Market analysis of prickly pear (*Opuntia ficus-indica*) production in Cochabamba, Bolivia.

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Presented to Dr. Ingrid Fromm

Zollikofen, 6th of December 2017
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List of Abbreviations

CIAD  Centro de Investigación en Alimentación y Desarrollo, Mexico - Food and Development Research Centre
CIREN  Centro de Información de Recursos Naturales - Centro de Centre for National resources in Chile
ER  Expected Results of the research
IRR  Internal Rate of Return
m.a.s.l.  Meters Above Sea Level
PROAGRO  Programa de Desarrollo Agropecuario Sustentable - Program of Development of Sustainable Agriculture
RMA  Rapid Market Appraisal
SDC  Swiss Department for Cooperation
UMSS  University of San Simon of Cochabamba
UCB  University Catholic of Cochabamba

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Abstract

The cactus pear (*Opuntia ficus-indica*) is adapted to semi-arid and arid climate. It is an alternative crop that has potential to help the Bolivian rural population to face climate change. One of the most important characteristics of the cactus is the wide variety of by-products that can be derivates from the plant. This thesis is an attempt to answer questions concerning the actual state of the value chain of cactus pear fruits in Bolivia and what are the opportunities for future developments. The methodology follows the Rapid Market Appraisal (RMA) approach and use tools such as literature review, questionnaires with key informants, observations on the market, producers interview and consumers survey. The research is the first on the topic and follows a qualitative approach. The three research questions could be answered.

The first one concerns the economic importance of the cultivation of cactus pear fruit in Bolivia. The study reveals that on the 28 producers having a measurable income from cactus pear production, none of them reach the minimal monthly income in Bolivia (BOB 2000). The unique producer specialized on cactus pear production reaches the BOB 1200 per year from the eight weeks of harvest. Those results confirm that cactus pear production is actually a side crop for the producers and that the main income for the families come from external activities or farming. This result is influenced by the actual pest situation around Cochabamba. The plantations are dying under cochineal attack. This parasite of the cactus pear was introduced 20 years ago for the harvest of carminic acid.

The second research question concerns the opinion of the consumers on cactus pear. Positive and negative characteristics could be collected. The outcome is that some customers refuse to eat more than 4-10 fruits per day, for fear of facing digestive problems. The reasons of this fear are myths surrounding the consumption of the seeds of the fruit. This disadvantage could be exploited. Transformed product without seeds and safe to consumption could respond to this new demand. Concerning the cactus pear stem, there is yet no established habit of consumption. It could be introduced in the market, by mixing it with other functional food and promoting his properties against diabetes and cholesterol to the population.

The third question concerns the future of the developments of the value chain. The main problem for the production is the actual infestation of cochineal on the fruits plantation. This lowers the quality and the quantity of the harvest. An elimination of the parasite could be only achieved with the support of the government and funding for a project a treatment and monitoring of the plantations. The producers actually receive no technical support, and only one engineer knows how to treat cochineal in Bolivia. This lack of knowledge has to be addressed. The potentials for the production are vast. The plant could bring an income to many more communities unable to keep growing traditional crops such as wheat and maize. The cactus pear offers an alternative for fodder in communities living from livestock production. This is specially adapted to regions missing crop residue to feed the cattle during the dry months. Concerning the commercialization, the hole process is informal and done without machinery. This offers the possibilities to many farmers to enter the production. The downside is that no producer organization exists yet. Some villages benefit from a local trader that organize the transport of the fruits to the two biggest centres of consumption: Santa Cruz and La Paz. With the increase of quality of the fruit, the commercialization could pass from informal markets to supermarket and fruits retailers.

The actual situation of the value chain is similar to the Argentinean’s case. If Bolivia decides to give importance to cactus pear fruit producers, the market could develop and in the future start exporting the fruit, like in Chile.

Key words: market research, market structure, *Opuntia ficus indica*, Plurinational State of Bolivia, supply chain
1 Introduction

Bolivia: setting the context

Bolivia is the biggest inland country of South America, neighbour of Peru, Brazil, Paraguay, Argentina and Chile. From the altiplano to the jungle, dry to humid climate; Bolivia is home to huge varieties of species of plants and animals. This natural diversity is nevertheless in danger. The climatic change has roughly affected the country. In the Department of Cochabamba, the main climatic change is the reduced access to water. From traditionally two rainy seasons, the main one from January to March and a minor one in October, now the precipitations occur at unpredictable timing sometimes later in the year or earlier and in less quantity. This generates insecurities for the population practising subsistence farming and encourages the migration towards the cities. The demographics of the country have changed. Now, 70% of the population is living in the urban areas and 30% remains in the countryside (Index Mundi 2015). The growth of the urban population generates a disorganized expansion of the cities and at the reverse, abandonment of agricultural land. The government takes measures to counter this phenomena by providing technical support through agriculture projects or allowing foreign fund’s projects in the countryside.

Context of the research region

The focus of this research was on the department of Cochabamba, which is the equivalent of 1.4 the size of Switzerland (41’285 km²) with a surface of 55’631 km². There are six times fewer inhabitants than in Switzerland in this department, about 1.758.143 persons in 2012. Traditionally, the agriculture centre of Bolivia has a very mild climate all year round and an important historical role in the supply of the mining cities of Oruro and Potosi in the 17th Century.
Participating organizations

Climate change is one of the central themes of cooperation for development agencies in the world and many actors approach this topic by delivering fund for research on alternative agricultural practices. The Swiss Department for Cooperation (SDC) in collaboration with the public University of San Simon of Cochabamba (UMSS) and the private University Catholic of Cochabamba (UCB) promote research about alternative agriculture practices targeting increased resilience to climate change. One of those practices is agroforestry systems. Agroforestry seeks the mix cultivation of crops and trees on the same plot of land. The system can also work uniquely with a mix of fruit trees and protective trees. The goal is to use the branches of the protective trees to protect the ground and increase soil fertility. Agroforestry is well researched in tropical region on production of cacao and coffee, but few references are available on dry climates. One of the privilege places for this type of research is the Research Institute of Conservation Practices in Andean Agriculture in Combuyo directed by Dc. Noemi Stadler-Kaulich, near Cochabamba. Thanks to more than 16 years of experience with agroforestry Dc. Stadler-Kaulich observed the adaptation of many native plants to dry climates and is aware of which tree species association reinforce the system. Agroforestry systems provide many advantages to farmers such as natural fertilisation of the soil, regeneration of the ground structure and protection against erosion. To help the diffusion and adoption of this system, the productive aspect has to be explored. The observation of the Dc. Stadler-Kaulich underlines the profitability of yearly harvest of the cactus pear fruit \( (Opuntia ficus-Indica) \). The research will explore the market of cactus pear products in the department of Cochabamba.

Introduction to \textit{Opuntia ficus-indica}  

The cactus pear fruit is an oval, elongated berry, with a thick receptacle (peel), and juicy pericarp. The edible part (pulp) contains a relatively large number of seeds. The peel of commercially ripe fruits of Opuntia accounts for 33 to 55\% of the fruit, while the pulp accounts for 45 to 67\%; seeds, contained in the pulp, accounts for 2 to 10\% \cite{Cardador Martínez, A. et al. 2011}. This fruit commonly called ‘tuna’ in South America is originally from Mexico and can be found nowadays in most dry areas of the world (Mediterranean Sea, South Africa and Australia). It was brought outside Latin America after the Spanish colonisation. It has many names, such as nopal and nopalito, referring to the green stem of the cactus \cite{Anaya-Pérez and Bautista-Zane 2008}. In English literature, it can be referenced by prickly pear in older researches or as cactus pear in more recent works. Sadly the low economic importance of cactus stem and cactus pear fruit, determined by the low volumes commercialized, has prohibited the lack of up to date information that would make possible to demonstrate its socioeconomic and environmental importance. \cite{Callejas-Juárez 2009}. The lack of market information observed by Callejas-Juárez is similar in the Bolivian context. Some documents about transformations of the product can be found in the Agriculture Faculty of the UMSS in Cochabamba but there is no thesis about the cactus pear market. Many more researches are necessary to try to understand the real socio economic and environmental impact of cactus pear in the department of Cochabamba. This thesis is an attempt to answer some of the questions concerning the size of the market and the economic importance of the fruit for the producers and to measure the consumer demand.

2 Objectives

The structure of the research was inspired by the Research Institute of Conservation Practices in Andean Agriculture Mollesnejta, near Cochabamba. They discovered that the cactus pear was well adapted to agroforestry on dry land and would like to know more about the market for the derivates of the plant.
Market analysis of prickly pear (*Opuntia ficus-indica*) production in Cochabamba, Bolivia

Elena Paiuc

The agricultural land around Cochabamba receive an annual rainfall of 550mm. With the climate change, this amount is not guaranteed and access to water is an increasing issue for unirrigated crops. Farmers have to regularly face loss of harvest because of the lack of water. Cactus pear is a crop with high potential to create an income for small farmers on a wide range of land areas. As experienced with the Ethiopia high adoption of cactus pear, it has a real power to bring additional income to poor farmers. The overall goal of the research is to obtain inside into the value chain of cactus pear fruit and stem in Bolivia. To achieve this overall goal, four different expected results (ER) have been listed. The first one concerns the need to describe the actual state of the value chain. The second one is focused on understanding the role of the different stakeholders and the existing producer organization. The third one aims to acquire information about future market developments. And the last one will try to collect knowledge about the cost and benefits of the transformation of some cactus pear products and give recommendations. All this information should help to understand which value chain development are possible and what is the feasibility of such development for the producers.

Table 1: Goal, objectives and expected results of the research.

<table>
<thead>
<tr>
<th>Goal</th>
<th>To contribute to an improved and sustainable income generation for rural poor families and to an increased productivity of fruit producers through the illustration of commercialisation’s possibilities of cactus pear fruits and stems.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objective</td>
<td>Demonstrate the value chain of the cactus pear fruit and stem of <em>Opuntia ficus-indica</em> and potentials development of commercialisation in Cochabamba Department, Bolivia.</td>
</tr>
</tbody>
</table>
| Expected Results (ER) | 1. Analyse existing value chain for cactus pear fruit and stem with key stakeholders in the context of Bolivian interandean valleys  
2. Map of the key stakeholders, potential partners for commercialisation and existing producer organizations  
3. Realize a market assessment of future uses and processing possibilities and propose recommendations  
4. Demonstrate cost and benefit structure of a transformed cactus pear product |

2.1 Hypothesis

To guide the research, three main hypotheses have been selected. The first one corresponds to the economical role of *Opuntia ficus-indica* products for small-scale farmers:

**Q1) What is the role of the cactus pear’s products in the economic life of the small farmer livelihood?**

H0) The *Opuntia ficus-indica* products (stem and fruit) are used for self-consumption by small scale farmers (<5-10 ha).

H1) The *Opuntia ficus-indica* products (stem and fruit) have other purposes than self-consumption by small scale farmers (<5-10 ha).

The second hypothesis investigate the perceptions of the consumers about Opuntia’s products.

**Q2) What is the opinion of the consumers (higher budget/ lower budget, organic/ health) about Opuntia’s products in the Cochabamba district?**

H2) The social and cultural perception of the consumers about Opuntia’s products is negative.

The last hypothesis concerns the future developments of the market of Opuntia’s products.

**Q3) What are the market potential for future Opuntia’s products?**

H3) Opuntia’s products have potential for new transformation and commercialization form (seasonality, packaging) in the Cochabamba district.

Each research questions will be answered with specific tools and population sample.
3 Methodology

The first part of this section gives the method used in this research and the correspondent theoretical background. The sampling method is explained and why it best suits the situation. In the third part, the tools to collect the data are presented. The fourth section develops how the hypotheses are treated into questions. Finally, the limitation and distortions of the methodology are exposed.

3.1 Methodology description

Rapid Market Appraisal (RMA) approach

A rapid market appraisal is a methodology with simple tools for participants of a market or external observers to quickly understand the need of the consumers and the actual state of the market. As presented in the ‘RMA tool kit’ from Joss, RMA is an effective way of obtaining relevant information about a market system for a specific production sector whilst at the same time minimizing costs, delays and working time (Joss S. et al. 2002). One of the objectives of this study being to understand the actual state of the cactus pear market in Bolivia, the method suits the need of this research.

1. RMA proposes to start with gaining an understanding of the actual market by using visual observations of the product offered on the market place.
2. The second step is to conduct interviews with sellers of the product investigated.
3. The third step is to ask questions to consumers to get more information about the market demand.
4. Finally, other actors such as producers, intermediaries, processors, can be interviewed to get a more global understanding of the full value chain.

Application of the RMA tools

1. In this study, the market observation took place from May to June 2017, which is outside the main season of cactus pear (January to March) in Bolivia. Nevertheless, some observations of cactus pear on the market could be made.
2. Later, it has been possible to interview sellers of cactus fruits from the ecological market, who happened to be producers as well. From this first observation, complemented by the ten key informant interviews, main areas of production could be localized.
3. From August to September, interviews have been conducted with producers in two production sectors in the department of Cochabamba. Each region had a different way of using cactus pear. One had the goal to use cactus pear stems as fodder and later sell the fruits as an alternative income. The other region had a tradition of cactus pear production for the fruit market of the biggest cities of the country. Those two propositions expose the large variety of usage of the cactus pear plant and the high adaptability to different climates and needs of the population.
4. For the third step, consumer interviews have been made in three different markets of the city of Cochabamba.

3.2 Sampling explanation

Snowball sampling

The snowball sampling effect is used in situation where few informants are available, or if only one is known. It helps to create a list of informants as the process goes on. It enables researchers to start with only one key informant and then ask him to nominate other potential participant matching the researched profile. If the first key informant can direct to a second one, more and more person
can be added to the research sample. This sampling technique is well adapted to qualitative research.

**Application of snowball sampling in the research**

With a sampling of participants, the results of this research have a qualitative importance. Thanks to the support of ECO-SAF and Agrecol Andes, some specialists on cactus pear could be identified and used as a starting point of the snowball sampling. Interviews were made with nine key informants. The same approach was used to find cactus pear sellers. Those interviews helped to localize sellers and producers of cactus pear. Three women selling the fruits during the season have been interviewed at the organic market of Cochabamba. Those three women gave indication about two producing area outside the cities. Those areas have been visited and each time cactus pear plantation could be seen, the people were asked if they knew the owner. This technique has been repeated in the two mains regions of the study.

3.3 Tools to collect the data

The first used tool is a literature study done during the preparation time before departure to Bolivia and during the stay in the country with the use of local literature.

**Literature study**

The literature study is a tool to gain inside into previously collected data, called secondary data. This tool is used to get information about previous researches done on a specific topic. It helps to understand the context of the research and to identify literature gap. The secondary data can be gathered and analysed to create results for the research. It helps the researcher to better understand the subject of the research.

**Application of the literature study**

Before going to Bolivia, a broad literature review on countries producing cactus pear has been studied. This research was based on literature found in English and German on library networks such as WebofScience, Google Scholar, Nebis, swissbib, prodINRA, Ovid (AGRICOLA). It contains a description of the Mexican, Chilean, Argentinia, Peru, South Africa and Italian market. As observed at that time, very few documents were available about the market of cactus pear in Bolivia. Only the work of Tekelenburg A. in 2001, ‘Cactus Pear and Cochineal in Cochabamba’ gave some information about the cactus pear in Bolivia. Unfortunately, this work, supported by the Dutch cooperation for development, focus on interactive design and doesn’t describe the market of the cactus pear fruit. Once in Bolivia, literature research has been done at the faculty of agriculture at the UMSS and the UCB. This research collected thesis made in the 90s about the benefit of the introduction of the Cochineal (Dactylopius coccus Costa) in cactus pear plantation. More recent thesis focused on the industrial transformation of cactus pear fruits. The conclusion of those researches is similar to the one made before departure: market information is available but not about the Bolivia market of cactus pear. Indeed, this crop is seen as marginal and commercialised on informal market, which explains the lack of up to date information. The same remark was made in 2009 by Callejas about the Mexican market.

**Observation on the market**

The first tool of the RMA approach is the observation of the market. One observation of cactus pear could be made in June 2017. The observation was done on the central market of Cochabamba on Saturday morning. During the month of June, the central market of Cochabamba was visited twice on Saturday morning between 7-8 am. Similar visits have been done at the market of Quillacollo (small city next to Cochabamba) during the same month. June is the second month after the end of the main harvesting season of cactus pear. Thus, the fruit was rare on the market and
only one observation could be made. The observation gave insights on the selling conditions of the fruit, the quality of the fruit at the consumer level and the products sold next to the fruit.

**Key informant interviews**

Key informant interviews were the second action taken to collect information on the market of cactus pear. The key informant interviews are semi-structured and aim at collecting qualitative results. It regroups the step two of RMA; sellers interview and the step four; interview of different actors of the value chain. To meet those actors the snowball sampling has been used. The research started with names of professionals with knowledge on cactus pear provided by Dc. Stadler-Kaulich.

- The first interview was conducted with **Alberto Cardenas**, an engineer from Agrecol Andes who participated in the implementation of organic markets throughout the country.
- The second interview was done with **Dc. Stadler-Kaulich**, the director of the Research Institute of Conservation Practices in Andean Agriculture in Combuyo. This expert has a lot of knowledge on Agroforestry and experiment on plant association with cactus pear since 2006.
- The third interview was made with **Ronald Patzi**, an agriculture engineer managing a plantation of cactus pear on his land. This interview gave many insights into disease resistance of different variety of cactus pear and local consumption of cactus pear.
- The forth interview has been made with **Serafin Vidal**, an engineer working at Agrecol Andes who participates in the implementation of agroforestry parcels and comes from Arani, a village with many cactus pear producers.
- The fifth interview was made with **Mario Veizaga**, who is working with the development program for a sustainable agriculture (PROAGRO), a collaboration of the Bolivian government with the German (GIZ) and Sweden cooperation for development.
- The next interview was made with the veterinary **Fredy Carbrera**. He is working in Paso-rapa for the implementation of cactus pear stem as fodder for the local cattle. In the last three years, many projects offered help for the plantation of fodder cactus pear in the region. This interview was very valuable to understand technique of dissemination of new agricultural practices. His collaboration made possible interviews with more than 30 cactus pear producers.
- The seventh interview was made with **Claudio Amaory**, a technical engineer owning many cactus pear varieties in Tarata. The broad experience of Amaory with cactus pear variety was solicited by the Centre of Investigation of fodder (CIF) in Cochabamba.
- The eighth interview was made with the director of the Valencia laboratories in Quillacollo, **Avidan Valencia**. The laboratory is specialized in the production of plant-based dietary supplements. The interview touched more the requisites of the plant before transformation and the possibilities of transformation in the laboratory Valencia.
- The final interview was made with **Marcelo Saenz**, an agriculture engineer from Sucre (Figure 1). Engineer Saenz has made cactus pear his specialization and he is the only cactus pear expert of the country. He knows about the trade of cactus pear between the biggest cities of Bolivia and handles himself a business with the trade of cactus pear stem for plantations.

The interviews followed the structure of the 5 P: product, price, promotion, place and policy with general question about the value chain of cactus pear. Those questions served as guide-line during the semi-structure interviews (see Table of Appendix). As each person had a different expertise on the topic, the questions have been adapted to the interviewee’s knowledge.
Producers interviews

The interviews with the producers have been conducted in six municipalities of the Department of Cochabamba. The municipalities can be divided in two regions, the first one being around Cochabamba and the second one being in the south of the Department. Around the city of Cochabamba, the producers came from Quillacollo, Tarata (municipality Esteban Arce), Villa Rivero (Municipality Punata), Sacabambilla (municipality Tiraque) and Arani. In the south, 32 interviews have been made in the city of Pasorapa (municipality Narciso Campero).

Figure 4: On the right - Localisation of the producers’ interviews in the Department of Cochabamba, Bolivia (see raw data)

The interviews with the producers were modulable depending on the purpose of the cactus pear. The first segment was about the geographical location, the second about the production data and management difficulties, third about fodder production, forth about the commercialisation process, fifth about the activities generating income and finally about transformation knowledge of the cactus pear. Sections have been selected depending on the producer time and information. To make the interview interesting for the producers, distribution of cactus pear recipes had been organised. Workshops on how to cook the stem of the cactus where as well a platform to meet producers and exchange knowledge. As the producers where outside of their home during the day, meeting them at meeting in the evening was more productive than going from door to door. The main difficulty in the community around Cochabamba was that no organisations were supporting the production of cactus pear. This engendered low interest from the population for this cultivation, which has declined after the introduction of the cochineal parasite. This parasite has spread very quickly to all the intensive plantation of cactus pear around Cochabamba, which has declined the quantity and quality of the cactus pear harvest.
Those questionnaires had for purpose to answer the first research question:
Q1) What is the role of the Opuntia’s products in the economic life of the small farmer livelihood?
H0) The *Opuntia ficus-indica* products (stem and fruit) are used for self-consumption by small-scale farmers (<5-10 ha).
H1) The *Opuntia ficus-indica* products (stem and fruit) have other purpose than self-consumption by small scale farmers (<5-10 ha).

The hypothesis is discriminating farmers with more than 10ha of productive land (open plot). The cattle breeders of Pasorapa had often far more land as extensive pasture, which is not counted as open plot.

**Consumers survey**

The other aspect of the RMA is the understanding of the product’s demand. This has been done by conducting interviews in three different markets in the city of Cochabamba. This was done outside the main selling season, which impacted the answers of the consumers. The goal of the interviews was to answer the third hypothesis:
Q2) What is the opinion of the consumers (higher budget/ lower budget, ecological-health) about Opuntia’s products in Cochabamba surroundings?
H2) The social and cultural perception of the consumers about Opuntia’s products is negative.

One of the markets is situated in the city centre and attracted consumers interested in organic vegetable, natural product and traditional Bolivian meals. It is called the Ecoferia (organic market) and takes place in a square right in front of a secondary school and next to the hospital and university of medicine. The profile of the consumers is well educated, health aware and looking for cheap and traditional lunch employees and students. The other market is placed in the north of the city in a more expensive area. It attracts a lot of stranger living in this part of the city and wealthy inhabitants. The market particularities are European specialities such as French bread, Spanish sausages and Italian preparations. There is a big choice of fruit, vegetable, corn specialities and local cheeses. The prices are higher than in other markets of the city. The last market is situated in the north west of the city in the suburbs of Cochabamba. The market is near the countryside, and it is well reflected in the organisation and the consumers. Everything is cheaper than in the city centre. The majority of the visitors speaks Quechua, the main indigenous language in the department of Cochabamba.

**3.4 Operationalization**

The major approach of this research is qualitative. Nevertheless, the research questions give a quantitative aspect to the research. The first and second research questions are closed and can be answer by yes or no. They are answered by one question in each interview. In the producer interview the question is:

What is your annual income from the cactus pear plantation? This question is reformulated again in the form: What are the three main economic activities of the household? Finally, the calculation can be done later if the producer can answer the following questions: At what price do you sell a basket of cactus fruit? How many weeks per year do you harvest cactus pear? And How many times per week do you harvest the fruit? This triple way of asking the same question increases the chance of having an answer and increases the accuracy of the answer. The other questions of the producer questionnaire aim at understanding the context of production of cactus pear. It covers the management of the plantation, the selling process, the use of cactus pear stem as fodder, the economic importance and the knowledge on cactus pear transformed products.

Concerning the consumer survey, the research question demands a qualitative answer. The purpose of this question is to understand the point of view of the consumer about the fruit. To answer
the hypothesis, the survey categorizes positive and negative opinions. The questions for testing the hypothesis are:
Why do you consume cactus fruits? And What are the properties of the cactus fruit? The other questions of the survey aim at evaluating the individual cactus fruit consumption, the knowledge of transformed forms of the fruit, the acceptance for cactus pear jam and knowledge about edible cactus pear stem.

3.5 Limitation and distortions of the method

The general context

The context on the study gave some restrictions and limitations to the study. The first aspect is temporal. The research was led from July to September which is outside the production period of cactus pear (January to March). This temporality lead to distortion in the answers of the consumers. Another limitation concerning time was that the data collection had to be done in six months.

Another limitation is the transportation to the countryside. Villages are accessible by public transportation (bus or taxi), but it took a long time to get out of Cochabamba. The bad conditions of the traffic and the roads made transportation slow. This limitation restrains the studied area to the surroundings of Cochabamba and the south region of Campero.

The third limitation concerns the language. In the countryside of Cochabamba, the main language is Quechua. The researcher didn’t spoke this language. The collaboration with a translator was possible twice. In other visits, it was possible to meet one person of the household speaking Spanish. This limitation is one of the factor that restrained the number of interviews done with producers and consumers.

Sampling method

One of the positive aspects of snowball sampling is that it allows research in places where otherwise it might be impossible because of a lack of participants according to Glen S. The disadvantages of this sampling method are that it is impossible to determine the sampling error or to make inferences about the populations based on the obtained sample (Glen S. 2016). For this research, the snowball sampling method is well adapted to collect primary qualitative data.

Analytic tool

Descriptive analysis will be used to present the results. No other statistic tool can be applied because the sampling size is too small. The results will be presented visually through graphics and tables.

Producers interview

The effectiveness of the sampling method for meeting producers was impacted by many factors. It was difficult to meet farmers during the days, since many of them have an off-farm job. The second difficulty is that the cactus pear plantations are not always next to a house, or the owner is not always living in the same village. The finally remark is that knowing the name of producers made the contact with the producer easier and this knowledge helped the research a lot in Campero. Fewer names were available for the municipalities around Cochabamba.
Consumers interview

The consumers were interviewed during their shopping at a market. The researcher tried to have a wide sampling of ages and a balance in sex. Nevertheless, it is possible that an unawarded discrimination happened since the sampling method isn’t random. The second limitation is the language. Many women are responsible for doing the shopping on the market and the ones coming from the countryside have sometimes little knowledge of Spanish. The survey couldn’t be led if the person that couldn’t speak Spanish or wasn’t in company of a Spanish interpret. Finally, many customers didn’t had time to participate to the survey or answered only to a part of the questions.
4 Current state of knowledge

Before diving into the research, it is important to have an overview of the existing knowledge about cactus pear requirement, management and the main market worldwide, as well as the concept of value chain.

4.1 Value chain Theory

Let’s start with some definition. What is a value chain? ‘The value chain describes the full range of activities which are required to bring a product or service from conception, through the different phases of production (involving a combination of physical transformations and the input of various producer services), delivery to final consumers, and final disposal after use (Kaplinsky R. Morris M., 8). This definition from Kaplinsky can be adapted to agricultural products. The design part would be the market research before the start of the plantation of cactus pear, the production would be the management of the cactus pear fruits, the marketing corresponds with all the intermediaries before it arrives to the final consumer and the recycling is not appropriate in this case, as the unused peel is biodegradable.

![Value chain diagram]

Figure 5: Four links in a simple value chain. Kaplinsky R (ibid.)

The concept of value chain is used to describe all industries or sectors of activity. Applied to agriculture, it is used to describe the chain of actors providing services or materials until the creation and distribution of the final product. In this study, the only value chain that is observable in Bolivia about cactus pear starts at the producer level and ends up with the sale of peeled cactus pear fruits in the cities. To understand the value chain and get an idea of all the intermediaries the method of Rapid Market Appraisal (RMA) has been applied.

4.2 Genetic diversity and characteristics

As Sáenz explains, the name cactus (nopal in Spanish) is used to denote the complete plant; cactus pear (tuna, in Spanish) to denote the fruit, and cladode to denote the stems (in Spanish nopalito refers to the tender cladode and penca to the fleshy mature cladodes or ‘leaves’. *Opuntia ficus-indica* is part of the family of the *Cactaceae*, subfamily: *Opuntioideae*, Genus *Opuntia*, Species *ficus-indica* (Robles A, and Julio E. 2009, 7). The fruit can appear in many colours depending on the variety. The main commercial colours are yellow (Amarillo), green (Verde), orange (Anaranjado) and purple (Púrpura), as presented in the table below.
Market analysis of prickly pear (Opuntia ficus-indica) production in Cochabamba, Bolivia

Elena Paiuc

Table 1. Description of eleven varieties of tuna (Opuntia sp.) cultivated in the nopalera experimental Dr. Facundo Barrientos Pérez de la Universidad Autónoma Chapingo. Chapingo, México.

<table>
<thead>
<tr>
<th>Especie</th>
<th>Variedad</th>
<th>Origen</th>
<th>Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>Opuntia sp.</td>
<td>Aleña Blanca</td>
<td>Celaya, Gto.</td>
<td>Verde</td>
</tr>
<tr>
<td>O. megacantha Salm</td>
<td>Plátano</td>
<td>Ojuelos, Jal.</td>
<td>Amarillo</td>
</tr>
<tr>
<td>Opuntia sp.</td>
<td>Aleña Roja</td>
<td>Celaya, Gto.</td>
<td>Rojo</td>
</tr>
<tr>
<td>O. ficus-indica (L.). Mill</td>
<td>Solferino</td>
<td>Chapingo, Méx.</td>
<td>Rojo</td>
</tr>
<tr>
<td>O. ficus-indica (L.). Mill</td>
<td>Roja Villanueva</td>
<td>Villanueva, Pue.</td>
<td>Rojo</td>
</tr>
<tr>
<td>O. megacantha Salm</td>
<td>Morada</td>
<td>San Martín de las Pirámides, Méx.</td>
<td>Púrpura</td>
</tr>
<tr>
<td>O. ficus-indica (L.). Mill</td>
<td>Jade</td>
<td>Desconocido</td>
<td>Púrpura</td>
</tr>
<tr>
<td>O. ficus-indica (L.). Mill</td>
<td>Copenhagen CEII</td>
<td>Chapingo, Méx. Zacatecas, Zac.</td>
<td>Púrpura</td>
</tr>
<tr>
<td>O. ficus-indica (L.). Mill</td>
<td>Copenhagen V1</td>
<td>Chapingo, Méx.</td>
<td>Púrpura</td>
</tr>
<tr>
<td>O. robusta var. Larreyi</td>
<td>Tazaponal rojo</td>
<td>San Martín de las Pirámides, Méx.</td>
<td>Púrpura</td>
</tr>
</tbody>
</table>

Figure 6: Different cactus fruit scientific names (Marcos Ramírez-Ramos et al. 2015)

Other characteristics of the plant depend on the variety, such as the size of the thorns on the stems or the amount of seeds in the fruits. Resistance to diseases and to altitude and frost differs also between varieties.

Cactus pears (Opuntia ficus-indica) are native to arid and semi-arid regions where growth of food is limited asserts Shongwe in his research on ‘The influence of the location, cultivar and season on cactus pear quality’. These species (Opuntia ficus-indica) are unique for their easy adaptability to a variety of weather conditions and unfertile soils with little effect on the fruit quality (Shongwe et al. 2013). Nevertheless, water logging can cause damages to the delicate root system, therefore a sandy deep soil is recommended. Grünwaldt comments that under different climatic conditions, the thermal limit (…) of Opuntia ficus-indica (L.) Mill. is a mean daily minimum temperature of 1.5 to 2.0°C. Cactus and other drought-tolerant and water-efficient fodder shrubs can survive under...
rainfall as low as 50 mm in a particular year, but with neither growth nor production. Mean annual rainfall of 100-150 mm corresponds to the minimum required to successfully establish rainfed plantations (Grünwaldt J. M. et al. 2015). Homrani agrees that the absolute minimum ecological requisite for rain-fed cultivation is 200 mm/year, provided soils are sandy. For a good development of the plant the annual mean temperature has to be between 16 to 28°C and the annual rainfall average should be of 150 to 1800mm, at an altitude of 800 to 1800 m.a.s.l. adds Robles A. Other research from Falasca indicates that the plant can grow from 0 to 3000 m.a.s.l. in loose soil, with low fertility containing stones. Humid and clayey soils are not favourable to the cultivation of cactus pear (Falasca 2011).

For fruit production, it is cultivated in specialized plantations. In Mexico, the biggest producer worldwide, the plantations are over 70,000 ha. Chile, Argentina and South Africa (little more than 1,000 ha), USA (more than 300 ha) and Israel (250 ha) follow in the ranking. In the North African countries, it is estimated that 50,000 ha are under specialized cultivation of cactus pear fruit, of which 25,000 ha in Tunisia (Tudisca et al. 2015).

Cactus pear has many environmental benefits especially concerning soil conservation as comments Nefzaou. Observations done in agroforestry systems demonstrate that the water accumulated in the stems of the cactus pear is potentially released by the root system to nearby plants during the dry season. The superficial root system of cactus pear reduces wind and rain erosion, encouraging the growth of other plants in arid conditions (Nefzaoui and El Mourid 2009). Thanks to this ability to grow in semi-arid region cactus pear is a great protection for other species and can promote the reforestation of those areas (personal communication with Stadler-Kaulich N. 2017). Nefzaou sees six reasons for the diffusion of cactus pear (I) the simple cultivation practices required to grow the crop, (II) its quick establishment soon after the introduction in a new area, (III) the ability to grow in very harsh conditions characterized by high temperature, lack of water and poor soil, (IV) the generation of income from the selling of much valued and appreciated fruits, (V) the use of its stems in the human diet and as fodder for the livestock, (VI) the many industrial derivations produced from the fruits (Nefzaoui and El Mourid 2009).

4.3 Cochineal in Bolivia

In general, the management of cactus pear plantation is easy. The plants are robust and resist to many climatic conditions. Only pruning should be done each year to have strong and young stems. Nevertheless, one parasite inflicts great damages to cactus pear plantations. It is the cochineal (Dactylopius coccus) introduced in some regions of the world for using the red colour of their body as a natural carmine dye. Peru is one of the country still exporting natural carmine dye. In Bolivia, the cochineal was introduced in the 90s in some plantations of cactus pear. Project and agricultural
engineer saw this insect has a new source of income for the countryside population. At that time, the price of dry cochineal was extremely high. It was easy to make hundreds of USD with some kilos of cochineal. Suddenly everyone disseminated the insect on their plantation to collect this red gold. At the end of the 90’s the price of the natural dye kept going down and nowadays the price of one kilo of fresh cochineal can be sold to Peruvian traders for BOB30. Depending on the density of the colony, harvesting one kilo can represent one day of work for USD 4.3 (XE currency converter 2017). Starting during the 20th Century, studies analysed the environmental impact of such an introduction and began to notice the great diminution of the yield of cactus fruits on the plantation.

After the general acceptation of the cochineal, producers started to criticize this innovation. Producers that never introduced the parasite were invaded as well. The cochineal is transported by the wind and is disseminated very quickly. Once well established, all the region suffers from the introduction of the parasite. Only some producers, having plants inside high wall are able to maintain a healthy plantation. At the moment of the introduction, no control methodology had been put in place and until now few researches exist on how to treat cochineal on cactus pear, even less producers know how to applicate chemical treatments and at which stage of development of the parasite.

4.4 The black spot fungus

The second main obstacle to production of cactus pear in Bolivia is the Nopal black spot caused by *Pseudocerospora Opuntiae* (Hernández-Sánchez 2014). This fungus is mainly a problem for the production of young cactus stems for human consumption in Mexico. The fungus could be observed in abundance in the municipality of Campero. In this region, the producers observe a stronger attack of fungus on the trees that don’t have access to water. The presence of a minimal amount of water seems important to manage the black spot disease. In this region, the cactus pear stems are harvested as fodder. The fungus damages the plant and slow the growing of new stems but isn’t an obstacle to cattle feeding.
4.5 Nutritive value of the fruits

Many studies present results concerning the nutritive value and properties of cactus pear fruit. The most praised characteristics is the high level of vitamin C, higher than the many other fruits like watermelon, grapes, apples, pears and bananas (Galdino, Plúvia O. et al. 2016) (Torres-Ponce R. L. et al. 2015). The fruits contain minerals salts such as calcium, potassium, magnesium, sodium and antioxidants. The taste is sweet, slightly acidic (Galdino, Plúvia O. et al. 2016). These fleshy berries are ovoid or round of 5-10 cm long and 4-8 cm in diameter, with small spines on the skin and white, yellow, red, orange or purple juicy flesh, with many seeds. (Torres-Ponce R. L. et al. 2015). The fruit is characterized by a high sugar content (12-17%) and low acidity (from 0.03 to 0.12% as citric acid). The high amount of water and the fibre content makes it a good ingredient to help to lose weight. The green cactus pear is the one with the biggest size on the market due to the higher amount of water. Consumers in producing countries prefer the green pear, also called white, as the colour of the pulp is white. It is observed that the green pear contains less sugar (carbohydrate) and more proteins than the two other varieties of Carrasco experience.

<table>
<thead>
<tr>
<th>Componente</th>
<th>tuna verde</th>
<th>tuna roja</th>
<th>tuna anaranja</th>
</tr>
</thead>
<tbody>
<tr>
<td>Humedad (%)</td>
<td>81,7</td>
<td>78,4</td>
<td>80,6</td>
</tr>
<tr>
<td>Cenizas (%)</td>
<td>0,4</td>
<td>0,4</td>
<td>0,5</td>
</tr>
<tr>
<td>Proteina cruda (%)</td>
<td>1,5</td>
<td>0,9</td>
<td>0,9</td>
</tr>
<tr>
<td>Fibra cruda (%)</td>
<td>3,7</td>
<td>3,5</td>
<td>3,9</td>
</tr>
<tr>
<td>Grasa cruda (%)</td>
<td>0,1</td>
<td>0,1</td>
<td>0,1</td>
</tr>
<tr>
<td>Carbohidratos (%)</td>
<td>16,3</td>
<td>20,2</td>
<td>17,9</td>
</tr>
<tr>
<td>Energía total (kcal/100g de muestra)</td>
<td>72,1</td>
<td>85,3</td>
<td>76,1</td>
</tr>
</tbody>
</table>

Figure 11: Composition of green (verde), red (roja) and orange (anaranja) cactus pear fruits (tuna) (g/100g of fruit) (Carrasco R. R. de & Encina Zelada C. R. 2008)

The exact mineral content of the fruit is presented on the table below. The amount is higher than the mineral value of banana, except for the potassium. Differences between varieties of cactus pear are explored in the study of Carrasco. Three types of tuna: green, red and orange have higher values of phosphor, calcium, iron, zinc and potassium than the tree tomato, the physalis fruit and the papaya. The cactus pear fruit proves to be a very good source of calcium with almost 40 mg/100g with the orange variety.

<table>
<thead>
<tr>
<th>Fruta</th>
<th>fósforo</th>
<th>calcio</th>
<th>hierro</th>
<th>zinc</th>
<th>potasio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tuna verde</td>
<td>332</td>
<td>29,8</td>
<td>0,5</td>
<td>0,2</td>
<td>25,6</td>
</tr>
<tr>
<td>Tuna roja</td>
<td>286,6</td>
<td>38,6</td>
<td>0,4</td>
<td>0,3</td>
<td>30,1</td>
</tr>
<tr>
<td>Tuna anaranjada</td>
<td>251,3</td>
<td>39,6</td>
<td>0,3</td>
<td>0,2</td>
<td>26,1</td>
</tr>
<tr>
<td>Tomate de árbol</td>
<td>44,7</td>
<td>25,56</td>
<td>0,9</td>
<td>0,45</td>
<td>441,03</td>
</tr>
<tr>
<td>Aguaymanto</td>
<td>37,9</td>
<td>10,55</td>
<td>1,24</td>
<td>0,4</td>
<td>292,65</td>
</tr>
<tr>
<td>Papaya de monte</td>
<td>600</td>
<td>14,6</td>
<td>0,4</td>
<td>0,1</td>
<td>242</td>
</tr>
</tbody>
</table>

Figure 12: Comparison of mineral content of cactus fruit (tuna verde, tuna roja, tuna anaranjada) with tree tomato (tomate de árbol), physalis fruit (aguaymanto) and papaya (mg/100g) (ibid.)
4.6 Uses and application of the fruit

The fruits are mainly consumed fresh in Bolivia but in other Latin American countries such as Chile and Mexico the fruit is commonly transformed. Many products are listed with applications on the cosmetic industry, the food industry, pharmaceutical industry and textile industry (Flores-Hernández 2006). We will start with the edible transformed products.

In general an increase of interest in the industrial transformation into different products such as juice, jam, marmalade, and jelly is observed (Cardador Martínez, A. et al. 2011) (Falasca 2011). Similar situation can be found in Brazil, where the fruits are consumed in the form of juices, sweets and dry fruits, representing an additional source of income for small producer. (Silva Júnior J. da et al. 2013). In Mexico, many products are made out of the cactus pear fruit: juices, honey, cheese, fruit paste, jelly and wine of good quality can be found on the market. Marmalade can also be made from the peel of the fruit (Cardador Martínez, A. et al. 2011). Finally, some by-products of the fruit can be extracted, such as colorants and pectin from the peel of the fruit (Jorge and Troncoso 2016) (Torres-Ponce R. L. et al. 2015).

Recently, there has been an increased interest in the antioxidant activity and health-improving capacity of cactus pear. Since some by-product constituents may be extracted and used as additives in food preparations or in the pharmaceutical and cosmetic sectors, the use of processed fruit by-products for human consumption has increased significantly in recent years (Cardador Martínez, A. et al. 2011). The use of this fruit is extended to the field of natural food dyes, since the pulp in powder presents itself as a water soluble, yellow-orange dye (Galdino, Plúvia O. et al. 2016).

4.7 Nutritive values of the stems

The cactus pear stem has many interesting characteristics and benefits for the health. The chemical composition of the stem is a wet basis of 91% water, 0.66% protein, 0.11% fat, 5.5% carbohydrates, 1.15% cellulose and 1.58% ash (Aguilar et al., 2008). Opuntia ficus-indica is considered as a food that has high nutritional value, mainly because it contains minerals, protein, dietary fibre and phytochemicals (Feungang et al., 2006; Bensadon et al., 2010). Among the contained minerals, the main ones are calcium and potassium along with magnesium, silica, sodium, and small amounts of iron, aluminum, and magnesium among some others. The proportions of minerals also change with cladode age (Hernández-Urbinola et al., 2010) (Torres-Ponce R. L. et al. 2015).

<table>
<thead>
<tr>
<th>Componente</th>
<th>Cladodo de edad (aprox.)</th>
<th>Cladodo de edad (aprox.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Humedad %</td>
<td>92,57</td>
<td>94,33</td>
</tr>
<tr>
<td>Proteínas (x 6,25) %</td>
<td>0,94</td>
<td>0,48</td>
</tr>
<tr>
<td>Grasa %</td>
<td>0,17</td>
<td>0,11</td>
</tr>
<tr>
<td>Fibra %</td>
<td>0,30</td>
<td>1,06</td>
</tr>
<tr>
<td>Cenizas %</td>
<td>0,08</td>
<td>1,60</td>
</tr>
<tr>
<td>Carbohidratos %</td>
<td>5,96</td>
<td>2,43</td>
</tr>
<tr>
<td>Vitamina C (mg/100g*)</td>
<td>37,27</td>
<td>23,11</td>
</tr>
<tr>
<td>Ca %</td>
<td>0,042</td>
<td>0,339</td>
</tr>
<tr>
<td>Na %</td>
<td>0,0018</td>
<td>0,0183</td>
</tr>
<tr>
<td>K %</td>
<td>0,00098</td>
<td>0,145</td>
</tr>
<tr>
<td>Fe %</td>
<td>0,0792</td>
<td>0,322</td>
</tr>
</tbody>
</table>

* Los resultados se dan en mg de ácido ascórbico / 100g de penca fresca

Figure 13: Nutritional value of cactus pear stem (Loayza and Chávez 2007)
Over the months and years, the cactus stem components change. The humidity increases from 92% to 94%, the protein level decreases from 0.9/100g to 0.1/100g after one year. The most significant change is the increase of fibre from 0.3/100g to 1.6/100g. This characteristic is used to define the use of the cactus stem. Young stems are preferred for human consumption and one-year old stem are used for planting new plantation.

4.8 Uses and applications of the cactus fruit stems

The cactus pear stems have many applications in the gastronomy, the construction, the medicine and the meat industry. We will start with the use for human consumption.

Cactus pear stems, also known as nopalitos are traditionally consumed in Mexico, but also have started to be exported to communities across the United States, Canada, Japan, Italy and Turkey due to its low calorific value, high in fibre and nutritional value (Torres-Ponce R. L. et al. 2015). The cactus pear stem is considered as a functional food because it is an important source of fibre, hydrocolloids (mucilage) pigments (betalains and carotenoids), calcium and potassium, and vitamin C. All those components are highly prized for a healthy diet and as ingredients to design new foods (Valencia-Sandoval K. et al. 2010).

In the Mexican cuisine, the consumption of cactus stems is deeply rooted in people’s diets because of their generally low cost, pleasant sour taste, herbaceous aromatic notes, and nutritional and functional characteristics (Osorio-Córdoba J et al.). The young stems (size of a hand) are harvested and sold fresh in supermarkets or in can ready for conservation. In the Mexican diet, the cactus pear stem is often eaten as vegetable in salads. The daily intake per Mexican of this cactus is 10-17 g/person/day (Torres-Ponce R. L. et al. 2015). The older stems can also be used as a pan to cook younger stem on the fire. On the image below, a traditional Bolivian salad with tomatoes, onion and boiled stem is presented. On the left, the traditional ‘Saize’ with minced meat, vegetable and boiled cactus stem is showed. Those two preparations are a twist of Mexican dishes adapted to Bolivian traditional recipes. The cactus stem is also consumed in juices, by mixing the freshly peeled stem in a food processor alone or with other fruits.
In addition, medicinal properties have been described, in the control of diabetes, as an antioxidant, antiviral, anticancer and anti-cholesterol and therefore being used in traditional medicine. (ibid., 1129) The mucilage contained in the stem has the reputation to regulate the digestion, helps to the good functioning of the kidneys and the heart, reinforce the liver and the pancreas. (Sierra A. 2014). The high content of fibres: lignin, cellulose, hemicellulose, and pectin, with amino acids help to eliminate toxins such as ammonia and free radicals (SÁENZ et al., 1997)(Oliveira Ribeiro, E. M. de et al. 2010).

In recent years, the commercialization of dried nopal fibre as auxiliary in digestive disorders started. The dried pulp of nopal is a fibrous material whose medicinal function is based, like any other natural fibre, in favouring the digestive process, reducing the risk of gastrointestinal problems and helping in treatments against obesity. Additionally, the fibre decreases the level of low density lipoproteins and lowers cholesterol in the blood by interfering with the absorption of fats that perform the intestines (Bensadón et al., 2010) (Torres-Ponce R. L. et al. 2015). An ethnobotanical study made by interviewing diabetic patients and herbalist vendors from Mexico, confirmed that Opuntia spp. is traditionally used for the treatment of non-insulin dependent diabetes. The medicinal parts are the tender stem, from which the spines are withdrawn; then washed and cut, to eventually liquefy them with water and drink it before breakfast. The result is a decrease in postprandial glucose levels (Andrade-Cetto and Wiedenfeld, 2011) (ibid., 1133). In addition, Opuntia fruits and young stems have been traditionally used in folk medicine to treat diabetes, hypertension, asthma, burns, edema, and indigestion (Cardador Martínez, A. et al. 2011).

Cactus stem as fodder

The largest area planted with cactus pear in the world is in the North-eastern region of Brazil with approximately 550 hectares (Araújo, Lúcia de Fátima et al. 2005). In Brazil, the cactus stems are mainly used as fodder for the livestock during the dry season. The stems are also transformed into flour after drying and added to the feeding mix for the cattle (Castillo et al. 2013., 21). In Ethiopia, the plant is used as fodder during the dry season. The stem and the fruits are given to the livestock (Falasca 2011). Cactus stems are consumed by cows (fattening or dairy), sheep, goats, rabbits and guinea pigs.

Innovation to increase the quality of cactus pear stem as fodder created cactus pear protein supplement. This product contains more protein than the natural cactus stem. It is transformed by adding yeast as an inoculum. The increase in percentage protein is up to 400%. The digestibility in vitro increased from 78.9% to 95.8. The final product is a non-conventional feed alternative to the cereal grains that are used in raising animals (the so called conventional supplements) (Araújo, Lúcia de Fátima et al. 2005).

Technical use of cactus pear stem

In construction, the mucilage of the stem is used to thicken whitewash protecting the mud brick construction. A cactus stem powder can be used to increase the strength of concrete surfaces. It can be used in the composition of paints, in waterproof and adhesive products (Robles A, and Julio E. 2009, 31).

The mucilage gives great results if used to clarify water. The study of Villabona: ‘Characterization of Opuntia ficus-indica as a natural coagulant’ gives results indicating that cactus pear mucilage has the capacity to remove 50% of the color and 70% of the turbidity from crude water with high initial turbidity without affecting significantly the pH (Villabona O. A. et al. 2013).
The cactus pear trunk and dried stem can be used as combustible in dry areas. The dry stem contains a lot of lignin and can be used like wood in regions where there is no electricity and natural gas (Robles A, and Julio E. 2009, 31)

4.9 Uses of cactus pear plant

The wild variety of cactus pear plant is used as a protection against free cattle and people. The variety with very long and dense spines can't be eaten or crossed by animals.

![Figure 16: Spiny cactus pear used as a fence of a cactus pear plantation (picture done in Sacabambilla, 2017)](image)

It serves as natural fences to cultivation or cactus pear plantation, like on the picture above. In Bolivia, that type of row can be observed along the cultivated plot or between the gardens of two houses as a delimitation.

The cactus pear plant has also an ornamental value. It is appreciated to announce a Mexican restaurant or to enjoy the beautiful flowers in the garden.

Finally, the plant is a host to the cochineal of cactus pear (Dactylopius coccus Costa). This insect belongs to the order of Hemiptera, Dactylopiidae family that contains nine species natives to North and South America (Rodriguez et al., 2001). The members of this family are important as source of natural colouring (Méndez et al., 2004) and as agents of biological control of cactus pear, considered as an invading weed in Australia and South Africa (Pérez-Guerra, 1991) (Méndez-Gallegos, S. de Jesús et al. 2010). Dactylopius coccus has great social and economic importance due to the dry body of females are able to produce carminic acid (CA) (Méndez-Gallegos et al., 2003), widely used as colouring principle in food, beverages, textiles, and in pharmaceutical and cosmetic industries (Baranyovits, 1978). Carminic acid is considered innocuous (Sugimoto et al., 1998), it is antiviral (Krabill et al., 1993), anticarcinogenic (Tütem et al., 1996), and antibiotic properties (Allevi et al., 1998) (ibid.) Grana is commercially produced in Bolivia, Chile, Spain, Mexico, and Peru (Gallegos-Vázquez and Méndez-Gallegos, 2000), the latter country is the most important producer and exporter of these insect (ibid.).
4.10 Properties and use of the seeds

Cactus pear fruit seeds properties are studied in the research of Preti-García ‘Opuntia spp. seeds grown in Hidalgo State, Mexico’. Cactus pear seeds contain high carbohydrate content, in particular fats and starches, they may have nutritional value that justifies their preparation as food products or supplements for human consumption. However, special attention should be paid to the lead content of the seeds, which could represent a disadvantage in this regard. Additionally, the starch granules found in the seeds resemble those reported for cereal grains. (Prieto-García 2016).

The seeds of the cactus pear fruits also have an economic value. They can be extracted to produce oil. This oil is used in the cosmetic industry. For one litre of cactus pear oil, 25kg of seeds are needed. Depending on the variety, up to 800kg of fruits are necessary for the extraction of one litre of oil. This precious oil has great anti-aging properties for the skin and is sold at EUR 1000/litre (Ptite Mule 2016).

The seed seems to have a potential use as a dietary fibre source for human consumption. It could be added to industrial bakeries to increase the fibre content (Cardador Martínez, A. et al. 2011).
5 Results 1 - Current state of the value chain

The following results correspond to the first and second expected result: Analysis of the existing value chain of the cactus pear fruit and stems with key stakeholders in the context of the Bolivian valley of Cochabamba (ER1) and Mapping of the key stakeholders, potential partner for commercialization and existing producer organisation (ER2). In this part, the two first research questions are exposed.

5.1 Description of the value chain

The value chain is described with the information collected during the key informant interviews with Serafin Vidal and Alberto Cabrera. The two engineers work for Agrecol Andes. This agency is in Cochabamba. The company is specialize in the design of agricultural projects with the following visions: support the sustainable development of the markets of fresh agro-ecological products for the low-income producers and consumers. The interview with Marcelo Saenz, agricultural engineer and specialist of the cactus pear in Bolivia gave inside into the value chain structure. The first part is a contextualization of the production with the example of the village of Arani. The second part presents the overall value chain.

The study case of Arani

Arani (2700 m.a.s.l.) is the municipality with the biggest plantation of cactus pear. This village is divided in communities and many of them cultivate cactus pear as a cash crop. Those communities are Chinguri, Villa Flores, Villa Barrientos and Arani (centre of the village). The sector is categorised as semi-arid to arid. Arani benefits from his location at the end of the valle alto (the high valley) to use the large slope leading to the top of the plateau 300 m.a.s.l. above to increase the exposition of the plants to the sun. Furthermore, this soil is poor in nutriments and sandy, which correspond to the need of the cactus pear. The local rainfall has been in average 330 mm per year during the last 10 years. The valley has an average of 583 mm of rain per year spread irregularly during the year and depending on the location and altitude (AMDECO 2016).

![Figure 17: Village of Arani in the lateral valley of Cochabamba, with the main cactus pear plantation (square). (Google Earth)](image-url)
In this region, the cultivation of cactus pear is a tradition. The engineer Vidal could assure that the plantation along the road to Mizque existed as he was a kid, which make it more than 40 years old (Vidal S. 2017, personal communication). The plantations are situated outside of the village and are divided between many families of the villages. No fences are used but natural marks, such as trees and stones serve as delimitation (see Figure 18).

![Figure 18: Old fence made of stones delimitating the plot of cactus (Arani 2017).](image18)

The plantations have grown in the recent years as the productivity of the flat land, originally used for corn, decreased. Because of the lack of water or fertility of the soil, villagers plant cactus pear where no other crop can grow. Therefore, the cactus pear is seen as a complement crop of the farm system. Traditionally, the farm system is composed of livestock such as sheep or pork, duck or chickens and production of vegetable and staple crop such as corn, wheat or potatoes.

![Figure 19: The cactus pear plantations are expendng, and villagers prepare new plots on the flat land (white square), (Arani 2017)](image19)
Management of the plantation

In Arani I met one of the producers working in the plantation. This producer is an exception to the other producers that participated in the interviews. This woman explained that cactus pear is her main income. She is almost 60 years old and has no more children at home. Cactus pear is a crop that requires low intensity of physical work and can be managed by the women. The woman works into the plantation during all the year and removes the spiny bushes growing in between the cactus. She also applies twice a year an herbicide to prevent the spiny bushes and other weeds to grow in between the cactus pear trees. The herbicide is applied on the all plantation and may affect the cactus itself. The parasite cochineal is cleaned from the stems by cutting herbs from the ground and brushing the stems with the herbs. The effect of cleaning the cactus pear is that the parasites fall on the ground. This technique is not definitive as the adult insect of the cochineal can come back to the stems. This practice might slow down the reproduction rate of the cochineal on the plantation. The effect of this technique is questionable. The plots of this woman can be notice from far away as there are the only one without weeds and bushes in the plantation.

Because the woman cut all the old stems and prune each year, the cactus appears younger. The producer owns three plots all located on the side of the road to Mizque. Recently she planted a new plot with the red variety of cactus fruit. This is a strategy of diversification, as all the cactus in this area are mainly from the yellow variety.

Transformation of the fruit

Regarding transformed product, villagers like to drink ‘Chicha’, a local maize fermented beverage. Following this tradition, one of the owners of such a brewery used cactus pear fruit to transform into ‘Chicha’, which was highly prised by the customers. The production of the brew is seasonal, from January to March. The main way of consuming the fruit is freshly peeled.

End of the study case
The harvest

During the harvest season, the women gather in the plantation to harvest the fruits. The fruits are of different qualities. The ripe ones are sold directly along the side of the road, as the fruit can’t be transported or conserved for a long time. The second quality ones are not yet ripe fruit that are collected once a week on Thursday on the sport place of the village, where a transporter selects them and bring them to the wholesale market of Santa Cruz, 475km away. Women collect the fruit by hand without using any type of protection against the tiny spines on the fruits. By using a special cutting technique, they achieve a higher conservation capacity of the fruit and therefore a better price for the harvest. After collecting the fruits in boxes or traditional baskets, the women brush away the spines of the fruits on layer of straw (see below).

![Image](image.png)

Figure 21: After the harvest, this place (white circle) is served to clean the fruits from the spines with herb’s stems (personal material, Arani 2017)

The harvest is always done early in the morning to avoid the wind and benefit from the cooler temperature. Those conditions insure that the tiny spines won’t fly in the face of the pickers, which prevents damages to the eyes. The cleaning of the spines is done in the plantation itself as shown above. After picking and cleaning, the fruits are brought to the house and packed in closed baskets a day before the arrival of the transport company.

Sale in Cochabamba

Some producers bring the fruits in baskets to the farmer market of Cochabamba. They bring their harvest by public transport and sell the cactus pears along the street next to the bus stop in the early morning. Some consumers buy directly to the producers on the Barrientos Street. Fruit retailers also buy the cactus pear directly from the producers. During the day, the fruit is available in the city, where it is sold by mobile merchant with wheelbarrows. The mobile merchant sells seasonal fruits all year long. During the season of the cactus pear, they peel the fruits and sell them in plastic bags to the consumers. Some fruit retailers also buy the cactus pear directly from the producers.
If the producers can't sell the fruits themselves, they resell the harvest directly to other women working on fruit markets in the city. The intermediary will then take a margin on the fruit and sell them on the street next to other goods. On figure 22, both categories are presented in plastic bags. The first quality is sold at BOB 1 per fruit and the second quality at BOB 0.5 per fruit. When the picture was taken, it was off season and the prices were higher than during the harvest season (January to March).

Prices

According to interviews with producers from Arani, the price of the fruit is influenced by the time of the year, the ripeness of the fruit and the variety. At the beginning of the season from December to January and at the end of the season after March, the fruits are more expensive. Reseller bringing the fruits to Santa Cruz pay less for well ripe fruits than for immature fruits. If the producer brings the harvest to Cochabamba or to a local market the price is better if the fruits are ripe. One producer informed us of the variation of the price according to the variety of the fruit. As stated during the interview: four buckets (10L each) of the yellow variety are sold for BOB 100, as four buckets of the red variety are sold for BOB 160, and four buckets of the green variety is sold for BOB 170-180. This is explained by the difference of size and taste between the varieties. For example, the red fruits contain more sugar and are sweeter, but have the same size as the yellow fruits. In contrary, the green variety is less sweet, bigger, and more in demand by the consumers. The green variety is supposed to have more health benefits and contains more pulp and less seeds.

The value chain

To sum up the situation of the value chain, the producers that participated to the research had four strategies to sell the cactus pear fruit. Some benefited from a local trader that organized the transport of the fruits to Santa Cruz. The producers in Arani sell the fruits directly along the road leading to Mizque. This option, is probably preferred to sell ripe fruits that wouldn’t be accepted by the local trader. The third option for the producer is to bring the fruits by public transport to Cochabamba, 56km away. Finally, producers living far away from the main cities sell the fruits on the local market like in Pasorapa and Tiraque. It is also often used as a present for families and friends. A lot of producers use the fruit as a currency on the local swap market, where cactus pear fruits can be exchanged against potatoes, vegetables and/or bread.
The local trader organizes the transport and the preselection of the fruits at the local level. He is the one controlling the producer’s prices and is in competition with other local traders to supply the big cities. According to the engineer Saenz, the two major markets for cactus pear fruits are the cities of La Paz and Santa Cruz. La Paz being too high in altitude (3700 m.a.s.l.) doesn’t have any production in its surroundings. The fruits have to be transported from lower regions, such as the lateral Andean valley of Cochabamba, 380km away. The city of Santa-Cruz is located in the tropical region of Bolivia and only some region at the border of the department are suitable for cactus pear production. Cochabamba itself needs fewer middlemen to supply the city, as the producers deliver the harvest by themselves directly in the central market.

The transport company is only responsible for the transport to the wholesale market in the suburb of Santa-Cruz. There, the goods are sold by wholesale traders to fruits retailers, and other fruit merchants. Some of the buyers are also wheelbarrow sellers, that move around in the city centre and offer freshly peeled, ready to eat fruits.

In smaller markets, like in Cochabamba, the final consumer can also buy cactus fruits directly from the producers. As the main production areas are located in the surroundings of the city, producers from Quillacollo, Carcaje, Tarata and Punata bring their harvest by themselves to the farmer market of Cochabamba.
Market analysis of prickly pear (*Opuntia ficus-indica*) production in Cochabamba, Bolivia

Elena Paiuc

### 5.2 Economic importance of cactus pear for producers

#### Description of the sampling pool

The interviews are based on sampling group of 56 producers, men, women and couples. Most of the interviewees are men (59%). In Pasorapa the participation of men is the largest with 72%. This is explained by the fact that the main economic activity in this municipality is cattle breeding. This activity is considered as a men’s task. The plantations of cactus pear are used as fodder for the livestock part of this activity and therefore also managed by the men. Some families had cactus pear trees in their yard. The fruit was then used for consumption or sold on the local market. The women then often participated in the interviews. Pasorapa is the furthest municipality visited in the department of Cochabamba. More producers participated in Pasorapa (57%) because the veterinarian of the municipality gave the names of 30 cactus pear producers. The engineer Cabrera played a key role to facilitate the contact with the plantation’s owners in the region.

Table 2: Gender of the participants of the producer’s interviews (September 2017, Cochabamba)

<table>
<thead>
<tr>
<th>Municipalities</th>
<th>Count of Woman</th>
<th>Count of Man</th>
<th>Count of Couple</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arani</td>
<td>6</td>
<td>8</td>
<td>2</td>
</tr>
<tr>
<td>Pasorapa</td>
<td>8</td>
<td>23</td>
<td>1</td>
</tr>
<tr>
<td>Punata</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quillacollo</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tiraque</td>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>19</strong></td>
<td><strong>33</strong></td>
<td><strong>4</strong></td>
</tr>
</tbody>
</table>

The four other municipalities: Arani, Punata, Tiraque and Quillacollo are located in a circle of 65 km around the capital of the department. In those municipalities, the name of the producers is not known. This involves lower chances of meeting the producers. The gender representation of men and women is almost equal in all the municipalities around Cochabamba with 46% of woman, 42% of men and 3 couples.
Research question

The interviews with farmers were done to answer to the research question: What is the role of the cactus pear product in the economic life of small farmers?

The questionnaire was built to collect information about the income generated by the trade of cactus fruits. Questions about the frequency of harvest, quantity, price and length of the season were asked. The question: “What is your annual income from the cactus pear plantation?” was answered only twice after calculation with the producer and is presented in the graphic below. The question: “What are the three main economic activities of the household?” gave interesting answer to calculate how many producers have an external job and how many live from agriculture.

The annual income generated by cactus fruit could only be calculated for 28 producers, with eight of them coming from Pasorapa. The length of the season varies between four to twelve weeks between December and March. The second factor is the price, producer give is either per unit/fruit or per basket. The price per unit varies from BOB 0.3 to BOB 1. The price per basket varies from BOB 10 to BOB 37. Producers harvest the fruits once or twice a week and harvest from one to four baskets per week. Ten of the 56 interviewees sell the fruits on the local market in Pasorapa, Punata or Tiraque, then sell the fruits to a local trader that organize the transport to Santa-Cruz and four bring the fruits to the market of Cochabamba.
It can be observed that none of the commercialization strategy presented in the value chain section, bring a good living wage for the producer. Knowing that the minimal salary in Bolivia is of BOB 2000 per month and the highest income from the fruit is BOB 1200 spread over three months (Instituto nacional de estatistica de Bolivia 2017). Cactus pear plantation remains a side income for the majority of the producers.

Questions about the main economic activities were asked to understand the combination with cactus pear plantation. The majority live from farming activities being livestock, cash crop or subsistence farming. From the interviewees, 21 participants said that livestock were there main economic activity, 19 had crops as main income, eight had a small business on their own, like selling meat, maize seeds, warm meals and seven are employed. Only one producer had cactus pear has main income.
Producers’ organization

After discussion with the specialist Marcelo Saenz, it has been confirmed that no cactus pear producers’ organisation exists in Bolivia (Saenz M. 2017, personal communication). The producers sell the fruits by themselves and not enough income is generated to justify the effort of creating producers’ association.

5.3 Opinion of the consumers on cactus pear

Sampling description

The interviews have been done on three different markets. One is an organic market in a park in the centre of the city organized by an independent committee of producers and trader of handmade artisanal. A lot of consumers come here to eat traditional Bolivian meal at the lunch break. Situated next to the medicine university, a hospital and middle school, the market attract many employees, parents and students at their lunch break. Producers of organically grown vegetables and fruits bring their harvest to this small market.

The second market, is located in the suburb of Cochabamba in a village called Tiquipaya. This market attracts consumers living outside the city and many producers come from the countryside. A lot of Quechua is spoken on the market and one street is dedicated to organic products. This market has a medium size and proposes everything from fruits, vegetables, all kind of meat, fast restauration, tools, plants and animals.

The third market makes place in the north of the city, where live the wealthier families of Cochabamba and expatriates. This market has higher prices for fruits and vegetables compare to the two other markets. It offers many specialities from Europe and high-quality cosmetic. It can be observed that children offer to carry the groceries of the consumers on wheelbarrows to make some extra money. This market is also the only one, where I met a teenager that didn't knew what the cactus pear is.

In the season of cactus pear those three markets are supplied by producers their harvest or by fruits retailers bringing the fruits they bought at the bus station to the producers.

Figure 29: Distribution of the consumers’ interviews on three markets of Cochabamba (September 2017, Cochabamba)

The participants of the consumer’s survey from the organic market represent 56% of the total sample. The visitors of the wealthiest market represent 31% of the participants, and 13% were from the farmer market. The inequality between the three groups is justified by the context of the different markets. It was easier to stop consumers at the organic market. It is a small market in a park
with a lot of space in the main alley. The consumers had time and weren’t stressed out. In the farmer market, many consumers spoke Quechua, so the communication wasn’t possible. The market was busier and less customers had time to answer the survey.

Participants from 18 to 74 years old were invited to join the survey. People who don’t consume cactus pear were included in the research. The main age’s group was the 35 to 44 years old. 78% of the respondents were women. The gender unbalance in the survey represent well the gender presence on the market. Selling products on the market and buying groceries is considered more as a women activity than a task for men.

![Gender and age group of the consumers' survey](September 2017, Cochabamba)

**Research question**

The goal of the consumers’ survey is to answer the second research question: **What is the opinion of the consumers (higher budget/ lower budget, ecological-health) about cactus pear in Cochabamba district?**

To answer the research question, the following questions have been used: Why do you consume cactus fruits? And What are the properties of the cactus fruit? Information about the quality, the quantity of consumption, the localisation of the buy, the price and the use of cactus pear have been collected. The goal of these survey is to better understand the demand for cactus pear and for transformed cactus pear product in Cochabamba. Cactus pear jam has been taken as an example of transformed product to measure the acceptability of transformed cactus fruit products by consumers.

**Peeled or whole?**

To better understand the consumption of cactus pear, consumers have answered the question: Do you buy peeled of whole fruits? The answer is clear with 60% of the consumers buying only peeled fruits and 40% buying the whole fruit. This is often correlated with the amount of the purchase and the frequency. Consumers that buy big quantities, rather buy the whole fruit to be able to conserve the fruit longer. The consumers buying peeled fruits want to enjoy it right away or don’t want to deal with the spines themselves.
It has been asked in which form is the fruit consumed and the clear majority of the answer is raw, without any other ingredient. Only one consumer used it in combination with milk, water or other fruit for the preparation of juices and deserts. This result is an opportunity for developing more transformed products that would be ready to eat.

**Quality criteria**

Concerning the criteria for buying the fruits, 75% of the consumers answered choosing the fruits depending on their preferred fruit variety. Only 9% of the participants had criteria concerning the presentation, the temperature of the fruit or the ripeness. Between the three main varieties of fruits, a strong preference is seen for the green cactus pear with white pulp (28/54 participants).

The following picture indicates the different fruit colours that can be found on the market of Cochabamba.
During the survey, one participant attributed beneficial properties for stomachs to the green variety. Other participants didn’t specify properties of the fruit per variety. The green variety is the least accessible on the market and the most sought by the consumers. The yellow variety is the most commonly available.

**Consumption quantity**

On the 59 interviews, five persons didn’t buy cactus fruit, two because they had the fruits themselves in their garden and three because they didn’t like the fruit. Other participants with fruits from the garden, still bought fruits on the market. ‘Fruits from the garden’ isn’t a criterion discriminating ‘buying fruits’.

Concerning the question: If cactus pears were available longer, would you buy more fruits? 90% of the participant answered positively. This implies a marketing chance for producers to provide the market later on the season, which insure a better price, because the competition would be lower.

**Frequency of buying**

Most of the consumers interrogated bought cactus pear once a week. The lowest frequency is once a month and the highest frequency is 20 times a month, which correspond to five times per week. Two participants also answered that they buy cactus pear whenever they see it, and eight didn’t answer to this question.

![Frequency of buy per month](image)

Figure 34: Frequency of buy of cactus fruit per month from the customer's survey (Cochabamba, September 2017)
Price of cactus pear

The result concerning the price is not very reliable, since the survey was conducted in September, months after the end of the cactus pear season. Nevertheless, the range of the price can give an indication of the price the consumes paid. This data should be checked again during the main season to have more accurate results.

Figure 35: Frequency of designation of price per unit of cactus fruit (Cochabamba, September 2017)

The price per fruit fluctuates largely between BOB 0.2 to BOB 1.60. On the market place, the prices are expressed in fractions. For example: 5 fruits for BOB 2. The price fluctuates largely depending on the hour of the day, the period in the harvest season, the number of intermediaries, the quality of the fruits and the quantity bought. Some consumers gave prices per basket instead of per unit. Buying bigger quantity at once is cheaper. A basket’s cost varies between ten to hundreds of bolivianos, depending on the size of the container and the variety of the fruit.

Market place

The participants of the consumers survey were asked, where do they buy cactus pear. The most answered option was on the big market place of Cochabamba, where the producers arrive by bus with their harvest (Barrientos Street). The second group buys cactus fruit on farmer markets in Tiquipaya, America Street, Punata and Quillacollo. The third group has cactus fruit in their garden. The last group buys the fruit to the mobile merchant or at the organic market.

Figure 36: Different market place for cactus pear consumers (Cochabamba, September 2017)
Transformed products

Only nine participants could name some transformed products made with cactus pear fruit. The following list has been identified: Cactus pear honey, cactus pear alcohol, cactus pear juice and cactus pear jam (in growing order of frequency).

Table 3: Known transformed products of cactus pear in the consumers’ survey (Cochabamba, September 2017)

<table>
<thead>
<tr>
<th>Transformed products</th>
<th>Number of statement about the cactus fruit product</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cactus pear honey</td>
<td>1</td>
</tr>
<tr>
<td>Cactus pear alcohol</td>
<td>1</td>
</tr>
<tr>
<td>Cactus pear juice</td>
<td>2</td>
</tr>
<tr>
<td>Cactus pear jam</td>
<td>5</td>
</tr>
<tr>
<td>Total</td>
<td>9</td>
</tr>
</tbody>
</table>

All the participants knowing cactus pear transformed products named the cactus pear jam. It may be the most well-known transformed product from the fruit. Other products such as jelly and honey have been produced in the countryside of Cochabamba but don’t seem to be as spread as the cactus pear jam.

To the question: Would you buy cactus fruit jam? 87% answered positively. The answer wasn’t a strong ‘yes’, since 56% add ‘to try’ to their answer. This uncertainty is understandable, because many consumers never tried the product before. Some consumers answered negatively to the question. 13% said that they wouldn’t buy the cactus pear jam. The consumers’ worry concerned the amount of sugar that the jam would contain. They only consumed jam with stevia or honey instead of sugar. Those answers where collected on the organic market, where consumers are more aware of their health and come to look for alternatives. It is an opportunity to sell products adapted to person suffering from diabetes or avoiding sugar.

The price of the jam stopped one consumer from buying. This consumer found the product for BOB 35 for a kilo and felt it was too expensive. The high price of the cactus pear jam should be address by using new marketing strategies or restructure the cost.

Finally, concerns about the presence of seeds in the jam was expressed. Many people see the seeds as the elements that can cause digestive problem. This should be taken in account during the creating of the label of the cactus pear jam.

Properties of cactus pear

The consumers were asked about the properties of the cactus fruit. Only 30% could explain some effects of the fruits on the health. 68% were positive effects. The following opinions were stated: helps the digestive system, contains good fibres and helps to fight diabetes. 32% of the answers named negative effects. Four participants gave a limit of consumption per day to avoid digestive problems. The limit varied from four to ten fruits per day. Many theories are shared about how some fruits have an astringent effect. Some advised to eat the fruit at cool temperature, others to avoid the seeds. Some of the interrogated consumers made opposite statements. One consumer said he could eat up to 50 fruits a day without any negative effects on the digestion.

The fear of astringent effect of the cactus pear could slow down the fruit consumption. Another repulsive aspect is the amount of tiny invisible spine on the skin of the fruit. Those two factors are a positive argument for the commercialization of transformed products without spines and seeds. One hypothesis from Dc. Stadler-Kaulich would be that not freshly harvested fruit would cause digestive problem because they start the fermentation if they are not kept in cool conditions. Finally,
many scientific researches have been done about the properties of the cactus fruit and their positive effect on health. The fruit is often labelled as functional food and should be commercialized as such.

Table 4: Named properties of the cactus fruit on health from the consumers’ survey (Cochabamba, September 2017)

<table>
<thead>
<tr>
<th>Positive</th>
<th>Negative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Makes digestion easier</td>
<td>Astringent if more than 4 fruits/day</td>
</tr>
<tr>
<td>Good for digestion</td>
<td>The seeds block the stomach</td>
</tr>
<tr>
<td>Helps against parasites</td>
<td>Stomach-ache if more than 10 fruits/day</td>
</tr>
<tr>
<td>Good for the stomach</td>
<td>Hurts if more than 7 fruits/day</td>
</tr>
<tr>
<td>Helps the immune system</td>
<td>Hurts if more than 10 fruits/day</td>
</tr>
<tr>
<td>Helps against diabetes</td>
<td>Hurts if more than 5 fruits/day</td>
</tr>
<tr>
<td>Fights against gastritis</td>
<td>Doesn't like the seeds</td>
</tr>
<tr>
<td>Clean the stomach</td>
<td></td>
</tr>
<tr>
<td>Contains good fibres</td>
<td></td>
</tr>
<tr>
<td>Refresh the stomach</td>
<td></td>
</tr>
<tr>
<td>Contains micro-nutriments</td>
<td></td>
</tr>
<tr>
<td>Good for the kidneys</td>
<td></td>
</tr>
<tr>
<td>Contains vitamins</td>
<td></td>
</tr>
<tr>
<td>Fibres help the digestion</td>
<td></td>
</tr>
</tbody>
</table>

Cactus stems products

To complete this investigation of the cactus pear value chain, the market of the stems or cladode had to be researched as well. For reaching this goal, consumers were invited to name products made out cactus fruit stems and to name some of their properties. 54% of the interviewees could name products made of cactus pear stems and 25% could name some of their properties.

In the list of products made with cactus pear stems, four main categories can be made. The use for cosmetic products, such as shampoo and skin care, was stated 16 times. The culinary use of the stem in salads, juices, on the grill or fried was repeated 27 times. The third category refers to medical purpose from cactus pear stems. Benefits to heal wounds, gastritis, diabetes, back pain and cancer were stated. The content in vitamins and antioxidants were appreciated. 18 mentions health benefits. The last category concerns technical uses of the cactus stem. It is mentioned for the use of cochineal breeding, clarification of the water, thickening of cement and painting eight times.

Table 5: List of the named cactus stem products and properties at the consumers’ survey (Cochabamba, September 2017)

<table>
<thead>
<tr>
<th>Uses</th>
<th>Number of statement of the cactus pear stem’s property</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cosmetic</td>
<td></td>
</tr>
<tr>
<td>For the hair</td>
<td>15</td>
</tr>
<tr>
<td>For the skin</td>
<td>1</td>
</tr>
<tr>
<td>Cooking</td>
<td></td>
</tr>
<tr>
<td>In salad</td>
<td>7</td>
</tr>
<tr>
<td>As juice</td>
<td>6</td>
</tr>
<tr>
<td>For cooking</td>
<td>5</td>
</tr>
<tr>
<td>Fried</td>
<td>4</td>
</tr>
<tr>
<td>On the grill</td>
<td>3</td>
</tr>
<tr>
<td>----------------------</td>
<td>---</td>
</tr>
<tr>
<td>In pickling brine</td>
<td></td>
</tr>
<tr>
<td>To eat</td>
<td></td>
</tr>
<tr>
<td><strong>Medicinal</strong></td>
<td></td>
</tr>
<tr>
<td>To heal wounds</td>
<td>4</td>
</tr>
<tr>
<td>Against gastritis</td>
<td>3</td>
</tr>
<tr>
<td>Good for digestion</td>
<td>2</td>
</tr>
<tr>
<td>Healthy</td>
<td>2</td>
</tr>
<tr>
<td>Vitamins</td>
<td>2</td>
</tr>
<tr>
<td>Anti-oxidants</td>
<td></td>
</tr>
<tr>
<td>Help regeneration</td>
<td></td>
</tr>
<tr>
<td>Good against diabetes</td>
<td></td>
</tr>
<tr>
<td>Against back pain</td>
<td></td>
</tr>
<tr>
<td>Protect from cancer</td>
<td></td>
</tr>
<tr>
<td><strong>Technical use</strong></td>
<td></td>
</tr>
<tr>
<td>Use for cochineal production</td>
<td>3</td>
</tr>
<tr>
<td>To clarify the water</td>
<td>2</td>
</tr>
<tr>
<td>In Construction</td>
<td></td>
</tr>
<tr>
<td>To paint trees</td>
<td></td>
</tr>
<tr>
<td>Natural paint</td>
<td></td>
</tr>
</tbody>
</table>

6 Result 2- Analysis of the market

This group of result aims at answering the third and fourth expected result: Realize a market assessment of potential future uses and processing possibilities (ER3) and demonstrate cost and benefit structure of a transformed Opuntia’s product (ER4). Those results are oriented towards the future of the market. In this part, the results concerning the third research question will be presented.

6.1 SWOT analysis of the production

The SWOT analysis of the production gives inside into the strengths and the weaknesses of the actual production. As a second step, it spots the elements of opportunities and threats that could impact the production system.

The **strength** of the cactus pear plant lies in his great adaptation to arid to semi-arid climate. With the changes in the precipitation patterns the lateral Andean valley of Cochabamba, the livestock holder can benefit from the cactus pear stems. It is a great alternative fodder during the dry season. When the natural pasture has been used, the crop residues of wheat, barley and maize are traditionally used as fodder. With the climate change, harvest of those crops diminishes, and the crops’ residue aren’t enough to feed the livestock. The cactus stem contains 68% of water during the dry season in Pasorapa (Cabrera F. 28.08.2017). It is a great source of water for the cattle.

The cactus pear completes the regional fruit production focused on peach and apples, with an alternative for villages that can’t irrigate fruit trees. A further strength is the low level of management to successfully grow this plant. All management of the plantation from planting to harvest can be done by hand, without any external input such as fertilizer, herbicide or tractor for ploughing. Farmers can have other crops that are more labour intensive such as dairy farming and alfalfa production next to the management of cactus pear orchards.
Thirdly, the fruits offer many opportunities of differentiation to the farmer. This can be achieved by introducing some transformation and offering new products to the market. Added value could be created by using the ripe fruit that can’t be sold to create transformed products. Finally, the plant starts producing fruits after three to four years, but the cactus stems can be harvested in the first year after the plantation. This allows a quick return on investment. The multiplication of a good variety is easy as well, as each stem or part of a stem can be replanted to create a new plant. Thus, the reproduction of great genetics is affordable for every farmer.

Table 6: SWOT analysis of the production of the cactus fruit (Cochabamba, 2017)

<table>
<thead>
<tr>
<th>Strengths</th>
<th>Weaknesses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry climate</td>
<td>Plagues (C, N)</td>
</tr>
<tr>
<td>Little management</td>
<td>Little harvest</td>
</tr>
<tr>
<td>Many derivatives</td>
<td>Little market</td>
</tr>
<tr>
<td>Grow quickly/ easy multiplication</td>
<td>Little management</td>
</tr>
<tr>
<td>Opportunities</td>
<td>Threats</td>
</tr>
<tr>
<td>Lots of adapted land</td>
<td>No extension</td>
</tr>
<tr>
<td>Low technology</td>
<td>Lack of knowledge on management</td>
</tr>
</tbody>
</table>

Concerning the weaknesses, the main pest problem concerns the parasite cochineal (*Dactylopius coccus*), the attack of the fungus black spot (*Pseudocercospora Opuntiae*), and the cactus weevil (*Metamasius spinolae*) in decreasing importance (Hernández-Sánchez 2014). The cochineal has seriously damaged the plantations around Cochabamba and the treatment of this parasite is the first obstacle to a healthy production. The second weakness is the low quantity of the production. The farmers don’t have access to the knowledge to treat chemically the cochineal, which seriously reduce the yield. Finally, the fact that all the producers bring the harvest at the same time to the market, lower the prices. Little knowledge about commercialization makes the differentiation between producers difficult.

About the opportunities, there is still a lot of uncultivated land suitable for cactus fruit production. This allows producers that specializes into cactus pear production to easily increase the surface of the plantation. The door is open for farmers to use unexploited land for the plant, that grows where no other crop grows. Finally, the preparation of the fruit for the commercialization needs no technologies, all the process can be done by hand, which make the production accessible to everyone. Concerning the threats, no information is given to the producer about the management of pests and diseases in the plantation. Only one engineer in Bolivia has a specialization into cactus pear production. Unfortunately, this is not taught in the agriculture universities of the country. State extension services are not present in the countryside. The lack of knowledge at the farmer and technician level has a negative effect on the quality of the production of cactus pear.

6.2 SWOT analysis of the commercialization

Strengths, weaknesses, opportunities and threats (SWOT) analysis of the commercialization of cactus pear helps to see the positive and negative aspects for the commercialization and highlights opportunities and threats of the actual supply chain. The arguments come from the interviews with key informants, producers and consumers.

The first strength of the actual commercialization is that no technology is necessary: from the harvest to the end consumers, no machine or special packaging is necessary. The only processing steps are the removing of the spine at the plantation and the peeling of the fruit just before selling the fruit. Anyone can join the chain of retailers and fruit merchant.
The second strength is the local value of the harvest. The cactus fruits don’t only have a value on the city market, they also provide home consumption and as a currency on the local market, where the fruit can be exchanged against potatoes, bread and vegetables. The ‘currency’ aspect is also visible, when women bring some of the fruits to the city to gain some cash and do the basic groceries for the families. It is a way to have a quick access to cash during the harvest season, a sort of debit card.

Table 7: SWOT analysis of the commercialization of cactus pear (Cochabamba, 2017)

<table>
<thead>
<tr>
<th>Strengths</th>
<th>Weaknesses</th>
</tr>
</thead>
<tbody>
<tr>
<td>No technology</td>
<td>Market saturation</td>
</tr>
<tr>
<td>Used as ‘currency’</td>
<td>No organization</td>
</tr>
<tr>
<td><strong>Opportunities</strong></td>
<td><strong>Threats</strong></td>
</tr>
<tr>
<td>Few producers</td>
<td>No organization of the producers at a department and national level</td>
</tr>
<tr>
<td>Few derivatives</td>
<td>No sales at retailers and supermarket level</td>
</tr>
<tr>
<td>More demand than offer</td>
<td></td>
</tr>
</tbody>
</table>

Concerning the weaknesses, the main problem is the market saturation in February. This has repercussions on the prices that varies greatly from one week to another during the harvest season. The saturation of the market can be explained by the fact that the fruit is difficult to conserve and unprocessed. Furthermore, it can’t ripe once harvested like avocado or bananas. This characteristic force the producer to sell the harvest right away, even when the price on the market is low. Finally, the fact that no organization of the sector at a local or national level exists, decreases the chance of a better management of the supply chain to the big cities.

Concerning the opportunities of commercialization, many are still open. The few numbers of producers and in general the low productivity per producer, let a lot of room for improvement of the production and the commercialization quality and quantity. As explained above, the short conservation period of the fruit can be improved by transforming it and so developing new markets for cactus pear derivates. This asks for more market research to discover which product has the best acceptability. Consumers responded positively to the offer of a longer season of the fruit, this is a great opportunity for producers who want to get higher price and specialize into cactus pear production. Furthermore, the unbalance between the produced varieties (mainly yellow) and the demands variety (mainly green) indicates an unsatisfied demand for green cactus pear, which also have a better price on the market. About the threats to the actual commercialization process, again the lack of organization of the value chain can cause a lack of market information at the retailer and producer level. This can also cause distortion of the price and unbalance of the offer and demand. Finally, the image of the fruit would be greater, if sold by recognized supermarkets such as IC Norte or Hypermaxi, which also sell fruits at a higher price than on the market. This implies the use of technologies for the packing and climatization of the fruit and would be possible as producers specialize on this crop.

6.3 Potentials transformed products and cost and benefice analysis

This section has for goal to express the diversity of transformed products made of cactus pear. The list (Table 8) is based on the table from the FAO document ‘Agro-industrial utilization of cactus pear’ published in 2013 (Sáenz 2013, 17) and completed with personal information.
Market analysis of prickly pear (Opuntia ficus-indica) production in Cochabamba, Bolivia

Elena Paiuc

Table 8: Food products, by-products and additives obtained from the cactus pear plant (Cochabamba, 2017).

<table>
<thead>
<tr>
<th>Products</th>
<th>Fruits</th>
<th>Cladodes</th>
<th>By-products</th>
<th>The plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Juices and nectars</td>
<td></td>
<td>Juices</td>
<td>Oil from seeds</td>
<td></td>
</tr>
<tr>
<td>Jam, gels and jellies</td>
<td>Pickled and brine-cured products</td>
<td>Jam from the peel of the fruit</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dehydrated fruits and fruit leathers</td>
<td>Jam and jellies</td>
<td>herbal tea with the dry flowers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sweeteners</td>
<td>Flours</td>
<td>mucilage from cladodes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alcohols, wines and vinegars</td>
<td>Young stems (nopalitos)</td>
<td>Pigs from the peel and fruit</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Canned fruit</td>
<td>Confectionery</td>
<td>Dietary fibre from cladodes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frozen fruit and pulp</td>
<td>Sauces</td>
<td>Pulp for animal feed from peel and seeds</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The fruits can be transformed into juices and nectars. In the less fluid category jam, gels and jellies are largely produced in Mexico. Dehydrated fruits and fruit leathers is a specialty that can be made industrially or handmade. Sweeteners can be extracted from the fruit. The process of fermentation helps achieve wine and alcohol. Cactus pear can also be used to create vinegar. The fruits are well conserved in a canned form or frozen. Many of those products are traditionally produced in Mexico.

Figure 37: Prickly pear candy, jam and syrup (Staber F. : Staber H.)

The cactus stems are often conserved in caned as pricked or brine-cured product. Jam and jellies can also be extracted from the mucilage of the stems. In Brazil, the stems are dried and grounded into flours to mix with cattle fodder. This flour contains high amount of fibre and research has been made to include it into cookies recipes. Confectionery like the cactus pear candy are produced with the cactus stems. The mucilage can be used as thickener agent in sauces. The young stems are consumed as vegetable in the Mexican cuisine.

By-products can be extracted from diverse parts of the plant. Oil used in cosmetic is extracted from the seeds. The extraction companies are located in Morocco and Tunisia. The flower of the cactus pear can be added to herbal tea. The mucilage from the cladode has many applications. It is used for the confection of shampoo, face treatment and to help healing wounds. Pigment can be extracted from the peel and the fruit of the red variety. Dietary fibres are extracted from the stems and used to give higher fibre content to industrial preparations. The pulp, peel and seeds are used as animal feed.
Cost and benefice analysis of cactus pear jam

To have an idea of the margin of feasibility of the transformation of cactus pear, an analyse of the cost has been made. This calculation takes in account the cost of the ingredient and the cost of labour. The benefits correspond to the total income after the sale of all the products. Cactus pear jam is the first example as it is the most known transform product of cactus pear in Bolivia. This calculation has been made with engineer Saenz, that produce cactus products for many fair and specialized markets. For this recipe, 25 fruits are used to extract 1kg of pulp, this is an equivalent of 20kg of fruit, knowing that a fruits weight on average 800g. After the peeling, 0.5kg of white sugar is added, this insure the conservation of the product and the final taste. Spices such as cinnamon and cloves reinforce the taste of the fruit. Pectin is used to give the final texture of a jam to the product. Finally, after letting the liquid cook for 3 hours, the equivalent of 4 lemon juices are added. The proportions from this recipe allow for 1kg of jam. The final cost of the ingredients and the 3.5h work is based on the local prices of Cochabamba. A farm employee is being paid BOB 60 per day those 3.5h correspond to BOB 25. This is the biggest share of the cost followed by the BOB 12.5 for the fruits and the BOB 10 for the jam jar.

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>Quantity</th>
<th>Handwork</th>
<th>Time</th>
<th>Price BOB</th>
</tr>
</thead>
<tbody>
<tr>
<td>25 cactus pears red/yellow</td>
<td>2kg</td>
<td>Extract pulp</td>
<td>15min</td>
<td>2.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cooking</td>
<td>3h</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Packing</td>
<td>15min</td>
<td>2.5</td>
</tr>
<tr>
<td>Sugar</td>
<td>0.5kg</td>
<td></td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>Cinnamon</td>
<td>0.2g</td>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Clove</td>
<td>0.2g</td>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Pectin</td>
<td>2g</td>
<td></td>
<td></td>
<td>8</td>
</tr>
<tr>
<td>Lemon juice</td>
<td>4 units</td>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Sticker</td>
<td>4 units</td>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Jar</td>
<td>4 units</td>
<td></td>
<td></td>
<td>10</td>
</tr>
<tr>
<td><strong>Production cost</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>66.5</strong></td>
</tr>
</tbody>
</table>

Conservation time          4 years

<table>
<thead>
<tr>
<th>Product</th>
<th>Quantity</th>
<th>Price BOB</th>
</tr>
</thead>
<tbody>
<tr>
<td>cactus jam</td>
<td>250g</td>
<td>20</td>
</tr>
<tr>
<td>cactus jam</td>
<td>250g</td>
<td>20</td>
</tr>
<tr>
<td>cactus jam</td>
<td>250g</td>
<td>20</td>
</tr>
<tr>
<td>cactus jam</td>
<td>250g</td>
<td>20</td>
</tr>
</tbody>
</table>

Sales benefits              80

Internal Rate of Return:    BOB 13.5 17%

The price of the final product was set at BOB 20 per jar of 250g. The price is a very sensitive parameter as it highly influences the Internal Rate of Return (IRR). Compare to other fruits jam, the price is high. A jar of 500g in the supermarket can cost BOB 18, if the same price was applied to the cactus fruit jam, the production wouldn’t be beneficial. The cost of the cactus fruit can also be considered as inexistent if using discarded fruits that can’t be sold. This assumption would make sense if the producers transformed the discarded fruits themselves. In this case the IRR would go...
up to 32%, if the jam is sold at BOB 20 per 250g. In conclusion, cactus pear jam is a good alternative for the producers at condition that they used fruits improper to commercialization and sell the jam as a speciality.

**Cost and benefice analysis of cactus pear juice**

The second transformed product has a short conservation time. The artisanal cactus pear juice can be conserved for 3 days. This type of transformation makes sense for punctual preparation linked with an event inducing a high consumption of juice. The cactus pear juice is made with the same ingredients than the jam. Spices and lemon helps to highlight the delicate flavour of the fruit. The recipe used for the analysis of the production cost and benefice come from the engineer Saenz. The following quantities of ingredients produce a 6L of juice. To start, 2kg of cactus pear from the red or yellow variety are needed. They have to be peeled, liquified and cooked in 0.5L of water. Sugar, cinnamon and cloves are added to achieve a stronger taste and after 40 minutes cooking, the juice of 10 lemons is added. The main production cost are the 25 fruits. If producer use discarded fruit this cost could be removed, and the IRR would be 63%. The actual IRR of 46% is based on the sale of 0.2L plastic glasses for BOB 2.5. The price is in the same margin as the other fruit juices sold on the street. The labour cost is BOB 10, because the working time is of one hour. More cost for the transport and the sale of the juice can be added depending of where the customers are located.

**Cactus pear juice production**

<table>
<thead>
<tr>
<th>Ingredients</th>
<th>Quantity</th>
<th>Handwork</th>
<th>Time</th>
<th>Price BOB</th>
</tr>
</thead>
<tbody>
<tr>
<td>25 cactus pears red/yellow</td>
<td>2kg</td>
<td>Extract pulp</td>
<td>15min</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cooking</td>
<td>40min</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Packing</td>
<td>5min</td>
<td>2</td>
</tr>
<tr>
<td>Water</td>
<td>0.5 L</td>
<td></td>
<td></td>
<td>0.5</td>
</tr>
<tr>
<td>Sugar</td>
<td>0.5Kg</td>
<td></td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>Lemon juice</td>
<td>10 units</td>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>Cinnamon</td>
<td>0.2g</td>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Clove</td>
<td>0.2g</td>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Glasses</td>
<td>4 units</td>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td><strong>Production cost</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>40</strong></td>
</tr>
<tr>
<td><strong>Expiration date</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>3 days</strong></td>
</tr>
</tbody>
</table>

**Cactus pear juice sale**

<table>
<thead>
<tr>
<th>Number</th>
<th>Product</th>
<th>Quantity</th>
<th>Price BOB</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>cactus fruit juice</td>
<td>0.2L</td>
<td>2.5</td>
</tr>
<tr>
<td></td>
<td>Sales benefits</td>
<td></td>
<td>75</td>
</tr>
<tr>
<td></td>
<td><strong>Internal Rate of Return:</strong></td>
<td>35BOB</td>
<td><strong>46%</strong></td>
</tr>
</tbody>
</table>

Figure 39: Cost and Benefit analysis of cactus pear juice (Cochabamba, 2017).

The cactus fruit juice produces less cost than the jam, but has a shorter conservation period. The juice is done quicker and needs less labour hours. In the two calculations, the price of gas is not taken in account, as it is difficult to estimate for such a short amount of time. As no special equipment is necessary to produce both recipes, it will not be included to the calculation.
6.4 Potentials commercialisation of cactus stem

Alternative commercialisation points were researched for the commercialization of cactus pear stem. This product could be promoted to the population by two different intermediaries. The first would be to supply green juice shops. Juices are highly appreciated by consumers in Cochabamba. The trend of vegetable juices is rising, and small retailers prepare many vegetables mix each attributed to help against a health problem. Following the same approach, the cactus pear stem could be offers and mixed with other vegetables. This would promote the positive properties of the cactus stem against diabetes. The commercialization by juice shop could help spread awareness about the benefits for the health in the population. Diabetes being one of the recurrent disease in the population, cactus stem has a real market potential.

The following approach would be to commercialize cactus stems through natural health shops, artisanal product retailer and traditional medicine merchant at markets. An exhaustive list of organic retailers has been made by Agrecol Andes. The guide is focussed on food retailers, but it could be a base to search for future cactus stem retailer. At the moment, the knowledge about the cactus stem is too low in the population to have a real demand, although the majority of the consumers asked me for more information about the properties and recipes of cactus stem. The organic guide can be found at the following address: http://guia.agrecolandes.org/.

6.5 Comparison to other South American markets

This comparison is made on the basis of the literature study. The Bolivian market will be compared to four other Latin American market, studied earlier in the ‘Market Analysis of diverse prickly pear (Opuntia ficus-indica) markets’ (Paiuc E. 2017). The Mexican market appears like the ‘expert’ being the biggest producer of cactus pear worldwide. It accounts for 72 500 ha of cactus pear fruit production (Sáenz 2013, 119). It is the market with the highest consume per person of cactus pear. "Cactus pear is the sixth fruit crop in Mexico, after orange, avocado, banana, mango and apples (SIAP, 2004)" (Gallegos-Vázquez et al. 2009). In 2004, the average consumption was 5kg year⁻¹ per capita (Paiuc E. 2017). Concerning the cactus stem the annual production is 563 443 tonnes and per capita annual consumption is around 6 kg, making young cactus pear stem, the country’s sixth most commonly consumed vegetable (Sáenz 2013, 119). Many companies are specialised in the transformation of cactus pear and cactus pear stem in Mexico.

Chile appears like a country specialized in cactus pear fruit production. "According to the Centre for National resources (CIREN), the planted area in 2012 is up to a total of 950 ha and most of the production goes to the domestic market (Latin American prickly pear snapshot). The value chain is similar to the one in Bolivia with some additional middlemen and traders like supermarkets. Export is also a major difference with the actual Bolivian market for cactus pear. In conclusion, the Chile value chain could be the future state of the Bolivian market if the production is centred on cactus fruit production.

In Chile, cactus pear is mainly eaten as fresh fruit, although it is also used in desserts or made into juices, which is similar to the consumption in Bolivia (Sáenz 2013, 112). Different from Bolivia, producers receive agronomic advices. The University of Chile provides training in small-scale production and processing of cactus pear (ibid.). Extension of the cactus stem market is also supported by the University of Chile and researchers at Food and Development Research Centre (CIAD) from Mexico.
The **Argentinian market** is similar to the Bolivian market. They have in common, no exportation of the cactus pear fruit, no habit of transformation of the fruit, and no habit of consumption of the cactus pear stem. In Argentina the population consumes only the fruit, mainly fresh (ibid., 111). The production is estimated of 2 000 ha of plantation crops grown in 2000 (Inglese, 2000: Ochoa, 2003).

### 6.6 Cactus pear a threat for the people and the environment?

Is cactus pear an invasive plant and thus a threat for the people and the environment? The question has risen in many countries, where the cactus pear is managed like a weed. In Australia and South Africa, the plant spread in the large grazing areas used for livestock fattening. It is then considered as taking the space of the grazing grass and has to be removed. The parasite cochineal is one of the favourite method to kill the cactus pear plant.

**Is it a danger for Bolivian pasture land?**

The University Catholic of Cochabamba pointed this worry during one of our discussion with the director of the environmental engineer section. The cactus pear reproduces itself quickly by multiplication from the falling stem. This type of natural reproduction is possible only on a short perimeter around the plant. The long-distance dissemination is done by the birds eating the seeds of the fruits and disseminating the seeds after digestion. The germination rate of the dissemination by seeds is much lower than the multiplication by the stems. From my observation, in the region of Arani and Punata, the livestock, specially sheep is driven by the guardian on the uncultivated land. Those surfaces are not as big as the ones in South Africa and are dry. Thus, anything that grows is considered fodder. Cows, goats, sheep, guinea pig all benefit from the cactus pear stem as fodder. On the other side, the parasite cochineal is well spread on the region, which reduce the fruit production of the existing plantation and therefore the dissemination rate of the cactus pear plant.
7 Discussion 1 - Current state of the value chain

This part of the thesis will develop the interpretation the first group of results. In this part, the two first research questions will be developed. The results will be explained and compare to other scientific references.

7.1 The value chain

The inside into the production process of cactus pear in Arani gives an idea of the level of management of the plantations done in the region. The harvest process is explained in detail. The base of this description is an interview with one producer and the engineer Serafin Vidal.

On one hand, it seems clear that the value chain is basic. The last transformation process is the peeling of the fruit just before selling the fruit to the consumer. No controls of quality of the fruits before the sale exist, and the transportation conditions and conservation practices are basic. There is a big room for improvement of the quality of the final product. This probably explains why the value chain stays informal and are not in accordance with the criteria of supermarkets. On the other hand, the value chain works because it is so simple. The low level of technology suits the capacities of the different actors.

Cactus pear is a plant well adapted to dry and poor soil condition and should keep supporting the population living in those regions. To do so, it is important to implement technologies that are accessible to the low-income farmers.

7.2 Economic importance of cactus pear

As presented in the results, cactus pear isn’t the main income source for the household. Within the producer sampling, the majority of the producers are cattle owners from Pasoropa. In this municipality, the economic benefit of cactus pear can’t be yet measured as the cactus stem as fodder doesn’t have an economical value and the plantations have only one to two years. In the coming years, it could be measure in the reduction of the number of heads during the dry season. Actually, farmers lose between 30-50% of the herd during this period. Another calculation would be a comparison with a commercial fodder such as soya beans. Following those two propositions, the economic value of cactus pear could be measured.

The second majority of the producers live from farming. The income from cactus pear fruit is lower than the minimal monthly income. Nevertheless, the cash flow in farming household follows another curve. In farming system, income is often in nature and cash comes once a year with the sale of a cash crop. The income of cactus fruit should be compared to the annual income of the family to have a better representation of the economic importance of the fruit. The results show that cactus pear isn’t in the three main income sources of the household. Nevertheless, it is important to keep in mind the role of cactus fruits to have access to cash during the harvest season. The fruits are also used as ‘currency’ on the local markets. The interviews show the social importance of cactus pears, since producers share the fruits with family in the city and neighbours.

7.3 Opinion of the consumers

This section explains the limitations of the results and gives a context to some of the results of the questionnaires. To start with, the consumers interviews are examined.

During the survey, the majority of the opinion on the cactus pear were positive. Only three persons interrogated didn’t like the fruit. Many consumers appreciated the benefits of the fruits for the
health. Concerns were expressed toward the consumption of the seeds and the handling of the fruits before peeling. Those two factors are a positive argument for the commercialization of transformed products without spines and seeds. One hypothesis from Dc. Stadler-Kaulich would be that not freshly harvested fruit would cause digestive problem because they start fermentation if they are not kept in cool conditions. Finally, many scientific researches have been done about the properties of the cactus fruit and their positive effect on health. The fruit is often labelled as functional food and should be commercialized as such.

**Consumption quantity**

In the results, it was shown that consumers would like to buy the fruits during more time around the year. This implies a marketing chance for producers to provide the market later on the season, which insure as well better price, because the competition would be lower. The acceptability of the fruits coming later in the year should be tested. The question: ‘if the season of cactus pear was longer, would you buy more fruits? Doesn’t give answer to which price would be accepted by the consumers for those special fruits. To be rentable, such a production should be equipped with drops irrigation and the yield would be lower. The fruits should then be marketed in exclusive selling points like supermarkets to justify a rise of the price for the consumers.

**Quality criteria**

The answer of the consumers indicated that the green variety is more difficult to find than any other variety. The favourite variety is the green one for 52% of the consumers interrogated. The availability and amount of each cactus variety on the market should be tested again during the fruit's season.

**Price**

The season of the investigation may have induced errors on the results of the questionnaires done with consumers. Sensitive questions from the consumers survey have been highlighted. Since the questionnaires have been answers in September about six months after the cactus pear season, quantitative answers about the price of cactus pear may be influenced. The price given by the consumers can be overrated or underrated. Therefore, they were used as a broad scale of what the consumer pays for cactus pear. Such results should be repeated between January to March on diverse commercialization points in Cochabamba and Santa-Cruz to have a more details view on the variation of the prices along the harvest season.

**Properties of the cactus stem**

Another sensitive question concerns the properties of cactus pear stem. A confusion with a well-known plant may have influenced the answers. The word ‘penca’ is used in Spanish to define the stalk of the cactus pear or to refer to the main rib of a leaf. In Bolivia, the word ‘penca’ is also used to designate the leaf of Aloe Vera. Aloe Vero is well known for its healing properties, rehydration power after sunburn and overall benefits for the skin. Thus, the medical properties attributed to the mucilage of the cactus pear stem may be overrated or influenced by this confusion.

**Cactus pear jam**

The question concerning the reluctance to consume cactus pear jam has to be explained. The most repeated explanation to not consume cactus pear jam is the high amount of sugar of the product. It is an opportunity to sell products adapted to person suffering from diabetes or avoiding sugar. The price of the jam also stopped consumers from buying. The high price of the cactus pear jam should be address by using new marketing strategies or restructure the cost. Finally, concern about the presence of seeds in the jam should be taken in account during the creating of the label of the cactus pear jam.
8 Discussion 2 – Analysis of the market

This part of the thesis will develop the interpretation of the second group of results. In this part, the third research questions will be developed. The results will be explained and compared to other scientific references.

8.1 SWOT analysis

The production

The SWOT analysis of the production gives clear indication of the actual problems of the value chain. For a further development, the help of specialists such as the engineer Marcelo Saenz is necessary. The engineer offered a new income opportunity to the cactus pear producers by buying cactus stems. The stems are disinfected and treated to be sold to other regions that wish to expand their plantations. This business offers a value of BOB 0.5 per stem to the producers. The engineer Saenz gives classes on cochineal management to the producers' communities. This work should be supported for a bigger impact into the value chain.

The commercialization

The SWOT analysis presents an analysis of the positive and negative aspects of the value chain, based on the information collected during the interviews. The participation of more stakeholders such as intermediaries and local traders could give more insights on the conditions of transportation and the quality criteria. With a better quality of the fruits, changes can be brought into the value chain and new types of commercialization can be developed. Concerning transformed products, only artisanal production was observed. Production of transformed cactus fruit and stem products is a real opportunity to develop the value chain.

8.2 Transformed products

Market opportunity

The global market for functional food is growing (Valencia-Sandoval K. et al. 2010). Cactus pear fruit and stem can both be located in this category. The demand for high-quality products is a great opportunity for future development of the cactus pear value chain. Bolivia could be part of this movement if investment into the transformation and increase of the quality of the fruit is achieved. The most important aspect of the cactus pear value chain is that it provides alternative income to farmers living in difficult conditions for other cash crops.

Cost and Benefit analysis

The cost and benefit analysis of the cactus pear jam and juice follow the recipes from Marcelo Saenz and couldn’t be observed. It would be important to discuss them with a producer to understand the feasibility and the difficulties. Supply of some ingredients or material could be a limitation. The price of BOB 20 for 250g isn’t optimal and doesn’t follow the recommendation for cactus pear jam from the consumer survey. The price is too high if referred to those results. It could nevertheless be justified if the product is sold as specialty or the health benefits of the plants are marketed.
The cactus pear juice offers a good alternative, but has a short conservation period. Developments of the recipe could help find a better process for the production of the juice.

8.3 Commercialization of cactus pear stems

As presented in the result, at the moment there is no habit of consumption of cactus pear stem in juices or in meals. The use for human consumption could be slowly introduced by mixing the stems with other ingredients in juices and promoting the health benefits of the beverage. This type of product should be sold on speciality markets such as the one in the north of Cochabamba, the organic market, or through shops that sell organic or healthy products. Cactus stem juices is a product directed to health-aware consumers, looking to improve their health with natural products.

8.4 Comparison with other markets

The comparison with the value chain of cactus pear in Argentina and Chile brings indication of future evolution of the Bolivian market. Those two markets are a competition and take part of the same trading union. The actual export and import between Bolivia and those two countries could be analysed to see if trade of cactus pear is a possibility in the future. If Bolivia manages to develop the value chain and start exporting cactus pear, it is likely that trade will be done with other continents. The fruit needs to be of a high quality to be accepted for export and the transport and packing facilities should be upgraded. Such a development would be possible in the long term.

8.5 Recommendations

The following steps support the producers and the commercialization process of the cactus pear value chain. They are inspired from the discussion of the results and the SWOT analysis.

Cactus pear cultivation provides many benefits for the population and the environment, like presented above. The main problem preventing the producers and the all value chain to develop itself is the actual lack of knowledge concerning the management of the pests (especially cochineal) in the cactus pear plantations. During this study, no literature could be found about the chemical treatment against the parasite. Only one man in Bolivia seems to know how to manage the pest. He should be supported in his effort of vulgarisation by other agricultural supports. The knowledge to treat the parasite should be made accessible to all the producers.

The diffusion of information to the producers could be made easier with the organization of producer’s committees. The grouping of producers and other stakeholders of the value chain could better the organization of the supply chain and increase the communication.

Additional value should be created at the producer level by implementing transformation of the cactus pear fruits. To do so, vulgarisation of the transformation processes should be addressed to producers.

The knowledge acquired with the consumer’s survey should be used to create transformed product matching the needs of the consumers. For example, sugar and seeds-free products have consumers’ attention.

An increase of the quality and quality of the production of cactus pear fruits would enable the commercialisation of the fruits through new retailers such as fruits retailers and supermarkets.

Finally, further research at the producer and consumer level should be made to better understand the feasibility and acceptability of cactus pear transformed products in the Bolivian market.
Conclusion

This research aims at studying the cactus pear (*Opuntia ficus-indica*) by answering questions concerning the actual state of its value chain. It answered three main questions about its economic importance, consumers’ opinion and opportunities for future development of the cactus pears. The answers are quickly presented here, as well as some remarks and recommendations for future research to dwell further on it.

The adaptation of the agriculture to climate change is a broad process. Nevertheless, some crops have more potentials to thrive in the future climatic condition than others. Cactus pear is a well-adapted plant to semi-arid and arid regions. It can support minimum annual rainfall as low as 150 mm and poor soil. This adaptation to dry land make it specially well adapted to the declining rainfall in the lateral Andean valley of Cochabamba. After interviewing 56 cactus pear producers in the Department of Cochabamba, it is noticeable that this crop isn’t the main income source of the producer’s household. It is due to low productivity of the plantation after the introduction of the cochineal parasite in the 90s. This is also explained by the non-existent to low technical input into the plantation and the short harvest season (3 months). It can be concluded that cactus pear remains a minor crop for the rural population. Support to manage pests should be provided to reignite the interest of the producers. To complete the results, it is important to collect more income of cactus pear producers and compare it with other regions. Knowledge about the prices fluctuation during the season is also necessary to calculate the rentability of producing fruits out-season.

Concerning the opinion of the consumers on cactus pear, the consumption limitation (4-10 fruits per day) expressed by consumers should be turned into an opportunity to sell transformed cactus pear fruit products. More information about the cactus fruit demand should be collected. The actual results are too small to calculate the consumption level throughout the country. The average consumption of the fruit per person per year could be an argument to boost the commercialization through bigger retailers such as supermarkets. Interviews with large retailers could explain the reason blocking the sale of the fruits on the shelves.

This description of the supply chain in Cochabamba is accurate, but the value chain is broader than the department. It extends to the cities of Santa Cruz and La Paz. There, it would be interesting to observe and describe the trading process as well. Concerning the value chain stakeholders, no local trader or transporter could be identified and interviewed. Those intermediaries are key for the construction of a value chain. In further researches, it would be important to contact them. Those actors influence the price of the fruit at the consumer level. Their margin and costs should be studied. Such interview could highlight the quality criteria of the trader and help identify new opportunities or threat in the value chain.
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XE currency converter. BOB to USD, 2017, http://www.xe.com/de/currencyconverter/convert/?Amount=1&From=BOB&To=USD
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Especially Karina Gonzalles Merino that took time to introduce me to producers and played the role of translator. To all the family of Roberta Gonzalles to host me several times during the six months and that accepted to add cactus pear stem to her marvellous recipes.

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My last thoughts go to my partner, family and friends for their support during my stay abroad and their warm welcome when I returned from Bolivia. Last thanks to my two proof-readers for their attentive reading and wise advices.
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Appendix 1: Semi-structured interview of key informants

Interview with experts

Presentation of the research questions and myself.

1. Introduction - Personal experience with cactus pear?


3. Work mapping: harvest, cleaning, drying, processing, packaging, storage (transport, advertising, selling)

![Figure 41: Example market mapping (SL RMA Rael 2017)](image)

4. Place-type of market (assembly market, wholesale market, retail market and local stores, farm store, supermarket) – Actors – Customs – Transport


6. Promotion-consumer choices, preferences – labelling – discount – advertising
7. People-market intermediaries (producer, family, wholesale, trader, processor, retailers, consumer)

8. Potentials/ constraints: wishes, potential intervention, investment

9. Cost/benefit analysis (production, harvest, transport, selling cost)

10. Gender-calendar/ Mandala- men’s crops? / access to land/ is produce close to the homestead?

Figure 42: Checklist RMA (SL RMA Rael 2017)
Appendix 2: Structured interview with producers

Entrevistas de productores de tuna

Soy Elena, una estudiante de agronomía de Suiza y trabajo con Agrecol Andes. Hago una investigación sobre la producción de la tuna en el departamento de Cochabamba, con fin de desarrollar nuevas posibilidades de comercialización de la tuna (frutas, pencas y forraje) por pequeños productores (5-10 ha). Esta entrevista será en castellano y tiene una duración de 20 minutos. ¿Quiere participar? / ¿Está bien por usted?

<table>
<thead>
<tr>
<th>Sección 1: Información geográfica</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Fecha</td>
</tr>
<tr>
<td>5. Nombre del encuestador</td>
</tr>
<tr>
<td>7. Numero de celular/ correo electrónico</td>
</tr>
<tr>
<td>8. Su dirección de casa (GPS coord.)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sección 2: Producción de tuna</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. ¿Cuántas hectáreas/arrobas tiene usted para la producción agrícola?</td>
</tr>
<tr>
<td>1-2 arroba(s) 1-2ha</td>
</tr>
<tr>
<td>2. ¿Dónde tiene tuna?</td>
</tr>
<tr>
<td>Alrededor casa</td>
</tr>
<tr>
<td>3. ¿Cuántas plantas de tuna tiene (estimación)? Densidad</td>
</tr>
<tr>
<td>Menos que 1m² 1-2 m²</td>
</tr>
<tr>
<td>4. ¿Sus plantas de tuna tienen algunas plagas (enfermedad o hongos)?</td>
</tr>
<tr>
<td>Cochinilla</td>
</tr>
<tr>
<td>5. ¿Cuál son los efectos de estas plagas sobre la producción de tuna?</td>
</tr>
<tr>
<td>6. ¿Desde cuándo tiene problema con la cochinilla/ mancha negra?</td>
</tr>
<tr>
<td>7. ¿Cómo manejas estas plagas?</td>
</tr>
<tr>
<td>8. ¿Cuántos años tiene la plantación?</td>
</tr>
<tr>
<td>9. ¿Cuál tipo de tuna tiene?</td>
</tr>
<tr>
<td>Amarillo</td>
</tr>
<tr>
<td>10. ¿Para que utiliza la planta de tuna?</td>
</tr>
<tr>
<td>Autoconsumo</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sección 3: Producción de forraje</th>
</tr>
</thead>
<tbody>
<tr>
<td>11. ¿Vende las pencas o es por los animales de la familia?</td>
</tr>
<tr>
<td>Venta</td>
</tr>
</tbody>
</table>
12. Si lo vende ¿A cuál precio? BOB

13. ¿Cuál animal comen de las pencas que producen? | Vacas | Ovejas | Cabras | Conejos | ……

14. ¿Cuál es el manejo de las pencas antes de dar las a los animales?

15. ¿Cuál es la dificultad más importante con la producción de forraje de tuna?

Sección 4: Venta de tuna (frutas)

16. ¿En qué período del año (cuáles meses)?

17. ¿Cuántas veces en la semana cosecha la tuna?

18. ¿Cuál cantidad por semana?

19. ¿Dónde la vende (nombre del mercado o localización)?

20. ¿Cuál son los criterios de cosecha?

21. ¿A cuál precio (por canasta/ balde)?

22. ¿Ha visto un cambio en el precio en este últimos 10 años?

23. ¿Cuánto dinero genera la venta de tuna en un año?

24. ¿Cómo hace el transporte de la tuna?

25. ¿En cuál recipiente vende la tuna?

26. ¿Cuál otro producto vende al lado de la tuna?

27. ¿Cómo prepara la tuna antes de la venta?

28. ¿Cuál es la dificultad más importante con la producción de fruta de tuna?

29. Si no lo venden: ¿Por qué? | Precio | Cantidad | Trabajo | ……

30. ¿Cuál cambio del mercado pude hacer la venta de tuna económicamente interesante por usted?

Sección 5: Ingreso

31. ¿Cuál es su ingreso familiar total en un año? Bs

¿En qué? | Ingreso anual (BOB) →
32. ¿Cuál es la actividad productiva principal para generar dinero?  

33. ¿Cuál es la actividad productiva secundaria para generar dinero?  

34. ¿Cuál es la importancia económica de la tuna por vuestra familia?  

35. ¿Usted y su esposo/a trabajan afuera de la casa?  
   - Sí  
   - No  

36. ¿Alguno de sus familiares le envía dinero del exterior o de Bolivia?  
   - Sí  
   - No  

**Sección 6: Transformación de la tuna**

<table>
<thead>
<tr>
<th>37. ¿Qué hace de los frutos que no se puede vender?</th>
<th>Autoconsumo</th>
<th>Transformar</th>
<th>Nada</th>
</tr>
</thead>
</table>

| 38. ¿Conoce productos hecho con la tuna? | Si | No |

<table>
<thead>
<tr>
<th>39. Si ¿Cuál?</th>
<th>Mermelada</th>
<th>Guarapo</th>
<th>Refresco</th>
<th>Miel de tuna</th>
</tr>
</thead>
</table>

| 40. ¿Usted come la penca tierna de la tuna? | Si | No |

| 41. ¿Conoce alguien que consume las pencas? |

| 42. ¿Conoce otros productores de tuna en la región? | Si | No |

| 43. Si ¿Quién? |

<table>
<thead>
<tr>
<th>44. ¿Puede decirme porqué trabaja/utiliza con la tuna?</th>
<th>No manejo</th>
<th>No regar</th>
<th>Solo cosechar</th>
<th>Solo con lluvia</th>
</tr>
</thead>
</table>

| 45. ¿Algo más que quiere decir sobre el tema de la tuna? |

Muchas gracias por vuestra participación. Si quiere conocer los resultados de la encuesta pueden dar me su correo electrónico/ número whatsapp.
Appendix 3: Consumer’s survey
Comportamiento del consumidor

Soy Elena, una estudiante de agronomía de Suiza y trabajo con la Universidad Católica. Hago una investigación sobre el consumo de la tuna en el departamento de Cochabamba, con fin de desarrollar nuevos productos con componente de la tuna (frutas, pencas y forraje) por pequeños productores (5-10 ha). Esta entrevista será en castellano de manera anónima y tiene una duración de 10 minutos. ¿Quiere participar? / ¿Está bien por usted?

<table>
<thead>
<tr>
<th>Sección 1: Información geográfica</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Fecha</td>
</tr>
<tr>
<td>2. Nombre del encuestador</td>
</tr>
<tr>
<td>3. Lugar de encuesta</td>
</tr>
<tr>
<td>4. Edad del encuestado</td>
</tr>
<tr>
<td>5. Sexo</td>
</tr>
<tr>
<td>6. ¿Por dónde vive?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sección 2: Compra de tuna</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. ¿Viene cada semana en este mercado?</td>
</tr>
<tr>
<td>2. ¿Por qué razón usted viene a este mercado?</td>
</tr>
<tr>
<td>3. ¿Dónde compra frutas normalmente?</td>
</tr>
<tr>
<td>4. ¿Compra tuna?</td>
</tr>
<tr>
<td>5. Cuándo quiere tuna, ¿dónde la compra?</td>
</tr>
<tr>
<td>6. ¿En cuál forma?</td>
</tr>
<tr>
<td>7. ¿A cuál precio (BOB)?</td>
</tr>
<tr>
<td>8. ¿En cuál época del año?</td>
</tr>
<tr>
<td>9. ¿Usted compraría más tuna si había oferta a fuera de esta época?</td>
</tr>
<tr>
<td>10. ¿En la época de la tuna cuantas veces compra la tuna?</td>
</tr>
<tr>
<td>11. ¿Cuál son los criterios de calidad por comprar tuna?</td>
</tr>
</tbody>
</table>
### Market analysis of prickly pear (Opuntia ficus-indica) production in Cochabamba, Bolivia

Elena Paiuc

<table>
<thead>
<tr>
<th>12. ¿Come tuna pura o mezclado?</th>
<th>Pura</th>
<th>Mezclado</th>
</tr>
</thead>
<tbody>
<tr>
<td>13. Si mezclado ¿Con qué?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14. ¿Por qué come tuna?</td>
<td>Por costumbre</td>
<td>Por su origen</td>
</tr>
<tr>
<td>15. ¿Conoce las propiedades de la tuna?</td>
<td>Si</td>
<td>No</td>
</tr>
<tr>
<td>16. Si ¿Cuál?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Sección 3: Derivados

<table>
<thead>
<tr>
<th>17. ¿Usted conoce productos transformado/derivados de la tuna?</th>
<th>Si</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>18. Si ¿Cuál?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>19. ¿Quiere encontrar más productos derivados de tuna?</td>
<td>Si</td>
<td>No</td>
</tr>
</tbody>
</table>

### Sección 4: Mermelada

<table>
<thead>
<tr>
<th>20. ¿Usted come mermelada?</th>
<th>Si</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>21. ¿Cuál tipo de mermelada tenía en su casa estos 12 meses?</td>
<td>Frutilla</td>
<td>Durazno/damasco</td>
</tr>
<tr>
<td>22. ¿De cuál tamaño es el recipiente? (Monstro recipientes)</td>
<td>1-200g</td>
<td>2-350g</td>
</tr>
<tr>
<td>23. ¿Cuántas veces al año/ al mes compra mermelada?</td>
<td>1-2</td>
<td>3-5</td>
</tr>
<tr>
<td>24. Si había mermelada de tuna en este mercado, quería comprarla?</td>
<td>Si</td>
<td>No</td>
</tr>
</tbody>
</table>

### Sección 5: Penca de tuna/nopal

<table>
<thead>
<tr>
<th>25. ¿Conoce los usos de la penca de tuna?</th>
<th>Si</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>26. Si ¿Cuál?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>27. ¿Consume la penca de tuna?</td>
<td>Si</td>
<td>No</td>
</tr>
<tr>
<td>28. ¿Conoce propiedades de la penca de tuna?</td>
<td>Si</td>
<td></td>
</tr>
<tr>
<td>29. Si ¿Cuál?</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Muchas gracias por vuestra participación. Si quiere conocer los resultados de la encuesta pueden darle su correo electrónico/ número whatsapp.
Appendix 4: Interview with Fredy Cabrera in Pasorapa (28.08.17)

Interview Fredy Carera

Presentation:
He is the veterinarian in the municipality of Pasorapa. Here the main income source is the livestock, from variety criollo kept for meat production. The main limitation factor being the lack of water. The population has strong losses of livestock because of the lack of fodder and water. Fredy is the first in the village, who implemented plantation of cactus pear to complement the alimentation of sensitive cows during the dry months. His father adopted this technique on the largest surface. The both of them are an example for the villagers and a lot of projects give cactus stems for free as an incentive for the farmers. They also have a stem-bank, only unused to grow pencas for further planting in the coming years. In one of the project, farmers have to give back half of the amount of pencas they received, to spread it in other communities of the municipality.

-In Pasorapilla people started to grow tuna for the fruits, with natural fence made out of branches. But with the time, they left the village and came to Pasorapa. As they went back everything was destroyed because the cows entered the plantation and eat everything.
-Here we feel strongly the effect of the climate change. The drought became stronger. We are forced to search alternative fodder adapted to the actual climatic conditions.
-We started with 3 families and now we got many benefits from those plantations. I now have plantation of 4 years and I use it each year to give it to my cows. So now other families started as well. But all the plantation you can see are mainly for the production of fodder.
-This year in April the local government bought 24’000 pencas from Sucre. The problem we have here is the black spot (mancha negra). And so, we started with those sick stems. It affect a bit the growth but since we cut them a lot each year to collect the pencas, it’s not affecting the plantation as much as a plantation for fruit production. The stems from Sucre are more healthy, not totally but a lot more than the ones we can find here. So this year 24 families received each 1’000 pencas. The idea is that next year they give back 1’000 plants per family, to give it to others 24 families.
-There is other projects that gave like 100 pencas to families but people participated only to received material and so didn’t build a fence around the plantation and a lot of them were distroided.
-The project we are doing, paroquia. We are working with communities here and with material local. He tried to collect the pencas the most healthy but it’s very difficult here. Almost everyone has mancha negra on his pencas. This is how we started here with about 20 families. So last year, we finally worked with the CIF (centro de investigacion forragera) in Tiquistay next to Cochabamba. We brought 1’800 pencas and worked with the local government to invite the CIF here. Now we implemented 10 demonstrative plots with healthy stems. Those plants from the CIF are from a variety for fodder. It doesn’t have the big spines but only the very small ones. But the spines are no problem for the cows, here we didn’t had this variety before and they still eat the cactus stems.
-The spines are no problem for the cows. I give it like that since 3 years. But it would be better to cut it a bit. The problem is that we give it to the livestock in August when the pencas on the cactus lost already a lot of water and so it becomes a bit chuy/chewy/flexible. Cutting the stems help the cows because otherwise they have difficulty to break it in pieces. They leave it for a while and come back and try again. This doesn’t happen when the pencas are fresh and juicy. They get cut in pieces very easily by the cows. The thing is that the pencas in the dry season have only 68% humidity compare to 90% normally. And with so little water content, they don’t really have spines neither.
-The guys who brought the pencas from Sucre, said that they have a machine to cut the pencas for the livestock. Let’s see if we get it once.
-There is another variety of white cactus pear from the hills. But this one has a lot of spines and is used to do natural fences, because the cows don’t eat it and cannot pass in it. If you have those as fodder, you still use them. Just need to burn the spines before to give it to the cattle.
-Here all the cattle is for meat production. It’s a criollo breed and gives very little milk. We let the calves with the mothers anyway. The cows are free to go on the hills to search for food. They are
like wild animals. The owner just come once a week to check on them. But during 3 to 4 months they are kept around the village. From May to August, they are kept here to eat the left over after the harvest from wheat, corn, caña pе (20 min.). After the rain, February-March, very few owner go with the herd for 2 weeks. He put them in a corral and collect some milk to do cheese. Put it’s very few production, the main purpose is meat production. Mainly they sell bull to Oruro for working in the field, the owners keep the females.

-On the hills, many producers don’t have they own land. They use communal land and the heard are a bit mixed up. They know which part is for who. It’s communal pasture land. They only have the name of owner but they can’t do any work on the land. No fence, no fields, no plantations of fodder. The others won’t let him. It’s a problem because it is communal. No one can start a cactus pear plantation to have more fodder because cows would eat it and it wouldn’t be his.

-The land is in process of desertification. The population of cattle has grown as well. There is a reduction of the rainfall and therefore less fodder. Last year 2000 heads were lost on 24000. People react very slowly to sell cattle. They should see that they a lot of livestock but very little fodder. Neither do they grow fodder. Only this year, people started to realize they need to reduce the size of the herd.

-Herding is the main income source for 80% of the population in Pasorapa. So they don’t want to reduce the amount of livestock. But if it was me, I would rather invest in this situation to make it better. Like start growing fodder, try to add value to my product, sell for better prices. It’s the mentality of the herders; cattle is their main income but they invest the minimum into it. Keep doing as before, with minimal effort.

-But I’m trying to find alternative with my cows and they are copying. So the situation is slowly changing.

-My role in this project is to better the situation of the livestock by introducing alternative fodder. For example, we also seed herbs well adapted to the climate here, that grows well under the shade of the trees. Also try to implement fodder conservation. But it need some investment of money and work. Since fodder can’t be sold directly, people are not so interested in it. They should have better price for better fed animals. The problem for this new fodder is that they need to make fence with wire around it but our project can’t afford it.

-I grow up here in Pasorapa and there was a lot of goats as well. But goat is they are not well managed, do a lot of damages. Where the goats are, there is nothing left to eat for the cows. The community, the families and the local government have seen that and decided that if they want to have cows, they had to stop having goats. And so they started to reduce the amount of goats. Now there is very few families with some goats. Even recently, in the last village meeting they forced them reduce even further the amount of goats. The proportion are if you have a community of 20 families, all of them have cows, 10 have sheep and 2 have one goat.

-Well there is a project of the government called seso, for the production of cheese from goat milk. But those goats are not free on the pasture, they are kept in stables. But this created problems as well, because the producers didn’t had enough fodder for the goats so they went in the nature and cut a lot of trees and bushes. The community saw that it was damaging the environment. Now in the second year of the project, they started producing their own fodder for the goats.

-It’s good that some people are learning to produce fodder, if it’s with pasture, or tuna, sorgo, oats, alfalfa. And are trying to resolve the problem of water, because without water you can’t produce those fodder. The rainfall are very low. Like 300mm:250mm per year.

-I collect data of yield of the pencas. The first year I got 1.300kg of penca per plant. Second year I collected 1.900kg per plant. I think this third year of production, I will easily have more than 2kg of harvest per plant. Because each year I cut all the new stems and let only the first one that I planted in the soil. Now for this third year I think I will let one more penca to see if it increase de production.

-The worst of the rainfall changes is that last year, on the 15 of December, it rained 55mm. Which is 1/5 of the total rainfall of the year. And at this date, there is almost no culture seeded. So all this water almost didn’t serve for anything. There is only some holes done to collect water next to the cultivation areas but they are filled up and then it infiltrates into the ground. It is necessary,
that there is really big collecting basin. After that, during the rainy season a lot of the rainfall get lost, because the soil is very hard and there is few vegetation, which generate erosion of the soil because the water cannot infiltrate. Furthermore, we use tractor here since 20 years and there is a formation of a very hard crust under the plough level. So in the fields water cannot infiltrate neither. So this year, I used a caterpellar to go 50cm under the surface to break this crust. Let’s see what are the result this year.

-In my plot with cactus pear I let the weeds grow in between of the tuna plants. What I have seen is that the cactus pear doesn’t work if it is on the shade, so those weeds can’t grow bigger than the stems. When the small stems are surrounded my weeds they get disease. So I tried to cut the grass with a brushcutter but it’s difficult to cut close to the stem without damaging it. So now, I use a horse. I let it in the plot to eat the weeds. The horse doesn't touch to the cactus pear and gives natural fertilizer. It’s perfect to clean the plot. But yes, there is also spiny bushes growing in the plantation. Those have to be cut with an axe. The horse doesn’t touch them. It’s a good exchange because a lot of herders don’t have horse so they invite the one who own horses to get the pasture for one and to clean the plantation for the other. It’s working very well. The owner of the plantation put water for the horse because he’s happy of his service. So the owner of the plantation doesn’t need to pay for the machine to cut the grass.

-But then there is no coverage of the ground. I have three plots. On is cleaned by the horse, the other by the debrousailleuse. So I will see the difference. The third one is recent, with variety from Sucre for fodder.

-If the penca have mancha negra, we still give it to the cows. It's not a problem. It only decrease the production of the plant. We are working on other factor. Like a trial to see what is the best fertilization level. As well, we want to see the impact of irrigation on the production. With a little bit more water, the production could be increased a lot.

-The plant with access to water are also less impacted by disease (here the mancha negra). The one around that are further from the pond are more affected.

-The superficies where the cows stay for the 9 months is huge. For example, my father, my brother and me, we have 120 cows for 1'100ha. Included everything, the river, the precipice, the forest. We have those figures because the INRA came to measure the lot. In this sector is private, not part of the communal land.

-This is why project can’t work individually, because share the land. They all have to agree on any changes. It doesn't work normally.

-The INRA come like once every 10-20 years and the community was afraid they would have to pay tax if they are declare owner of the land, so they said it is communal land. There was one person that owned almost all the land. He was only missing some documents and was the owner from many generation. He worked on his land, he had fences, plantations. But he got scared and said it was communal and now there is nothing left. The tax was only 200bos to have the final title of owner.

-With the neighbour, the border is well defined. In the pasture, there is also 2 divisions. It would be good to devide it in 4 but some of the fences have to be done with the neighbour. But he is not gonna agree yet to invest in it.

-We started a project of drip irrigation on a cactus pear plantation, at home. To measure the impact on the yield. The problem is that the cactus stems have no market, so if I produce more I can’t sell them here. Only the fruits have a market, in Cochabamba, in Santa Cruz. During February-March, they are sold in big box lie peaches and apples and expensive. In Santa Cruz the price is never below 1 bob per unit.

-Cactus pear grows well on poor soil like on the hill in Arani. Also being on a slop is important because water logging is very bad for the plant. The cactus doesn’t grow well on heavy soil. I have a bit this problem because I put one of my plantation in an ex-corn field. I prepared the soil the same as before seeding maize. Ploughing, flattening. The problem I have is that the soil is a bit too heavy for the cactus.

-Here in the community the first need is the need for fodder, but I observed some families that planted the penca at a low density (1-2m between plants). This practice is done to collect the fruit. Because for fodder production they are planted in lines very close to each other with a way
in between the lines of 1.5m just to collect the penca. I think some families are interested in collecting the fruits as well. Maybe for home consumption or maybe for selling. Also people got an class from this engineer from Sucre (Marcelo Saenz) about transformed product from the cactus, like flour from the stems (Brazilian engineer), ice cream, shampoo, medicine for the stomach, against cold, as cataplasm, juice of the stems, than honey from the fruit, jam from the peal of the fruit and deserts. This could also explain, why they planted the cactus at a lower density.

-I did jam myself with the pulp of the cactus fruit. I took out the seeds, but I put less sugar than in conventional jam. Already with 40%, it seems very sweet to me. I brought the jam at an exposition in Tarija. There I met a woman that also did jam out of the cactus pear, but with cinnamon. I think it’s better without because the taste changes a lot. It’s very sweet naturally, I didn’t add any water to the fruits.

-I really like to give the juice to my children, because I remove the seeds and than there is no more danger for the children and they love it. It’s really tasty.

-I think it’s not a problem to commercialise transformed product from the cactus pear, because people like the taste very much. A lot of people are afraid to eat cactus fruit because of the seeds. The seeds in excess can give stomach pain. So you could have a lot of consumers that would like the properties of the fruit. Without the danger of the pain caused by the seeds.

-Actually this plant is ‘sleeping’ because it has so many applications and potentials.

-It is also possible to have more harvest, outside of the main season. Like I heard that if the plant has water it can theoretically produce fruit all year around. It should also be protected from the frost. This is very interesting to receive better price outside the main harvest months (January-March). It could be the same system as for tomatoes. Now (August) we are outside of the main production and the price are really high. A box of tomato of 20kg costs 55bos now. A kilo 15bos. One tomato cost more than 1 bos. But during the main season, there is an excess of tomato are they are really cheap.

-Colleague of Fredy. The problem with vegetable, when the price goes up and the producers start to earn sthg the government import vegetable and so the prices decrease again. Producers are very angry because of this politic.

-There is also the difficulty of the climate change. Farmers are used to see natural factors as indicator for when it is gonna rain or be dry. Looking at the plants, the birds, the animals. It helps them a lot. Or used to work. But even natural indicators are not relevant anymore nowadays to know when the rain is coming.
Appendix 5: Interview with Serafin Vidal in Arani (15.09.17)

Serafin Vidal Interview

Presentation:
Serafin Vidal in an engineer from Arani. He left the village to work in another part of Cochabamba department for 15 years. He arrived back in Arani with his family 5 years ago. As specialization, he works a lot with trees like peach and he’s a practitioner of agroforestry in his own land. As a kid of Arani, he knows very well the cactus pear production zones around and in Arani. He also has family (a aunt) that sells fruits from her plantation every year to a reseller that brings the fruits to Santa-Cruz. He showed me the different production zones and different communities. He also helped me with the interview of his aunt in Quechua.

- Before not that many cochineal, but now, there is a lot in Arani.
- Before there was not much pest, more mancha negra
- Now the area of production has increased a lot and there is more cochineal.
- People here try to produce more fruit by planting more cactus.
- Don’t know if they tried already to eliminate the cochineal here.
- But I was present when they introduced it. We had to bring small bags with cochineal into the plantation.
- It was a big project to bring the cochineal in the region.
- Some time after the implementation, I spoke with the engineer responsible. He was still saying the triple use of cochineal, cactus pears, and used as fodder would be the solution to bring the farmer out of poverty. I told him: don’t go back to Arani, the farmer are not gonna welcome you. Because the production of fruit was destroyed after the introduction of the cochineal. Here the cochineal quills the plants. As soon as it is on the plant, the production decrease. The producer removes it or cut the stems. As soon as the plant grows again the cochineal comes back. The fruits are then not good for consumption, the taste is acid and they lose the sweet flavour. In the city, consumers ask if the fruit doesn’t have cochineal because they know that the fruit is of less quality.
- The cochineal is like a powder and it disseminate very quickly. It was introduced here, so it doesn’t have natural enemies. So I don’t know how we could treat it.
- There is 4 varieties. The yellow one, the red one, the green one and then another type of green one with less spines, which is also used as fodder. There is a lot of demand for the green/white fruits. There are a bit bigger than the others and have higher price but consumers love them. But here in Arani and Carcaje there is mainly the yellow one and a bit of red one.
- Do you take a cool bier when it’s very hot outside. Yes. And it wound;t be that nice when it’s cold outside. Of course. It’s a bit similar with the cactus pear. When it’s cloudy like today and it’s cooler. It’s the best time to eat the fruit. If on one day you eat 10 warm cactus pear, it’s sure I will feel bad afterwards (can’t go to the toilet). With 5 tuna per day, you won’t have any bad effect. We have another variety called ‘tapa culo’ with a lot of seeds and spines. And it is what it does. Hurt your ass after eating it.

Interview with woman working in the tuna field
Appendix 6: Recipe of cactus stem juice with banana (Dc. Stadler-Kaulich)

Receta de jugo de penca de tuna

Lista de ingredientes

Cuantidad por 2 personas

- 1 penca tierna de tuna
- 2 maduro plátano
- 250 ml de agua

Preparación

- Cosecha de nopales. Del tamaño de un mano (jóvenes)
- Con un cuchillo cortar alrededor del nopal (ver la foto)
- Cortar les espinas con un cuchillo en los dos lados
- Lavar el nopal con agua fresca
- Cortar el nopal en el liquidador
- Añadir 2 maduros pequeños plátanos o un grande plátano
- Triturar todo en el liquidador por 1 minutos
- Servir en 2 vasos
Propiedades de la penca tierna de tuna

- Baja el azúcar en la sangre
- Combate diabetes
- Baja la grasa en la sangre
- Baja el colesterol
- Ayuda a tratar úlceras
- Contra el cáncer
- Contra viricos
- Contiene minerales: calcio, magnesio, sodio, hierro
- Contiene buenas fibras
- Ayuda a eliminar partículas toxicas
- Contiene antioxidante
Appendix 7: Recipe of vegetable dish with cactus pear stem (Dc. Stadler-Kaulich)

Recepta de plato de nopales

Lista de ingredientes:

Cuantidad por 2 personas

- 1 penca tierna de tuna
- 4 zanahorias
- 4 acelgas
- 2 tomates
- 4 cebollas
- Perejil
- Un puñado de maní
- Una cuchilla de aceite
- Sal
- Pimienta negra
- Olla

Instrucciones

1. Cosecha de nopales del tamaño de un mano (tierna)
2. Con un cuchillo cortar alrededor del nopal (ver la foto)
3. Cortar las espinas con un cuchillo en los dos lados
4. Lavar el nopal con agua fresca
5. Lavar las otras verduras
6. Cortar toda las verduras y la penca en pequeños cubos
7. Poner todo en la olla con el aceite
8. Dejar cociné hasta listed, 15 minutos
9. Servir sobre un plato
Propiedades de la penca tierna de tuna

- Baja el azúcar en la sangre
- Combate diabetes
- Baja la grasa en la sangre
- Baja el colesterol
- Ayuda a tratar úlceras
- Contro el cáncer
- Contro vínculo
- Contiene minerales: calcio/magnesio/sodio/ hierro
- Contiene buenas fibras
- Ayuda a eliminar partículas tóxicas
- Contiene antioxidante
Appendix 8: Convention relative au travail estudiantin

1er travail de semestre 1er essai ou répétition
2e travail de semestre 1er essai ou répétition
Travail de bachelor X standard ou compact X 1er essai ou répétition
Travail de minor 1er essai ou répétition

Nom et n° de téléphone de l’étudiant-e : Elena Paiuc, 0041 0798875250
Domaine / division responsable : IL, agriculture internationale
Intitulé provisoire du travail : Market analysis of prickly pear (Opuntia ficus-indica) production in Bolivia, Cochabamba

Travail confidentiel : X non ou oui ⇒ Contrat1 signé
Grille d’évaluation utilisée : X standard HAFL ou grille ad hoc
Usage important de méthodes propres aux sciences sociales : X oui non (en particulier enquêtes, interviews)

Nom et n° de téléphone de l’enseignant-e responsable : Dr. Ingrid Fromm, 0041 76 549 31 27
Autres personnes participant à l’encadrement :

Délai de remise de la planification temporelle et des ressources (pour 1er TS obligatoire) :
Délai de remise du plan du travail :
Délai de remise du travail complet (cf. § 4.2 des directives2) : 06.12.2017

Lieu et date : Cochabamba, 02/10/2017
Signature de l’enseignant-e responsable : 
Signature de l’étudiant-e :

……………………………………………….  ……………………………………..

Veuillez remettre ce formulaire à Mme Sibylle Ackermann, administration des étudiants (bureau A.0.03). Vous pouvez aussi le déposer dans son casier.
Délais de remise : semaine 40 (semestre d’automne) / semaine 14 (semestre de printemps)

À remplir par l’enseignant-e responsable :

Conditions préalables selon les directives² (§ 4.1) remplies :
oui non ⇒ Signature de la personne responsable
⇒ Veuillez noter vos explications au verso
⇒ Accord du/de la responsable Enseignement

1Contrat régissant les travaux estudiantins (contrat de confidentialité)
2Directives concernant les travaux de semestre, de bachelor et de minor
Market analysis of prickly pear (Opuntia ficus-indica) production in Cochabamba, Bolivia

À remplir par l'administration des étudiants
Inscrit dans IS-A au semestre d’automne / de printemps de l’année d'études Inscrit dans la liste
BASAMA= Visa StudAdmin :

Elena Paiuc