ABSTRACT
We performed a study on the adoption of technology based on ethnobotanical knowledge of lechuguilla growing in Mezquital Valley and Victoria City, Mexico, as a model of interactions between scientific and empirical knowledge to increase its profit. Thirty Hñahñu individuals participated in the process of selection, collecting and technological adoption. Two experimental plantations of lechuguilla were used; the first is located in the Mezquital Valley (Plantation 1) and the second located in Victoria City (Plantation 2), the lechuguilla plants were physicochemically characterized and their yield to elaborate shampoo were evaluated. A technological transfer in situ was performed. The lechuguilla plants with highest yield were obtained of the plantation 1, the number of suitable leaves to elaborate shampoo was 50% higher in the plantation 1 respect to plantation 2. The physicochemical characteristics were similar in both shampoos elaborated with lechuguilla leaves obtained both of Mezquital Valley as Victoria City. Technological transformation was carried out satisfactorily, principally into women's group. Lechuguilla plants obtained from Mezquital Valley showed best yield to elaborate shampoo than lechuguilla plants obtained from Victoria City, the income that can be obtained from technological transformation is five time higher than the obtained from sale of fiber. The integration of ethnobotanical and technological knowledge increased the net profit in relation with the traditional use of lechuguilla.

KEYWORDS: Agave lechuguilla, shampoo, HñaHñus, Technological transformation, xithe.

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INTRODUCTION
Otomí Indians (Hñahñus) in the Mezquital Valley of Mexico, have traditional or local knowledge in a sociological, environmental and historical context, however the Hñahñus are not motivated to adopt new ways on the basis of logical evidence of better results or of charts or scientific arguments due that the most people fear experimentation, or fear excursions into the unknown, since only the tried is known and safe [1]. Nevertheless the Mezquital Valley is a rich zone of diversity for member of cactus and succulent plants that can be used in technological applications, in particular Agave lechuguilla as a commercially harvest plant that is an important source of income for the inhabitants of the arid and semiarid regions. The utilization of lechuguilla is principally focused to fiber obtention, however during fiber extraction a residual bagaze and sap is obtained[2]. The bagaze is stored for dishwashing, clothes or even their hair; the sap obtained contains high content of saponins which have natural detergent or surfactant properties because they contain both water-soluble and fat-soluble components for this reason the Hñahñus have used sap (xithe, term used by Hñahñus) of Agave lechuguilla from ancient times as a detergent, on the other hand the saponins have antifungal and antibacterial are also important in cosmetic application in addition to their emollient effects [3].

The xithe is obtained of the whole plant, but in the Mezquital Valley higher quantities are obtained during the carving of the leaves for fiber obtention which is used as raw material for handicrafts and other minor applications [4]. The saponins content of the Agave lechuguilla is variable due at differences in carving abilities, plant age and origin [5, 6]. However for Hñahñus, in addition to economic context, the lechuguilla is too important in ecological system because it prevents soil erosion and decreasing fertility.
For all above reasons, considering the economic and ecological value of *Agave lechuguilla* for inhabitants of arid and semi-arid regions in this study addresses the importance of new knowledge and emerging technologies and adoption by the Hñahñus of Mezquital Valley as a need to adapt to new conditions allowing them to transform low value added items in high-value products, for this reason this paper describes the shampoo development methodology and technology adoption process by Hñahñus.

**MATERIALS AND METHODS**

**Area of Study**

Mexico is a multicultural country. Great part of the Mexican “essence” is reflected in the legacy of indigenous people and pre-Columbian cultures that have retained distinct social, cultural, economic and political characteristics. Otomies are an ancient culture and apparently the Otomi population was the first in separate from original gene pool and supports the hypothesis that the Otomi culture is one of the oldest in Mesoamerica [7]. The Mezquital Valley, region/place inhabited by the Hñahñus is conformed by 28 municipalities being the most populated in decreasing order Ixmiquilpan, Actopan, Zimapán, Tasquillo, Alfajayucan, Nicolas Flores, El Cardonal with population higher than 500,000 inhabitants. This ethnobotanical and ethnoeconomic study was conducted over the course of 36 months (between 2006 and 2010) in three Hñahñu communities in the municipality of Ixmiquilpan in the Mezquital Valley located in Hidalgo State, Mexico. It is a semi-arid region with a mean annual temperature and precipitation range from 16.5°C and 432 mm at the north portion of the valley to 17.2°C and 647 mm at the south portion. The mean elevation at the agriculture flat-lands is 2000 m above mean sea level and up to 2400 m in the surrounding mountains. The original Valley’s vegetation is xerophytic shrub land with mezquite tree as dominant element. In this environment are located the HñaHñu communities that participated in this study (Figure 1). The people of the community are primarily subsistence agriculturalists. Their main activity is the cultivation of lechuguilla, however because of low profitability in recent years, a significant number of in habitans (mostly men) have migrated to the United States mainly for economics reasons.

![Figure 1. The map of study area. Highlighted in red the localization of HñaHñu communities.](image-url)
Vegetal Material

The project of technology transfer proposal was carried out using two experimental plots, the first established in the Mezquital Valley in Hidalgo (Plantation 1) and second in Victoria City, Tamaulipas, Mexico (Plantation 2), considering in both plots the same plants density (20,000 plants per hectare) in the quincunx system. The second plantation was used to show to the Hñahñus that the cultivation site does not affect the xithe quality. The plantations were established between June and July 2006, two months later agricultural labors were performed by the Hñahñus in order to avoid damage in the root.

In order to determine the yields of the plants produced in each experimental plot a completely randomized design was used, so half a hectare was arbitrarily chosen as a hypothetical minimum area requirement, in this area, 13 quadrants of a meter square were identified, and then the plants with commercial size from each quadrant were collected. The total number of plants with commercial size per m² was calculated with the formula 1.1.

\[
PNCZ = \frac{Plants\ Number}{Quadrants\ Number}
\]

Where:
- \(PNCZ\) = Number of plants with commercial size per m²
- Plants number = Total number of plants with commercial size in alls quadrants
- Quadrants number = Total number of quadrants sampled

On the other hand, the number of available leaves per m² was determined according to the formula 1.2.

\[
Number\ of\ Availables\ Leaves\ per\ m² = PNCZ \left( \frac{Pencas\ Number}{\text{plants}} \right)
\]

Where:
- \(PNCZ\) = Number of plants with commercial size per m²
- Number of leaves = Total leaves in all quadrants.
- Plants = Total plants with commercial size in alls quadrants.

Technological proposal

The training process for shampoo elaboration was conducted with 16 members of the community: The change of mentality was not easy and there was doubt about the necessity of the implementation of technology, however the women were more active than men and for this reason the training process could be performed efficiently. The first step was to treat the leaves of lechuguilla with six per cent sodium hypoclorite solution. The cleaned leaves then were grounded in an industrial blender (International, Model L1) the sample obtained was homogenized with four liters of water to approximately 80°C maintain this temperature during 40 min, the extract obtained was filtered in two layers of cotton cloth. Then, the extract was diluted 1:14 with sterile water, to formulate the shampoo of lechuguilla, definite amounts of triethanolamine lauryl sulfate (22%), sodium chloride (1%), Glycerin (3.5%), methyl paraben (0.3%), EDTA (0.2%) and diluted extract (73%). The pH was adjusted a 7 by the addition of citric acid.

Rheological evaluations

Apparent viscosity of the samples was determined at room temperature using a rotational spindle Brookfield Viscometer (Model BROOK-LVDV-1+T, Middleboro USA) set at different spindle speeds from 0.3 to 1000 rpm.

Foaming ability

To evaluate the foaming ability of shampoo prepared, 10 mL of shampoo prepared were placed within a 400 mL glass beaker and 100 mL of distillated water were then added. This solution was agitated for one min at room temperature (about 25° C) using and Ultra Turrax homogenizer (Model T-25; Ika-Werk). The produced foam was poured into 100 mL measuring cylinder and the height of produced foam was measured.

Physicochemical properties

The pH of the shampoo was measured with a glass electrode and an Orion pH meter (Model 720 A), the soluble solids content and refractive index was measured with a 2WAJ Abbe Refractometer. Variations in color were evaluated using an Oberco-Hellige Aqua Tester, with water being assigned a value of zero.

Economic feasibility

The economic importance of technological innovation was evaluated based on the amount of extract availability content per hectare; based on the sampling design used, the gross profit of each plantation was calculated using formula 1.3.
RESULTS AND DISCUSSION
Economically and culturally the Mezquital Valley is very backward, for this reason is important to show that, in this region, the climate is clearly more beneficial than the Victoria City, apparently the development of the plant influence on the amount of extract obtained, on the other hand, the results showed that in the Mezquital Valley the number of harvestable plants per hectare, was 50% higher than in Victoria City (18,500 and 12,300 plant respectively). These results were important for the investigation due to their importance on the state of mind of Hñahñu Indians, which generated a greater commitment to research. In addition the results obtained from size and weight of harvestable plants too were an important factor to convince the Hñahñu Indians to adopt new methodologies for the utilization of natural resources, considering that the yields were higher in the Mezquital Valley plantation that in Victoria City plantation (Table 1) apparently the plants collected in the Mezquital Valley have adapted to the soil conditions in this region. On the other hand, the plantation density is not a decisive factor in the plant growing however, is necessary to establish good phenotypes to guarantee high levels of adaptation and development in order to obtain higher yields of xithe.

Table 1. Physical characteristics of lechuguilla plants (Means ± SD)

<table>
<thead>
<tr>
<th>Plantation 1</th>
<th>Plantation 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quantity of leaves per plant</td>
<td>14 ± 3</td>
</tr>
<tr>
<td>Weight of each leaf (Kg)</td>
<td>1.59 ± 0.65</td>
</tr>
<tr>
<td>Size of each leaf(cm)</td>
<td>42.2 ± 18</td>
</tr>
</tbody>
</table>

Sample size 5000 plants,

These results are important, because the Hñahñu Indians have allowed establishment of lechuguilla plants with improved phenotypic that permit obtain higher quantity of xithe compared with the native plants, moreover, the ecological benefits derived from new plantations of lechuguilla are very important considering that the lechuguilla is an adequate plant for soil remediation. On the other hand the number of suitable plants and leaves per m² is summarized in the table 2, the total number of suitable leaves in the plantation 1 is higher in 47% compared with the total number of suitable leaves in the plantation 2, changes observed in the climatic conditions during acclimatization help to understand better adaptation process of lechuguilla in the Mezquital Valley for this reason the total number of suitable plants is higher in the plantation 1 than the plantation 2. Apparently the agricultural labors have not influence on the xithe quality due probably to high adaptation capacity of lechuguilla to extreme conditions of temperature and shallow soils, according to Rzedowski [8], the lechuguilla is a plant that, in natural form can be adapted to changing environment for this reason the lechuguilla is an excellent forest plant species.

The best adaptation process for the plants established in the Mezquital Valley have a better developed of leaves, therefore the leaves number in the plantation 1 is higher than in the plantation 2, this was an excellent result due that HñaHñu Indians observed that plants grown in their communities have higher maturity index than plant grown in the Victoria City, this favoured their motivation and permitted to change the mindset as farmer to a business mindset.

Table 2. Number of suitable plants and leaves per m² (Means ± SD)

<table>
<thead>
<tr>
<th>Plantation 1</th>
<th>Plantation 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suitable plants</td>
<td>1.85±0.2</td>
</tr>
<tr>
<td>Suitable leaves</td>
<td>25±2</td>
</tr>
</tbody>
</table>

Sample size 5000 plants

Technology adoption
During the technology adoption process, was observed the HñaHñu Indians’ ability to assimilate new knowledge, however the research group continually faced many difficulties including sociocultural and
work-related factors due principally to women discrimination, but the persistence and social change, make a difference in the technology transfer process.

Results reported in this paper, represent the integrated work of HñaHñu Indians and researchers and show that the products obtained in the communities complies with international recommendations, for this reason considering that the sebaceous secretion, have acid pH values about pH 4.0, the shampoo obtained with Agave lechuguilla was adjustment to this value in order to avoid scalp damage [9], all quality parameters studied are showed in the table 3.

The shampoos obtained with Agave lechuguilla, showed an adequate viscosity enough to stay in the hand before application, respect to foam it was dense and luxurious but without a high surfactant concentration, on the other hand the shampoos obtained from the two plantations had not differences in color, refraction index, percentage of soluble solids and pH, this suggest that the quality characteristics of obtained xithe of each plantation is similar. This step was a turning-point in the technological transfer because the external technology had to be adapted to local conditions, however the HñaHñu Indians drawing on their empirical knowledge about obtaining extracts, this knowledge was considered strategically useful.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Plantation 1*</th>
<th>Plantation 2**</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH (20ºC)</td>
<td>4.36±0.1</td>
<td>3.92±0.1</td>
</tr>
<tr>
<td>pH (in 50% aqueous solution)</td>
<td>4.68±0.1</td>
<td>4.38±0.1</td>
</tr>
<tr>
<td>Color (C. U.)</td>
<td>450±2</td>
<td>450±3</td>
</tr>
<tr>
<td>Foam volume (mL)</td>
<td>130±3</td>
<td>140±5</td>
</tr>
<tr>
<td>Refractive index (20ºC)</td>
<td>1.355±0.1</td>
<td>1.355±0.1</td>
</tr>
<tr>
<td>Total solids (%)</td>
<td>14.5±1.4</td>
<td>14.5±1.4</td>
</tr>
<tr>
<td>Average viscosity (c. P; 20ºC)</td>
<td>2,850±50</td>
<td>2,937±75</td>
</tr>
<tr>
<td>Stability</td>
<td>No apparent change</td>
<td></td>
</tr>
</tbody>
</table>

The ethnobotanical knowledge about Agave lechuguilla in the Mezquital Valley was very important and much of the richest data arose from the women, who take advantage of daily use of agave lechuguilla for foam generation due to the high concentration of saponins in the leaves [10], however the HñaHñuindians also use the plant to treat the postpartum belly inflammation and signs of inflammation in scalp hair follicles; this empiricknowledge was significantly associated with healthy hair, for this reason HñaHñuindians wanted to corroborate this new product in volunteers and demonstrate that the shampoo had similar effects than the xithe. Is important to mention that some researchers indicate that aqueous extract of some agave species have anti-inflammatory activity due to saponins content [11].

The net profit generated by the shampoo production (Table 4) showed that the plantation one had higher yield than the plantation two, this result reflect that in the plantation one the number of plant with commercial sizeis higher than plantation two, for this reason the xithe content, aqueous extract and net profit in the plantation one were 50% higher than plantation two, with this results, the HñaHñuindians corroborated the benefits of transformation process of xithe into shampoo.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Plantation 1</th>
<th>Plantation 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Xithe (L)</td>
<td>25,900</td>
<td>17,220</td>
</tr>
<tr>
<td>Aqueous Extract (L)</td>
<td>388,500</td>
<td>258,300</td>
</tr>
<tr>
<td>Net profit (US dollars)</td>
<td>1,165,500</td>
<td>774,900</td>
</tr>
</tbody>
</table>

The interactions of the researchers and HñaHñusindians in this stage was fundamental, since with the net profit data available, the integration of ethnobotanical knowledge and pharmacological application allowed the development of a new approach to the study and the pharmaceutical use of plants in addition to the ecological importance of the lechuguilla forrestoring soil fertility and productivity in the Mezquital Valley.

CONCLUSION
The soil condition of the Mezquital Valley is suitable for establishment of Agave lechuguilla plants with good phenotypic performance and permit a much better yield of xithe than the plants obtained of Victoria City plantation, the application of technological information on traditional medicine and ethnobotanical knowledge was positively accepted for the HñaHñuindians and the technological transfer of abilities was
perfectly assimilated for the HñaHñu Indians. The integration of ethnobotanical and technological knowledge increased the net profit in relation with the traditional use of lechuguilla.

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REFERENCES


Cite this article