). Also, new potentials and uses are recently discovered. In the study areas there is a high potential of

producing cactus pear and there are companies of producing cactus oil. We aim to describe the local knowledge of people toward cactus pear and cactus oil by using the methods described below.

Value chain. The value chain can be defined as a set of activities, services and products, leading to a product or service that reaches the final consumer (Gloy, 2005). The term ‘Value Chain’ was used by Michael Porter in his book ‘Competitive Advantage: Creating and sustaining superior performance’ published in 1985. The value chain analysis describes the activities the organization performs and links them to the organizations competitive position. Value chain analysis describes the activities within and around an organization, and relates them to an analysis of the competitive strength of the organization. The value chain can be a very useful conceptual tool when trying to understand the factors that impact the economic channels of a product.

The value chain can help us to know the traceability of a product. Generally, it comprises all the activities required to create a product from conception to physical transformation up to final use (Kaplinsky & Morris, 2000). The value chain includes the entire process lead by various actors, the economic relationships between players in the chain, how this structure is likely to change over time, the key threats to the entire value chain and the key determinants of profits created by this chain.

In most industries, it is rather unusual that a single company performs all activities from product design, components' production, and final assembly to delivery to the final user by itself. Most often, organizations are elements of a value system or supply chain. Therefore, value chain analysis should cover the whole value system in which the organization operates (Daniels and Fors, 2015).

In the next section, the value chain of cactus oil produced by Tunisian companies since the raw material to the final product is presented. An interesting part of the chain related to production is done within the company; other activities such as its incorporation in the beauty industry and marketing are done by extra actors.

Mapping a value chain. A value chain can be complex and contain a big number of actors. Each actor can also be connected to more than one value chain. Therefore, it's important to know the aim of the study and the point of interest (Kaplinsky and Morris, 2000). The first step in a value

chain study is to identify actors and connections between them to get the chain mapped out. This can be done with a qualitative study, followed by a quantitative study when the map of the chain is completed.

In the case of cactus oil, many stakeholders are implicated in the value chain. Some of them have a direct influence such as companies' managers, wholesalers, point of purchase, international customers, etc. Some other actors have an indirect effect such as local people specially women, farmers, projects, different administrations, Non-governmental organizations (NGOs), etc.

3.2 Study areas

The study was conducted in the two governorates of 'Kasserine' and 'Kairouan' in Central Tunisia (see Fig 3-1).

3.2.1 Location and characteristics

- **Kasserine**

Location. The governorate of Kasserine is located in west central Tunisia; it is opened to the Algerian territory by a border line of 220 km. The geographic coordinates of Kasserine are 35°10'03" N latitude, and 8°50'11" E longitude.

Characteristics. Mountainous area, its average altitude is 800 m above sea level; it is characterized by a semi-arid to arid climate. Annual rainfall averages 335 mm with hail as a major problem affecting agricultural season. It houses the Jebel Châambi, the highest point of Tunisia. The study area covers 8066 km² with a population of 439,243 inhabitants. Administratively, the governorate is divided into thirteen delegations, ten municipalities, six rural councils and 106 imadas.

- **Kairouan**

Location. The governorate of Kairouan is located in the center of Tunisia. It is located 160 kilometers from the capital. It is limited by the governorate of Zaghouan in the north, Siliana, Kasserine and Sidi Bouzid in the west and the governorate of Sfax, Sousse and Mahdia to the east. The geographic coordinates of Kairouan are 35°40'41"N latitude, and 10°05'46" E.

Characteristics. It is located on the Low Steppes, a fairly dry alluvial plain. It is characterized by a semi-arid to arid climate. The average temperature lies between 5 and 21° C in winter and between 25 and 42° C in summer. The annual rainfall is 250-400 mm.

The study area covers 6 712 km² with a population of 570 559 hab. Administratively, the governorate is divided into eleven delegations, twelve municipalities, seven rural councils and 114 imadas.

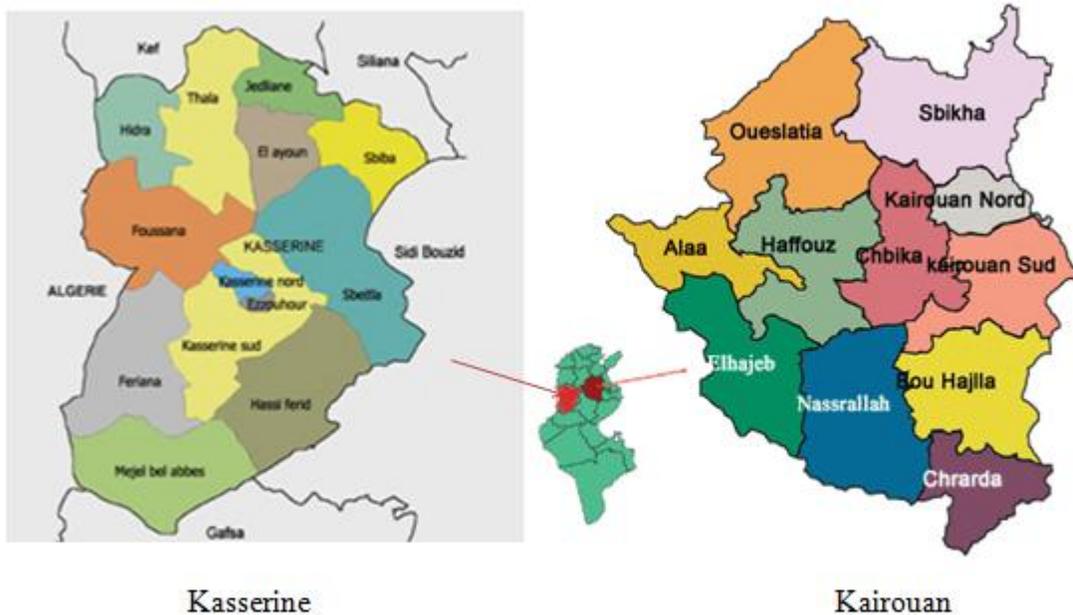


Figure 3-1. Map of the governorate of Kasserine and Kairouan (localization and administrative division)

(Source: Web 1)

These sites were selected based on the importance of prickly pear crop. We have conducted a preliminary recognition, with positive results, to check if, in both cases, LK was an important factor in farm management and diversification of uses of cactus pear. In both cases, the main land uses are pastorals and traditional agriculture with small-scale monetary flows, integrated livestock and limited use of chemicals. Main land user groups include: farmers, minor livestock holders, pastoralists, and villagers.

The two areas are located in regions that are economically marginalized according to various indicators. In 2012, Kasserine and Kairouan registered the lowest indexes of knowledge (0.03 and 0.11), wealth and employment (0.21 and 0.39), justice and fairness (0.32 and 0.40) and it has

the last ranking of governorates according to regional development index (0.16 and 0.25) (ITCEQ, 2012) (see Appendix1). There are limited livelihood options and employment opportunities, suggesting that introducing alternative economic activities may be important. Actually, it is a challenging area, but if properly studied and invested in, it can be leader in Indian fig production. For instance, it has large estimated area of cultivated *Opuntia* species. They occupy long tracks of roads and are used as fences for agricultural lands. This regions, specially Kasserine, are well-endowed with competitive varieties of opportunities for trading, industrialization and exportation.

3.3 Choice of the species

Opuntia ficus-indica (Sweet Prickly Pear) is the most widespread species grown in Tunisia. Cactus pear is a part of the tradition, culture and dietary habits of the inhabitants. It reflects some community's interests and indicates practices important to locals.

* It is drought resistant; *Opuntia* species grow commonly under water-stress conditions (Nobel et al., 1992).

* It doesn't need many nutrients and pesticides, so organic cultivation can be promoted very easily.

* It is a multiple use plant; fruit, pulp and the leaf-like structures called cladode can be used in different ways, both with traditional and new technologies.

* In degraded forested areas, cactus is considered as an alternative solution for rehabilitation. Due to their efficient water use, this crop is abundantly distributed in the arid and semi-arid regions of many countries (Russel and Felker, 1987; Mohamed-Yasseen *et al.*, 1996; Saenz *et al.*, 2004).

* It is used as fences and barriers reducing the erosion. Its utilization is common in the field of management (windbreaks, soil erosion control, hedges).

* The industrial development for cactus transformation and packaging is considered as one of the remarkable solutions for arid and semi-arid areas through its simple and less demanding process. It has economic profitability and wide possibilities of agro-industrialization.

* Concerning the value chain of cactus oil, there is a lack of information in its traceability.

3.4 Data collection

The data collection has been organized mostly with a qualitative approach. The survey method to gather data was a mixture of semi-structured and structured interviews. The elaboration of field methods was guided by three main questions: who can provide the information? How this information could be collected? What are we going to ask?

The study started by obtaining a substantial background knowledge through the existing data and information available in literature and through official statistics. Bibliographic research and consultation of administrative authorities were both essential elements to have a clearer view of the use, distribution, and current status of *Opuntia* spp. in the studied areas. These information include the evolution of prickly pear surfaces, plantation programs made over time, and the main users. Different administrations were consulted such as CRDA (Regional Offices of Agricultural Development), OEP (Office of Livestock and Pasture) and Forest Districts belonging to the DGF (General Directorate of Forests). Some guidelines were followed (Appendix 2). Snowball sampling or chain sampling has been used at this level to contact some responsible in administrations and companies' managers. This method is a non-probability sampling technique based on the information and recommendations by interviewed persons to find new people with specific knowledge and skills.

Semi- structured interviews were addressed to companies' managers processing cactus oil. These interviews had more of a conversation character and were based on open ended questions (Appendix 3). The objective if these interviews was to collect maximum information about industrialization, packaging and commerce.

A set of questions and guide outlines were used to focus on our main objectives; from where do you get the raw material "fruit", questions about processing, packaging, selling, who are the potential customers and the final consumers, etc... . Also, the focus was on the difficulties and facilities that they might face, and what the interviewee thinks is important. Indeed, there were some questions related to quantity produced, collected, sold, exported of cactus and/or cactus oil, but generally the answers were not satisfying.

In Tunisia, 13 companies operating in the oil extraction and/or powder processing prickly pear and 3 emerging companies are recorded (TREKASS, 2014); however, when contacting them we discovered that the number was lower since some of them were closed or converted their activities to other businesses. Only 2 functioning and 1 start-up companies were willing to

participate in the study: Nopal Tunisie in Zalfane-thala north Kasserine and Nopal Zaafrana in the governorate of Kairouan. Also, one manager of organic beauty products using cactus oil and two points of purchase were involved in the value chain assessment of cactus oil.

The mentioned companies as well all the other operators were interviewed in their workplaces. Within each stage of the chain, the same questions have been asked to all respondents to obtain comparable answers. Some chain actors are missing in the study because it was not easy to find them in the field or in the market such as transporters and wholesalers. Also, the survey was carried out not in the period of harvesting, so investigation of chain actors was less reliable. Another problem is the lack of answers to the questions about production and productivity.

Then, the survey of local people was conducted throughout structured interviews. Due to the tight time-period spent in the field and the availability of the interviewees, we reached 48 interviews in a period stretching from mid April to mid June.

The classification of villages along the administrative division was considered a good starting point to organize the interviews: delegations or districts, municipalities, rural councils and imadas. Since it was difficult to cover the entire region, and due to the limitations of transport facilities, it was useful to localize the delegation of high production, make field visits to these delegations, visit the farms near the roads, and make a stop every few kilometers (opportunistic sampling).

The visited district, in the governorate of Kasserine, were Hassi El Frid, Kasserine Sud, Sbeitla, Thala and Zelfane. In the Governorate of Kairouan, we visited El Alaa, Hajeb El Ayoun, Nasr Allah, Chbika, Kairouan Sud, Oueslatiya, and Zaafrana.

We took care to involve informants from different households and places. Our selection included 26 informants from Kasserine including 10 farmers, and 22 from Kairouan, including 7 farmers. The remaining interviewees were officers, students, rural women, street vendors, daily laborers and unemployed people. Table 3-1 presents the breakdown of people interviewed according to profession, age and gender. These categories of people represent the most common categories in the studied areas.

The ages were coded in the following way: 1 as young generation aged between 15 and 29 years, 2 as senior aged between 30 and 55 years and 3 as elderly people aged more than 55 years.

These structured interviews were based on a list of questionnaires with both open ended questions and question-answer character (Appendix 4) to get more precise answers (Daniels and Fors, 2015).

Table 3-1. Breakdown of people interviewed according to profession, age and gender

Site	Major profession	Number of interviewed	Age range	Sex
Kasserine	Farmer	1	1	male
		6	2	
		3	3	
	Worker	2	1	1 female- 2 male
		3	2	
		1	3	
	Student	3	1	2 female- 1 male
	Officer	2	2	1 female- 1 male
		1	3	male
	Jobless	1	1	female
		1	2	
		2	3	
Kairouan	Farmer	1	1	male
		3	2	
		3	3	
	Worker	1	1	3 female- 2 male
		5	2	
		1	3	
	Student	2	1	1 female- 1 male
	Officer	1	1	male
		2	2	female
	Jobless	1	3	female
		1	2	
			1	3

During the interviews, we investigated local knowledge in terms of people's ability to identify varieties, techniques of multiplication, if the plant had several uses such as medicinal, culinary and in management, if they know about cactus oil and its production, and if they personally used

it. Some questions concerned the agricultural practices such as planting, fruiting and harvesting, animal feeding and yield. In most cases, each informant was asked about the importance of this crop in his/her dietary habits, in agricultural management and he/she was requested to express its aptitude to resist the drought. Each person was asked a total of 12 questions. In addition to these questions farmers were asked 6 supplementary questions related to farming, difficulties for cactus pear and cactus oil production, their readiness to join association or companies working on this issue (Appendix 4). Also, we made use of phone conversations. This mean of data collection was time efficient and mostly used for companies which were closed or that have changed their activities. In this case the interview was more about knowing the causes of failure of their business.

Reliability. All research methods have their pros and cons, the problem comes when we rely on just one method and/or just one source of information. To check whether the collected information are reliable or not, it is helpful to use the triangulation. Also known as “mixed method” research, triangulation is the act of combining several research methods to study one thing (Kennedy, 2009). Information could be complementary sometimes, overlapping or contrary. Triangulation has the effect of balancing knowledge sources.

Whenever it is possible, we tried to investigate information from more than one standpoint or source. In the present research, we used stakeholder interviews, questionnaires, telephonic conversation, market research data, consulting different administrations for statistical data. For instance, to get a whole view of the situation, CRDA, OEP and DGF were consulted singly as they are concerned with separate sectors and territories, respectively, private agricultural lands, pastoral lands, and public and forested areas. So, lots of data and different views were collected. When combined, they allow a degree of cross checking. A kind of triangulation can also be achieved by having two (or more) people in the comparable projects and stage of the value chain and/or in different levels, asked about the same issue. This is especially when things are related to prices and quantities which are mostly secrets of the managers. Also, self observation helped to balance out the problem.

3.4 Data analysis

The data were recorded and analyzed using an Excel spreadsheet. The data related to dietary habits, uses, benefits of cactus were summarized in graphs with percentages depending on groups

of age, gender and/or profession. Mainly, percentage, sum and other elementary statistical indicators have been used.

Local knowledge tends to be qualitative rather than quantitative (Berkes 2009; Gadgil *et al.* 1993) so the speech of some interviewees were reported as they were recorded.

To describe the value chain, figures and diagrams were used. Making a value chain map is a way of simplifying the traceability of the final product: the whole chain starting from the fruit till the final product (oil) being delivered to the consumer. Mapping allows visualization of the networks to get a better understanding of connections between actors and processes. It demonstrates interdependency between actors and processes in the value chain.

All these information were considered and summarized in a SWOT analysis of the situation of cactus and cactus oil. The SWOT analysis describes the sector in terms of:

- Strengths: advantages linked to the organization of the sector which is more related in our case to the available resources and the quality of the products.
- Weaknesses: specific causes of failures of the sector which is more related to the lack of organization in the sector, and the problems of distribution and marketing of the product.
- Opportunities: external benefits, independent of the sector indicating the potential importance of institutional bodies.
- Threats: negative external constraints to the sector connected with the climate conditions, the marketing and its limiting factors.

In our case the aim of the SWOT analysis was to identify constraints and possible solutions, identify the weak and strong points in the value chain.

4. Results and discussion

4.1 Local knowledge

In this section, we present the results of field survey with local people made in Kasserine and Kairouan. The interviews include 17 farmers and 31 persons distributed as described in the methodology.

Dietary habits. The knowledge of local people about some uses of cactus is variable. Their skills varied also among groups of age (young:15-29; senior:30-55; elderly people: more than 55). Figure 4-1 presents the major dietary habits of local people towards the cactus pear.

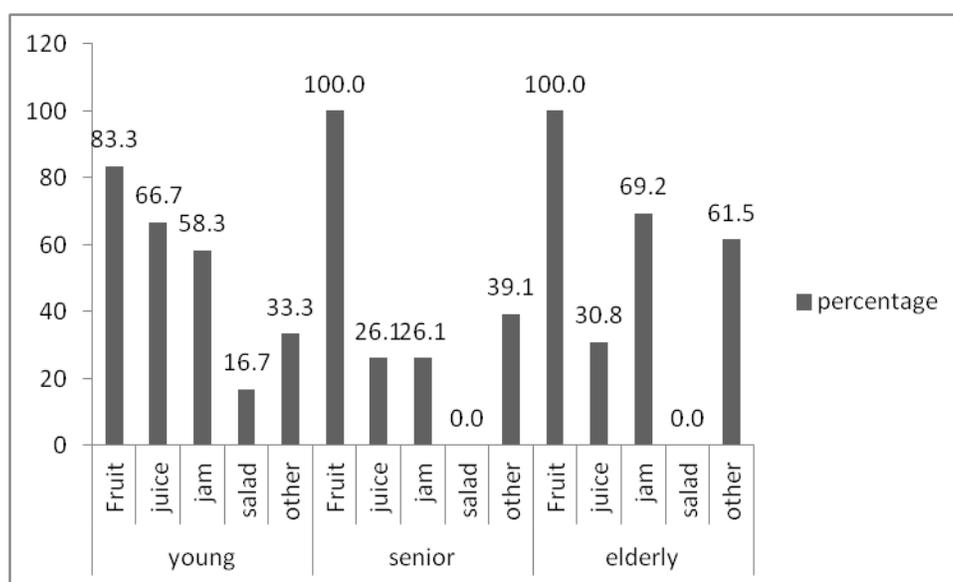


Figure4-1. People's dietary habits related to cactus pear (% of users on the total population by class of age)

All the interviewed people from senior and elderly groups confirm that they are mainly consuming cactus as a fresh fruit. In the high season, they are consuming cactus pear daily. "*Consuming it cold is refreshing. It quenches my thirst*", that's what some interviewees said. They believe that cactus pear is very beneficial for health. For youngster, most of them like consuming it as a fresh fruit, but there is a tendency for other forms of consumption such as juice. 66% of young people confirm their preference to this form in comparison with senior and elderly people. Concerning salad, it seems that it is a strange form of consumption for local population. Only 16% of youngster tried it. We can consider it as a new recipe emerged with new generation who might know about it from media. The very special form of consumption is the jam. More than

58% of young people and 69% of aged interviewees confirm that they like it and use it habitually. Preparing a jam is a skill associated generally to elderly women. In my sample, interviewees confirm this, except one student of 25 years old ensures her capability to do it. This is a good sign for transmission of this type of knowledge among generations; Woman wait for the last period of the season when the fruit is mature and/or overripe to transform it into jam using traditional means. Women do it as a common activity with her neighbor or family members. Children, in particular, like eating it in the breakfast with bread and olive oil.

Some recipes are explained below.

- Barbary fig jam:

Picking fruit

Maceration in water and fruit washing to eliminate the maximum amount of thorns

Peeling fruit

Cutting and kneading of fruits

Removing seeds with colander

Overlaying the filter in Pottery utensil. The utensil has to be Pottery

Cooking during 25 minutes over medium heat, stirring

Turning off the heat and waiting until it cool down

Pouring the jam into well dried pots

Now, the jam is ready for consumption and conservation for a long period. The good thing is that there is no addition of sugar, agar or any chemical product.

- Juice:

The recipe is easy. It consists on peeling of the fruit, kneading with a masher and filtering with colander. The addition of sugar and some drops of lemon is optional. After cooling, the juice is ready for drinking.

- Salad:

This recipe consists in:

Choosing small cladodes of spineless cactus

Removing areoles

Washing

Cutting into strips

Cutting a clove of garlic into thin slices

Pouring cacti and garlic in a saucepan

Filling with water to half

Covering and cooking

It is ready when the cactus is getting with dark color

Draining and rinsing

Pouring in a pan with olive oil, finely chopped onion, oregano and tomato.

Addition of the cactus to this mixture and the salad is ready to be eaten.

More than 61% of interviewed people affirmed that they have other uses of cactus pear such as the use of the fruit for medicinal purposes. Some people, specially elderly, said that they are using it to stop diarrhea and intestinal colic. Some others mentioned that they are using it for diabetes. Some persons mentioned the use of paddle as cicatrizing of injuries. Actually these purposes are proofed scientifically by many researchers such as Boulos (1983), Sijelmassi (1996) and Bellakhdar (1997) etc. Doctors of traditional medicine believe that it can supplement a healthy diet. The high-fiber cactus is rich in antioxidants and carotenoids. Prickly pear cactus is a good source of several important minerals such as calcium, potassium, magnesium and phosphorus are among them. In total three persons mentioned another form of use of cactus which is the vinegar. Compared to other cultures, the local populations in the study areas have differences and similarities. There is no mentioning of the use of dried flowers. However, dried flower are used in traditional medication especially against the renal diseases, diabetes and constipation and it is mentioned among the Moroccan exported products (Bellakhdar, 1997). In Italy also, the flowers have served as a diuretic. For instance, a tea made from the blossoms has treated colitis (Ben Salem, *et al.*, 2004). Ben Salem *et al.* (2004) mentioned the Chinese way to be dressed abscesses with the fleshy pad of the plant. Also, they indicate the Indians way to use the fruit in food, and the syrup preparation for treating whooping cough and asthma, etc. These habits are absent in our case.

Agricultural knowledge. In this part, we present how much our sample is familiar with some agricultural practices related to the cactus farming. Planting, maintaining, harvesting techniques and varieties used were the main topics considered.

Planting. Cactus pear may be reproduced vegetatively or by seeds. *Opuntia* may be reproduced from seeds, and will sprout readily if they are simply scattered in shade with water to keep the

soil moist until germination. Seeds need a shady bed, whereas plants need full sun. However, growth from seed is slow, and three to four years may pass before flowers and fruits appear. Propagation from pads is simpler and faster. After harvest, a well-developed young cladode is selected. It is preferable to take the ones between 1-3 years old and medium-large. The cut should be from the attachment point. It is necessary that the cladode should be healthy, undamaged, and free from specks or deformations. Then, it has to be placed in a shade for two weeks in sand until the cut has healed. This operation usually takes a place on March. The plantation will be on the months of April and May when there is no risk of frost and rain. It is recommended to have made two months before, soil preparation and fertilization. Half or two thirds of the pad must be buried on the floor, cut side down and pressing the terrain. If buried less than half of the pad, the wind may lie it down or too shallow roots may develop. If we bury more than two thirds of the palette, we are limiting their growth since it will have little surface for photosynthesis.

Flowering and fruiting. Over a period of several weeks in late spring and early summer, each pad produces several flowers that bloom in an array of colors, depending on the variety, from subtle to brilliant tones of yellows and oranges, pinks and reds. When the blooms fade, the edible fruits form. Depending on the climate, it can have two blooms a year; once in spring and one again in late fall. Generally, it bears fruit within two or three years after being planted, and reaches its highest production at seven or eight years old.

Harvesting. Fruit harvest is staggered over a period of seven months; since June until December. Prickly pears are thus available on the market from June to July until December to January. The fig pear harvest is done manually, separating the fruit from the stalk with a slight twist. Hands must be protected with gloves. The time of harvest is known by the color of the fruits (different depending on the variety) and the disappearance of the depth of the floral receptacle.

The fruit yields vary from 1.5 to 3.5 t / ha for the spineless varieties and 3 to 6 t / ha for spiny varieties.

Varieties. Two principle varieties are known: the thorny and the spineless one.

For a defensive hedge fruit, the thorny one is used. The spineless are particularly hardy and not aggressive with (almost) without thorns. Areolas on pads and on fruit, are equipped with brownish glochids that peel easily and strongly cling to the skin.

Among these two categories rely many cultivars which differ in at least one of the following criteria: strength, pad form (elliptical to oblong), pad color and thickness (bright green to blue-gray in color), fruit size, fruit color (light green, orange, yellow, red, purple), fruiting time.

We mention some varieties such as *sanguigna* (red fruit), *surfarina* (yellow fruit), *muscaredda* (white fruit), etc.

In both studied sites, respondents were able to provide accurate information on plantation and harvesting (Figure 4-2)

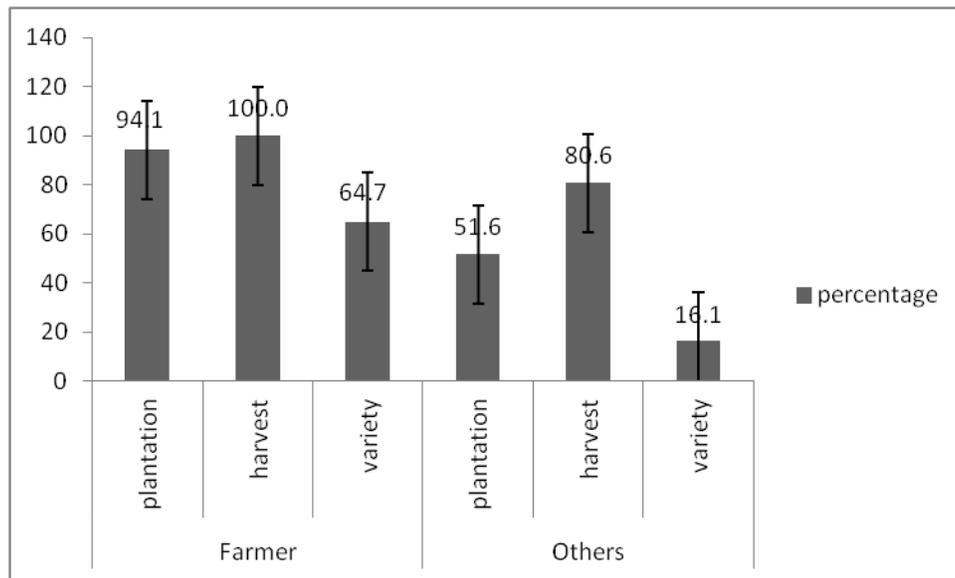


Figure4-2. Agricultural knowledge distributed by profession (farmers and the rest of people)

Almost all the farmers and more than 50% of other local people know about plantation issues such as the date and the technique. They consider it as a simple issue. "*Even if one paddle fall down, after a period of time, it will regenerate and produce new plant*" said one respondent. All the respondents indicate only the vegetative way of multiplication. The existing plantations are the main source of providing pads for further expansion. Generally, the cactus production in this area is pluvial and without chemical fertilizers. Information about spacing and irrigation are lacking.

For the harvesting, interviewed in our sample (100% of farmer and 81% of people) were able to explain the flowering and fruiting periods, harvesting manner and date. It is related to the environment where they are living; the cactus pear is available everywhere, along roads, in farms

nearby their home, in their garden, etc. Concerning the varieties, the interviewees make difference between the spineless and the thorny cactus pear, but only 16% of people and 65% of farmers were able to describe more about varieties and plant origin. For instance, the varieties brought from the region of Thala-Zelfene, and the variety Moors originated from Andalucía. More than 42 varieties and accessions from Tunisia, Algeria, Morocco, Italy, Mexico, Ethiopia and south Africa are brought and cultivated in a nursery in Kairouan since 1974. In most cases there is a lack of knowledge towards the varieties and their classification or origin.

Benefits. Responding to our question about the benefits of cactus and its use in the region, the sample of people answered as summarized in Figure 4-3.

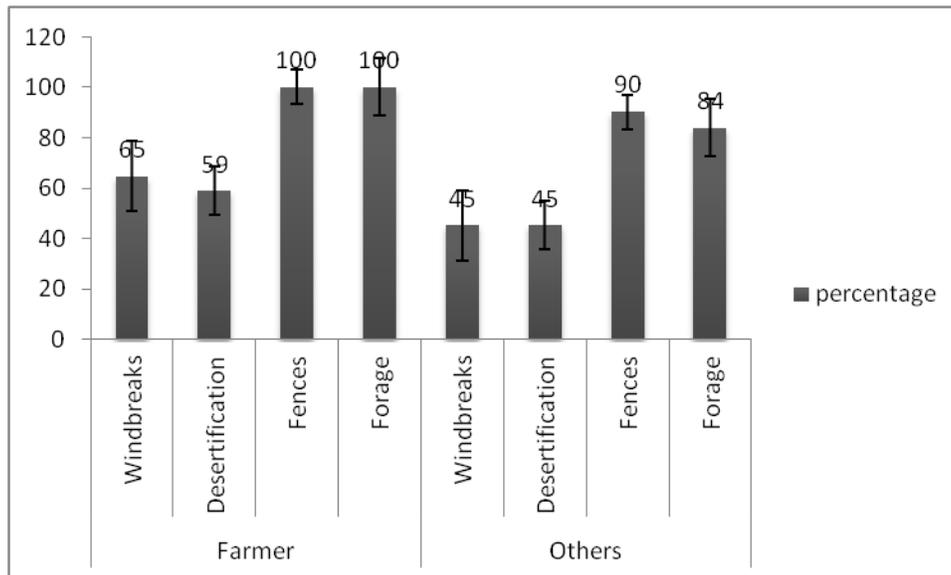


Figure 4-3. Benefits of cactus in the region known by local people distributed by profession

Concerning the different uses of cactus pear, there is a large consensus, between farmers (100%) and the interviewees from different professions (more than eighty four percent), about its use as forage and fences. They indicated the use of thorny cactus as fences around the farms and along roadsides. It is used for preventing animals passage, protecting farmers' properties and for delimiting the boundaries of each farm. Farmers in the studied areas, use the cladode of spineless cactus for the alimentation of their cows and goats. During the period of June, July, August and September, farmers cut the cladode and give it to their animals as complement of food. Spineless cultivars are the most preferred for forage production because they are easier to handle and

process. They are also associated with fewer problems during feeding. For the thorny cactus, only camels are able to eat cladodes directly. For cows, farmers burn the surface and spines are rapidly degraded. Farmers and local people agreed that cactus pear constitutes source of additional revenue, especially for street vendors in the high season.

Cactus pear is one of the promoting alternative crops, in particular for marginal lands (The VIIth International Congress on Cactus Pear, 2010). Around 50% of the answers point out the role of cactus pear in fighting against desertification. They mention the aptitude of this plant to resist water scarcity and irregularity of rainfall which are major problems in the region. It has an important role in agropastoralism. For instance, these characteristics are proved by several studies and researchers such as Barbera *et al.* in 1995. Recently, there are many local programs to enhance the use of spineless cactus in improving natural rangelands.

Cactus oil

Concerning cactus oil, our sample of inhabitant is not familiar with it. Only 5 persons out of 48 mentioned it. Even the persons who know it, they don't use it because of its high price. Only 5.6% of local women know about virtues of cactus oil (Figure 4-4). This is at variance to Moroccan women who recognize the anti-wrinkles effects of the prickly pear seeds oil (Ait Hamou, 2006).

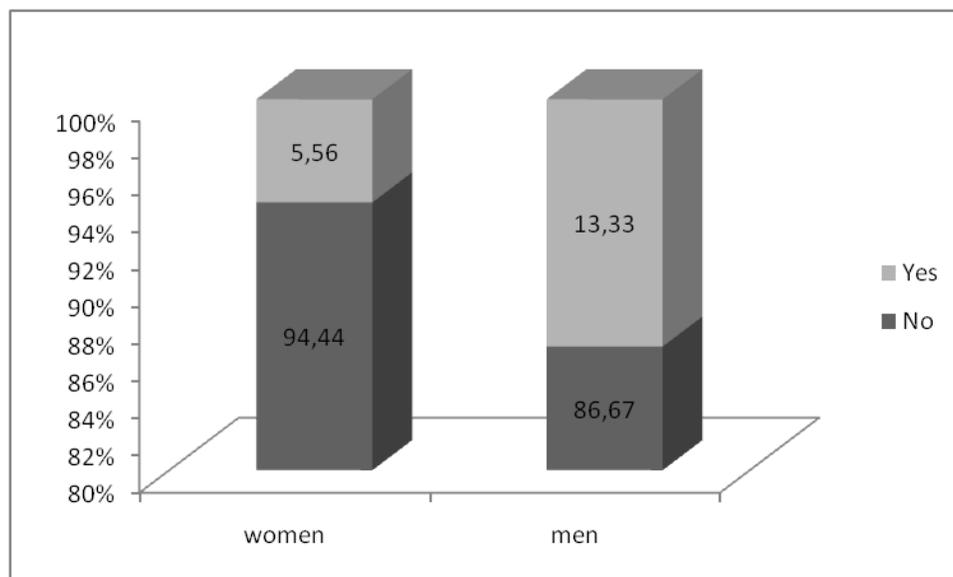


Figure 4-4. Percentage of people knowing cactus oil distributed by gender

There are companies producing cactus oil in the study areas, but there is a lack of information among people about the cactus oil and companies. Even farmers, most of them do not know about these companies. There is a problem of flow of information. Persons who have an idea about it, mentioned that they start knowing and hearing about cactus oil during the last 4-5 years. Before this period, they had no idea about it. This might be due to the juvenility of the sector in the studied areas. The industrialization of cactus pear is an emerging industry which starts recently to be recognized. However, more than ninety percent of farmer showed readiness to join associations or companies in case there is a good plan for integrating them in terms of technicality and training. They do not lack motivation, they require guidance and organization.

4.2 Value chain

Among the multiple derivatives of cactus, interest is devoted to one innovative and valuing product deriving from this plant which is the cactus oil. Its value chain is presented making reference to the two companies 'Nopal Tunisia' and 'Nopal Zaafrana'. The value chain starts from the raw material till the final product delivered to different customers. These manufacturing companies create value by acquiring fresh fruits and using them to produce oil. They are trying to produce the high competitive quality product in order to access and gain a place in the international market. The procedure in the value chain of cactus oil may exhibit some differences and particularities according to the company producing it, but the whole process and steps follow the same model shown below (Figure 4-5).The value chain description focuses on systems, and how inputs are changed into outputs.

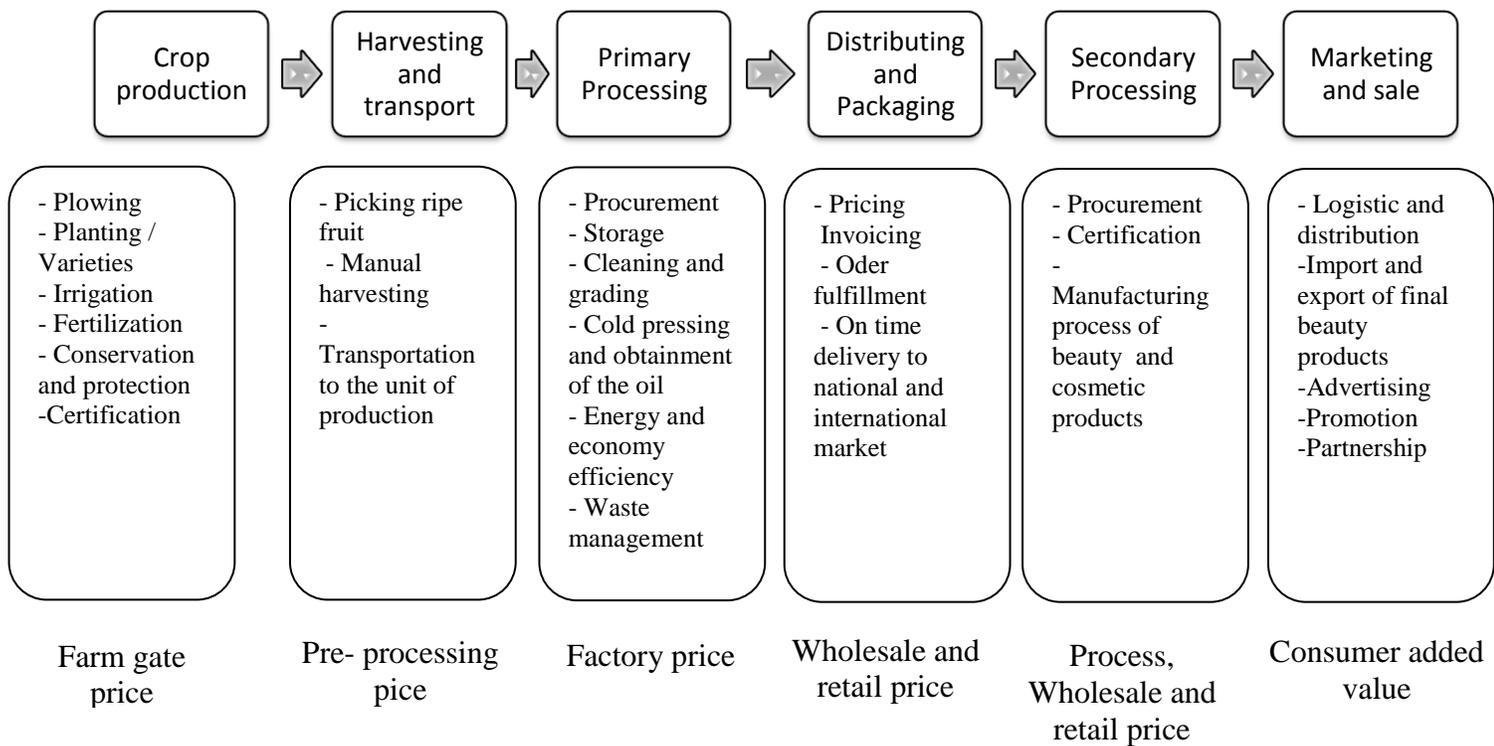


Figure 4-5. Cactus oil value chain mapping

The cactus oil value chain comprises many operations. Production crop is specific to farming, irrigation, etc. Fruit harvesting includes, not only harvest from agricultural lands, but also from pastoral and marginal areas which is considered as a source of profits for the company as they only pay for the cost of labor which is very low. The agro-processors companies dealing with cactus oil production, and its packaging, add value to raw agricultural material "prickly pear fruit". They provide employment and opportunities for more expended market. Healthcare and cosmetic industry using cactus oil are at national and mainly international level. Several companies in Europe, Japan and America import this oil from Tunisian companies, and use it in beauty and cosmetic industry. Multiple products are produced such as shampoos, beauty creams, soap, skin oil, hair oil, serum, etc. Export for those products is very dynamic. They are distributed at international level, and imported to Tunisia with a very remarkable added value.

With more details, the case of two Tunisian factories 'Nopal Tunisia' and 'Nopal Zaafrana' is presented (Table 4-1).

Table 4-1. Value chain of cactus oil produced among two Tunisian companies

	Nopal Tunisia_Kasserine	Nopal Zaafrana_Kairouan
Company	<p>- "Nopal Tunisia" was established in 2005. It is specialized in the production, processing and export of cactus pear <i>Opuntia ficus indica</i>, its derivatives and by-products. It produces fresh prickly pear fruit, Nopal powder, dried flower, seed flour, juice, jam, prickly pear seed oil and soap products. Thus, the valorization of each part of the plant is strongly present. The company has Ecocert, USDA, NOP and JAS certifications for the South America, European Union and Japan markets. It has buildings suited to their activity which are: cleaning and grading room, cold storage rooms, processing room and warehouses.</p> <p>-Workers: the whole process of oil production may take four days of work. The motivations and the good training of permanent (20 persons) and seasonal (30 persons) workers are also important, in particular of women. Women are working mainly on manual peeling and fruit harvesting. Men are working on heavy work and transportation. According to the responsible of the company: <i>'women are more productive and they are less paid'</i> which is a positive factor for the company's profit.</p>	<p>- The company."Nopal Zaafrana" is a familial company founded on 2012. It produces prickly pear and sell it in local and national market. It produces cactus oil on command. It produces many other oils like almond and castor oil.</p> <p>-This company is more traditional; one processing room, the number of workers is limited to 4 seasonal and 3 permanent.</p>
Crop production	<p>- Fruit: It comes from two sources; farms belonging to the company's property (198 ha), and 40 farms contracting with the company (830 ha). All of the farms are located near to and in the region of Zelfan, 25 km from Kasserine center. Zelfan is well known region for its top quality prickly pear.</p>	<p>- Fruit: The fruit comes from two sources: the farms belonging to the company's property (40 ton/year), and through an intermediary responsible for providing the necessary quantity (60 ton/year). He is dealing with collectors to gather fruits. The source of this fruit is not precise; it could be coming from cactus planted along the roadside, from fences around farms, from near farms or marginal lands. Since the company doesn't have a sufficient quantity of raw material necessary for its production, this issue is considered as a good solution. Also, it constitutes a new income for the collectors, especially women, and for the intermediary. Moreover, these fruits will be spoiled and</p>

	<ul style="list-style-type: none"> - Certification: All the farms are following the organic farming mode controlled by ECOCERT for the plantation, fertilization, harvesting and storage operations. - There is absolutely no danger to the environment. It is non-irritating natural plant product and not environmentally harmful. - It is mix of pluvial and irrigated system 	<p>wasted in most of the cases. So its use is considered as valorization of unused resources to produce a useful product. The price is reduced.</p> <ul style="list-style-type: none"> - It is a natural product, but it still not certified. There is no use of fertilizers. -There is absolutely no danger to the environment. It is non-irritating natural plant product, non-corrosive and not harmful. <p>- About irrigation, it is mostly pluvial (company's farm) with supplemental irrigation in need.</p>
Harvest and transport	<ul style="list-style-type: none"> - The duration of production season is relatively long: 7 to 8 months a year. - Harvesting is manual, mainly women. - The transportation costs to the company unit of production is easy and with reduced cost. 	<ul style="list-style-type: none"> - The prickly pear harvesting and transformation period starts from the month of August until the month of December. It is shorter than the case of the first company. - Harvest is manual, mainly women.
Primary Processing	<p>- Fruits are received in the unit of production. They undergo all the necessary transformations described in Figure 2-1: washing and draining, manual peeling, grinding and sieving, washing and drying, second sieving, washing of seeds</p> <p>At this level, seeds have different destinations. They could be stored for later pressing out of season of production or on demand. It could be transformed into flour and distributed to the agro-alimentary industries. The third destination is to be directly cold pressed in order to extract the oil. Then, the oil would be ready for storage and packaging.</p> <ul style="list-style-type: none"> - The products carry ECOCERT and USDA label. ECOCERT approved and recognized in 86 countries. USDA enables the access to the North American markets. Indeed the company has a JAS (Japanese Agricultural Standard) certification which enables the access the Japanese market. <p>Nopal is also approved with ANSM, the French Agency for the Safety of Health Products.</p>	<ul style="list-style-type: none"> - Concerning the cactus oil processing, fruits are collected and stored in the unit of production. Then, they are sieved until obtaining seeds. In most of cases the procedure of extracting oil is done without peeling of the fruit. So, a huge amount of waste is produced although it is used as a manure to restore the quality of soil. Then the seeds are washed, drained and sundried. At this stage, seeds could be sold, stored, or cold pressed.

<p>Distributing and Packaging</p>	<p>- Oil should be stored in a dark and cool place. The final phase consists on conditioning. It can be in bottles, vials or in bulk. The packaging can be realized outside the period of harvesting of cactus pear as an extent of marketing of the product. It could be in vial, small bottles or in bulk.</p> <p>-Destination: The oil has two paths: National market (20%) and International market (80%). The company is responsible for its transportation to laboratories, pharmacies and soap plants in big cities located in the Coastline of the country (Tunis, Sousse, Sfax, Gabes, Jerba). For the export, 'Nopal Tunisia' transports the oil to the commercial port in the capital or to the airport of Nfidha-Sousse. Cactus oil is exported to various European countries, America and Japan to. It is exported to factories in France and Germany in the framework of a subcontract.</p>	<p>-Stable product but to keep away from moisture, heat and intense light and transport in the same conditions to preserve its properties. No special precautions are observed</p> <p>- In bulk or conditioned (depending on demand).</p> <p>- Destination: Cactus oil has two paths: being sold at national market (70%) and international market (30%). The national market includes the final consumer which represents 20%. They are mainly welfare people who know the beneficial properties of cactus oil and they are looking for it. The national market includes also the industries mainly soap factories (40%) and wholesalers (40%).</p>
<p>Secondary Processing</p>	<p>-Laboratories, pharmacies, soap product factories and cosmetic plants use cactus oil as a component of multiple beauty products. One example of soap plant is called 'Tunisia Cosmetics' which is working on producing natural soap and creams using natural other products like camel milk. Certification of those products as natural and organic has an important role for increasing the selling price.</p>	<p>-Mainly soap factories and laboratories. They use the cactus oil as a component of multiple beauty products. Those products have a high price recognized as non-irritating natural plant product.</p>
<p>Marketing and sale</p>	<p>-The final products are: shampoos, beauty creams, soap, skin oil, hair oil, serum, etc. These products are re-imported to Nopal Tunisia to be distributed in the national market (pharmacies, beauty centers, exhibitions, etc.).</p> <p>-Environmentally friendly staff in packaging.</p> <p>-Retailer and reseller are involved.</p> <p>-The final consumers, who buy those final products, are belonging to the category of wealthy people with preferences to healthy natural products.</p> <p>-High added value</p>	<p>-The final products (soap, cream, oil, etc.) can be sold to the final consumer in the big areas of beauty products and in exhibitions. The export is low and on command for France, Germany, Scandinavia and Russia.</p> <p>-Retailer and reseller are involved.</p> <p>-The final consumers are wealthy people with preferences to healthy natural products.</p> <p>-High added value</p>

Along the chain, the value of the product acquires an added value at the benefits of different actors. Many factors contributed to gain competitive characteristics and higher prices. The certification and control are considered as a key element for gaining the reconnaissance of the consumers and for facilitating the entrance of cactus oil and its by-products in the international market. The farms certified organic have many benefits such as receiving premium prices for their products, access to local, regional, and international markets, etc. Cactus oil is considered one products having very high added value (Table 4-2).

Table 4-2. Summary table of the evolution of prices of cactus oil

Price (euro)	Nopal Tunisia_Kasserine	Nopal Zaafrana_Kairouan
Cost of production of 1 liter	90	100
Wholesale price of 1 liter from Tunisia to other countries	380 - 450	In bulk: 300 - 350 Conditioned: 400-600
Selling price in international markets	800 – 1000	600- 800
After secondary manufacturing; final product	the wholesale price of final products (excluding tax)= is 1/2 detail price	

The price of fruit is variable depending of its source, but generally it is low. For instance, if the acquired fruit is coming from the farm's property, it is cheap. Only the costs of harvesting are counted. The cost of irrigation, fertilization and transport is minimal. Seasonal workers, in most of cases, are not paid on a daily basis, but according to the number of boxes they collect per day. They are paid 70 cents for each box weighting 20-25 kg. Collectors are mainly rural women, dealing with an intermediary; they are paid around 45 cents for each filled box. The salary of permanent workers is ranging between 150 and 200 euro/month.

According to the company manager of 'Nopal Tunisia_Kasserine', the cost of production of 1 liter of cactus oil is estimated at 90 euro (200 Tunisian Dinar - DT);the wholesale price of 1 liter from Tunisia to other countries is in the range of380 - 450 euro. Once it reaches the market in foreign countries, its selling price increase to reach about 800-1000 euro. Resellers have an important role of this increase. After manufacturing and implementation of cactus oil in the healthcare cosmetic industry, the wholesale price of final products (creams, serum, etc.), excluding tax, is generally the half of the price at detail. For example, one cosmetic product of 15 ml is sold at 16

euro as wholesale price, and it will be sold to final consumer in Tunisian pharmacies or in the French market at 32 euro.

In the case of Nopal Zaafrana Company, the value chain seems to be less complicated. Its production is mostly intended to the national market. In the case of this company, there is no certification and the prices are lower than in the first company. In bulk, the price is 300 - 350 euro/liter depending on quantities ordered. If it is conditioned the price vary from 400 to 600 euro depending on the capacity. The same principle of implementing cactus oil in cosmetic industry is applied. These transformation activities that change inputs into outputs that are sold to customers, represent the operational systems creating value. Marketing and advertisement are definitely sources of value here. For instance, the retail price of a by-product manufactured by soap industry and sold in exhibitions is doubled. The manager of 'Nopal Zaafrana' said that *'the Tunisian market is very promising. Most people, who might use our products, are not reached yet. The target population is the wealthy people with preferences for healthy natural products'*.

Certainly, the added value of cactus oil and its by-products is high, but the profit does not reach the rural population who received reduced payment. It is more significant with the other chain actors. The increase of raw material costs and salaries of workers may create financial problems for companies and may induce the increase of selling prices along the chain. Thus, the review of these prices has to be well studied. The control of prices also is important for making a balance and improving the income of rural population. Establishment of cooperation in cactus production grouping farmers and villagers may be a solution.

SWOT Analysis. A SWOT analysis for the cactus oil industry has been carried out through the review of some documents and through the interviews with promoters of companies working in the sector (Table 4-3). Specially the failed companies gave us an overview of the difficulties in this field. The SWOT analysis describes the sector in terms of:

- Strengths: advantages linked to the organization of the sector which is more related in our case to the available resources and the quality of the products.
- Weaknesses: specific causes of failures of the sector which is more related to the lack of organization in the sector, and the problems of distribution and marketing of the product.
- Opportunities: external benefits, independent of the sector indicating the potential importance of institutional bodies.

- Threats: negative external constraints to the sector connected with the climate conditions, the marketing and its limiting factors.

Table 4-3. SWOT analysis

Strengths	Weaknesses
<ul style="list-style-type: none"> - Importance of the area occupied by the prickly pear - Importance of fruit production - Existence of organic producers and a significant number of refrigerated warehouses - Existence of fig valorization companies - The optimal valorization of prickly pear includes the use of all the parts of the plant which implies an optimal benefit - Continuous production throughout the year (seeds can be stored and pressed on demand) - Positive image of organic products which is a driving force for its use - Reputation in marketplace of certified cactus oil products - High product quality level - Interesting selling prices for promoters. Cosmetic and pharmaceutical products are characterized with a high added value - willingness of farmers and promoters to join the cactus valorization industry 	<ul style="list-style-type: none"> - Lack of statistics and reliable data on the sector - GIS (Geographic Information System) existing but untapped - Lack of organization of circuits of production, commercial distribution and advertising - No structured plan for logistics and transport of production - Lack of cooperative in the sector (which unite the small scale farming) -Geographical dispersion between oil production companies, and plants of transformation and points of purchase - Lack of commercial facilities - Competitiveness of other countries (Morocco, etc.) - Lack of technical support - Lack of qualified labour (process, marketing, quality control ...) - Technological weaknesses for oil extraction. Current used technology requires a long duration which means higher energy consumption compared to other technologies - Drying technology that causes degradation of plant constituents
Opportunities	Threats
<ul style="list-style-type: none"> - Existence of new technologies respecting green process, preserving the oil components and doubling the yield - Existence of public bodies able to ensure the link between research structures and businesses in order to conduct studies, experiments and development of the sector - Existence of public bodies consulting and supporting farmers as well as industrials 	<ul style="list-style-type: none"> - Climate conditions; irregularity and aggressiveness of rainfall -Marketing has limiting factors related to the economic, social and political stability. This last factor disrupts not only the production but also the export activities and the insurance transactions

5. Recommendations

The prickly pear currently takes a place in cosmetics and agro-alimentation, thanks to its exceptional properties. Recent research discovered the method for producing electric energy through the cladodes. So, the exploitation of this resource is promising and challenging for Tunisia. For this, there is a need to spread the knowledge of the current and potential uses of cactus pear, stressing its role in fighting against desertification and its efficient valorization in industry. Since most local families have their own plot, the scheme to transform small scale production into a significant industry is interesting. For a futuristic vision, establishment of a Cactopole could be very useful for the advancement of the sector.

As farmers are the first level in the agro-industry, a technical assistance for them is important. Therefore, creating cooperatives for farmers to unite and direct them seems to be the first step to do. The cactus sector is promising, so there is a need to encourage young promoters to invest in the cactus industry. Thus, optimizing the coordination and performance of various support structures for better services toward manufacturers could be efficient. It is important to bridge the gap between producers and researchers promoting a strategic alliance framework that allows research according to the needs of enterprises and the region.

Concerning the institutional framework in Tunisia, the sector lacks specific incentives. Cactus projects receive the benefits provided for any other project in the investment phase. There is no national plan designed to promote the product on foreign markets.

The cosmetics industry development using inputs from the prickly pear allows producing products with high value-added both at national and international level. The strategic development for companies could have these main axes; first, adopting modern methods for extracting seeds oil, and diversifying products containing this oil (creams, shampoos, soaps, etc.), second, reaching the target population in the Tunisian market and third, accessing foreign markets and building network relationship between producers and customers. Certification of the product and adoption of the organic system is indispensable. Also, it is necessary to improve the marketing of innovative products which could be by developing a website on the prickly pear sector, its products, companies and their contacts. Indeed, one way is to negotiate contracts for major strategic area for export.

6. Conclusions and perspectives

Although local knowledge may not offer a panacea it can still be a means for making environmental management and conservation systems more inclusive and just, and, hence, potentially more sustainable in the long run (Byg *et al.*, 2012). This overview shows that there is a large knowledge among local people about cactus pear, its different uses and benefits. Some medicinal and cosmetic uses are known, some others are not. Some researchers (Nefzaoui *et al.*, 2007) propose to adopt cactotherapy as a new word to differentiate this medicinal plant. The concept of cactus oil is still considered as new approach among rural and even urban areas. Thus, a wide field is open to research and development. By the one side, this need is becoming more impressing because Tunisia has to cope with a natural challenge which is mainly rain irregularities. Cactus is viewed as one of the tools that can help to fight against desertification. Actually, there are some programs to more implement cactus in the region, but they still have many obstacles. Cactus is considered as a source of additional revenue for rural population, and a raw material for interesting products with high added value specially cactus seeds oil. There are various development options like fodder, fruit, production, cochineal production, soil and water conservation, etc. In these last years, there are some attempts to create companies valuing cactus industries. Some are persistent and successful, many others faced several problems.

As seen in this study, the sector of oil derived from the prickly pear is relatively young. By supporting the work of sustainable production chains, there will be a chance to consolidate the specialization of actors in the chain, improving the quality and quantity of raw material, supply and diversification of innovative products from cactus pear. There is a need to promote the implementation of good manufacturing practices, good agricultural practices and good management plans. Specific projects that integrate technology, industry and research should be encouraged.

The ambition is to create a cactopole in this region; a real industrial zone in rural areas about the production and valorization of cactus, that respects environmental standards with the aim of zero waste. Also, keeping abreast of new discoveries, is necessary to take advantage from it. For instance, the electric energy produced from cactus pads is an impressing source of alternative energy. It is really needed to set out the economic circuit in this region, and it is feasible in case of adequate orientation and management.

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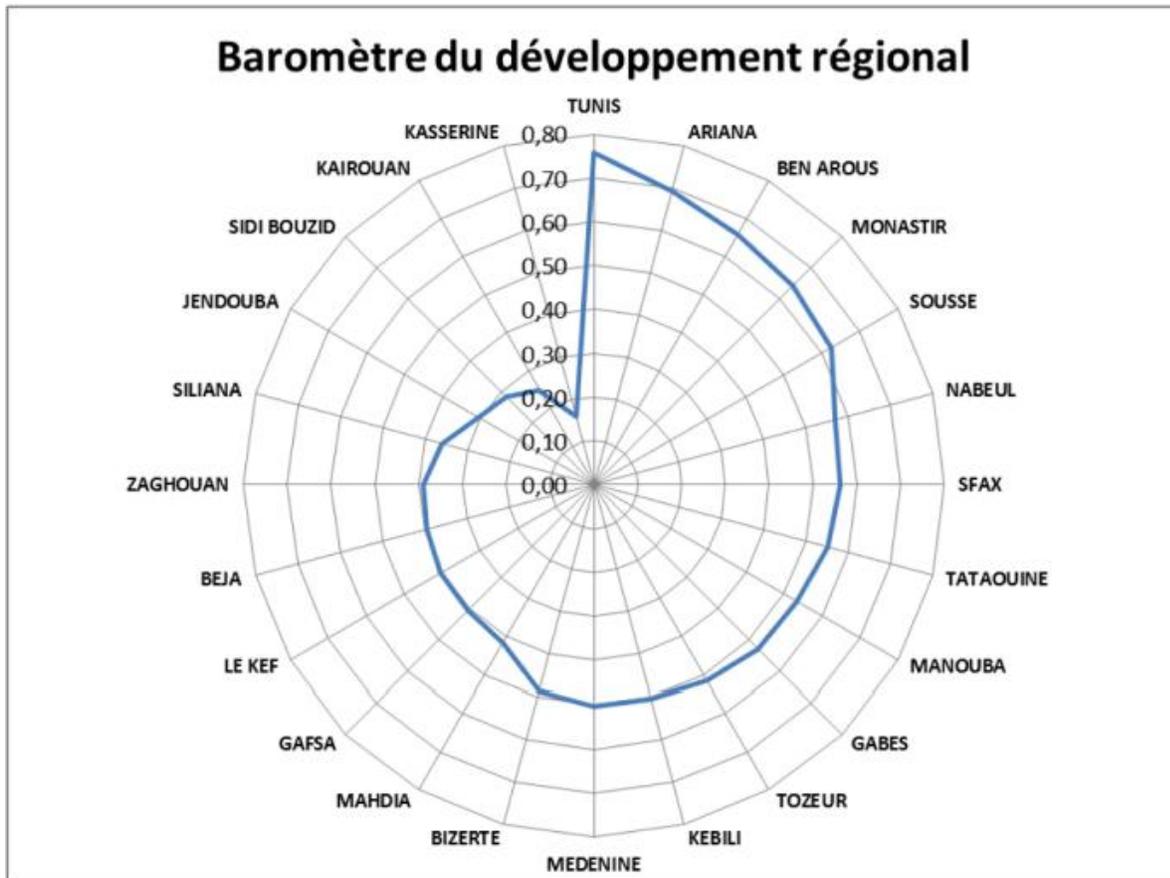
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Yahia, E. and Mondragon-Jacobo, C. (2011). Nutritional components and anti-oxidant capacity of ten cultivars and lines of cactus pear fruit (*Opuntia* spp.). Food Research International 44:2311-2318.

Annexes

Appendix 1. Graphic of barometer of regional development



Source: ITCEQ

Appendix 2. Guideline for major questions addressed to ADMINISTRATION

Form N°:

Date:

Name of the interviewee:.....

Direction:

Activity:

Location

Governorate: Delegation Imada:

1. What is the area / surface of Cactus (*Opuntia Ficus-Indica*) in Tunisia?
2. What is the region of higher production?
3. What is the area of Cactus in Kairouan?
4. What is the area of Cactus in Gasserine?
5. Is it private or public?
6. What is the number of farmer/cultivators of Cactus?
7. Is there any nursery?
8. What are the categories? Varieties?
9. Is there any preferable one? Why?
10. Is there any constraint ?

- Adaptation to climate
- Quality
- Production
- Diseases

11. What is the production per hectare?

12. When is the period of harvest?

13. What is the price of *Opuntia*

Fruit

Rackets

14. What are the advantages?

- Pastorals

- Contributes to fight against desertification
- Contributes to soil conservation
- Contributes to job creation
- Contributes to revenue generation
- Industry
- Other.....

15. Is there any future program to more exploit Cactus?

16. Is there any encouragement or investment to promote people to start Cactus projects?

What are they?

17. Who are the producers?

- State
- Companies
- Local people

18. Who are the companies contributing to cactus production?

19. Are they satisfied? What are their needs/ cons/suggestion to improve?

Appendix 3. Questionnaire (COMPANIES)

Form N°:
Date:
Company:
Name of the interviewee:.....
Activity:

Do you, as a respondent, wish to be treated confidentially in our thesis?

Do you want the company's name to be treated confidentially in our thesis?

Company characteristics:

1. Location

Governorate: Delegation: Imada:

2. How long has the company existed:

3. Activity Cactus oil /principal

Cactus oil/ secondary

4. Ownership? Partnership?

5. Nationality; National

International

6. Annual turnover? Sales?

7. What is the number of employees?

8. When is the period of high production?

9. What is the annual production of cactus oil?

10. From where do you buy the fruit?

	Quantity	Price
Company's properties		
Farmer		
Association		
trader		

11. Transportation? of fruit? of oil?

12. Which type of client?

final consumer

wholesaler

pharmacies

industries

13. Is there stability? Or growing market?

14. What is the price of selling in Tunisia and abroad?

15. How much do you need to produce 1 liter of Cactus oil?

16. What is the cost of production?

17. What do you do with the waste?

18. People, are they aware of the Cactus oil virtues?

19. Do they ask for it?

20. Do you make ads?

21. List point of purchase?

22. Give me some examples of products (names, brands, label)?

23. What have you perceived to be the main factors affecting the strategic development of your company? External? Internal?

24. How do you view competition? How has this changed over time?

25. How do you view the institutional environment (i.e. government)?

Appendix 4. Questionnaire (FOR LOCAL PEOPLE; FARMER, CULTIVATORS, HABITANTS)

Form N°:

Date:

Name of the interviewee:
.....

1. location

Governorate: Delegation Imada:

2. interviewee

Name and Surname : **Age :**

Marital status: Married **Single** **Divorced** **Widow**

Number of children (total):

What is your main economic activity?

Activity Principal Secondary

	(put 1 cross)	(put many crosses)
<i>Farmer</i>	<input type="checkbox"/>	<input type="checkbox"/>
<i>Breeder</i>	<input type="checkbox"/>	<input type="checkbox"/>
<i>Functionary</i>	<input type="checkbox"/>	<input type="checkbox"/>
<i>Trader</i>	<input type="checkbox"/>	<input type="checkbox"/>
<i>Artisan</i>	<input type="checkbox"/>	<input type="checkbox"/>
<i>daily worker(in a farm)</i>	<input type="checkbox"/>	<input type="checkbox"/>
<i>Other(.....)</i>		

Education: Illiterate Kotteb Primary Secondary High

3. Land Capital

- Do you have *Opuntia ficus-indica*?

No
Yes

If yes, is it

- in agricultural land
- in pasture areas/hilly terrains
- As fence

4. When are they planted?

5. When is it collected

6. Which category do you collect?

- prickly
- thornless

7. Which part do you harvest

Fruit

Racket

8. With which tools? Has this changed over time?

9. What are the different benefits?

- Contributes to the fight against desertification
- Contributes to soil conservation
- Contributes to revenue generation
- Setup as windbreaks
- Other.....

10. Are you in favor of artificial regeneration programs for these species?

Yes

No, Why ?

.....

.....

11. What skills / local products of Cactus you make ?

Type	Yes/No	Interested to valuate this product?
Oil	<input type="checkbox"/> Yes <input type="checkbox"/> No	<input type="checkbox"/> Yes <input type="checkbox"/> No
Juice	<input type="checkbox"/> Yes <input type="checkbox"/> No	<input type="checkbox"/> Yes <input type="checkbox"/> No
Jam	<input type="checkbox"/> Yes <input type="checkbox"/> No	<input type="checkbox"/> Yes <input type="checkbox"/> No
Other : (specify)	<input type="checkbox"/> Yes <input type="checkbox"/> No	<input type="checkbox"/> Yes <input type="checkbox"/> No
Other : (specify)	<input type="checkbox"/> Yes <input type="checkbox"/> No	<input type="checkbox"/> Yes <input type="checkbox"/> No

12. Do you know about Cactus oil?

If No,

❖ Don't you use any product with cactus oil (I expect to list some examples)

If yes

❖ What do you know about it?

❖ Do you know how to prepare it?

***The following questions are addressed only to Farmer**

13. Cactus Productions

Question	CODE1	2014
area	ha	
Type of irrigation	CODE	
production	qx	
	DT	
familiar consumption	qx	
livestock consumption	qx	
	DT	
Production cost (TD)	racket	
	irrigation	
	Equipment	
	Tillage	
	family worker	
	paid worker	

(Irrigation source : Private / Collective / no irrigation)

14. To whom do you sell them?

- Market
- Intermediate
- Company
- Others.....

15. What are the constraints that you find associated with Cactus production?

- | | High cost ? | Low availability? |
|----------------------|--------------------------|--------------------------|
| Seeds | <input type="checkbox"/> | <input type="checkbox"/> |
| Irrigation water | <input type="checkbox"/> | <input type="checkbox"/> |
| Equipment | <input type="checkbox"/> | <input type="checkbox"/> |
| Manpower | <input type="checkbox"/> | <input type="checkbox"/> |
| Access to the Market | <input type="checkbox"/> | <input type="checkbox"/> |
| Others..... | | |

16. What are the main constraints that you find to participate in the economic development of product "oil"?

- Difficulty for the marketing of products (eg lack of buyer)
- Lack of raw material

- Lack of technicality
- Other

17. Do you participate in some cooperatives, associations to valorize cactus oil ?

No, why?

.....

Yes-What is the name?

18. Are you ready to join an association or a company to provide services (cactus oil)?

- Yes
- No

If not, why?

- Lack of resources
 - Lack of confidence in prospective partner
 - Access problem
 - Lack of skills
 - Lack of motivation
 - Other.....