# Stockholm Junior Water Prize Ecuador 2018-2019

# Upcycling *chochos* (*Lupinus mutabilis*)

## Sustainable reuse of water from the hydrating process

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***Abstract***

Chocho *(*Lupinus mutabilis*) is a traditional Andean bean that in the last years has gained importance due to its widely appreciated nutritional value. Chochos need to be processed before their consumption because of the presence of anti-nutritional substances, mostly alkaloids, which are chemicals that protect the plant against insect attacks.* Chochos *are grown by small farmers in the Ecuadorian Andes, they are then dried and stored for their commercialization. For consumption,* chochos *need to be rehydrated, after which the hydration water is discharged. The main issue covered is the unnecessary waste of water which represent the rehydration of chochos. Linking up sustainable sanitation, water management and agriculture plays also a great role in this investigation since the rehydration process of chochos takes a lot of water. The aim of this research was to test debittering water on seedlings of selected agricultural species found in the Andean region as irrigation water. The results of this research show that debittered chochos' water could be beneficial for seedling depending on the concentration of alkaloids in the water. This project aims at testing the possibilities of upcycling the water used as debittering agent of a valuable food item, as irrigation water for crops in the production area of chochos.*

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# 1. Introduction

A traditional product of the Andean region is lupine (*Lupinus mutabilis)*, popularly known as *chocho* in Ecuador but also called *tarwi, tarhui* or *chuchus muti* in the Andean region (Jacobsen & Mujica, 2006). It is a bean with great calcium content which is an important part of the diet of the Ecuadorian population. It is important to mention that in the region 83 different sweet and bitter species of the genus *Lupinus* have been identified (Jacobsen & Mujica, 2006: p. 459). Among them, the species *Lupinus mutabilis* Sweet is the preferred species for cultivation. An important fact is that traditionally these species were mainly used by indigenous communities in the Andes, where the introduction of other legumes have displaced *chochos* from the local tables. However, in the last years the consumption of this bean has increased significantly due to nutritional and cultural factors.

*Chochos* are a leguminous plant first described by Sweet in 1825 (Chinos-Arias, 2015), therefore this highly extended specie is named *Lupinus mutabilis* Sweet. It is hilarious that the biologist's last name sometimes is regarded as a quality of the bitter *chocho* that is suitable for eating. The *chocho* grain when ripe is cropped and dried for its conservation and marketing. Traditionally, *chochos* are sundried even though there are projects promoting combined methods to dry chochos, as the ones reported by Ninaquispe Zare (2013): osmotic dehydration with hot air and microwave.

For their consumption, *chochos* require to be hydrated with a lot of water in order to make them able for consumption. Ninaquispe Zare (2013) reports that chochos obtain 68% of humidity during this process. Most of that water is usually discarded. This is why my project aims to find a way to upcycle the water used in hydrating chochos and make it beneficial for plants. *Chochos* contain a high amount of alkaloids, known to have toxins that may be used as pesticides, but also depending on the alkaloid concentration it is possible to use them in the germination process of certain plants. However, by experimenting with different concentrations of alkaloids in water, in order to complete the water cycle the debittered water can be used in the irrigation of crops.

The project is based on the ancient and traditional Andeans indigenous way of hydrating *chochos* and ridding them of the alkaloids, which was leaving them in rivers for them to be hydrated and ready to eat.

The major issue covered is the unnecessary waste of water used in the hydrating of *chochos*, since 4,5 liters of water are approximately used to hydrate 100 grams of chochos, data I found during my experimentation. Now talking of a greater chocho production, chochos need about 3-4 L per $m^2$ per day, meaning that there is a large water waste. However, the answer is not to reduce the consumption of the bean, which has been proved of extreme high nutritional levels, but instead finding a way to convert this water into something useful for agriculture, so it is important to promote the upcycling of water to complete the water cycle.

My hypothesis is that the water obtained from hydrating *chochos* could be used for agricultural purposes in order to benefit the crops and reduce the water. Depending on the concentration of alkaloids in the water it may also help plants grow, so this could be used in different type plants. Furthermore, water resulting from hydrating chochos instead of being wasted, can be spared to water small crops, even inside home gardens both in rural and urban areas. In this way, the upcycling of water can become fashionable because of its usefulness and meaningfulness bringing awareness towards water usage and its importance.

# 2. Theoretical framework

The importance of *chocho* has been a matter of deep study in the Andean region, from Colombia to Chile. In Ecuador, the recognition of the high calcium content of lupines has derived from a number of research studies undertaken by INIAP, the national institute for agriculture and livestock. A quick search at INIAP's data repository (http://repositorio.iniap.gob.ec) brings up to 129 different studies containing the word *lupinus* in the last 20 years. The last study uploaded is a paper presented at the International Congress of Cereals and Leguminous by Elena Villacrés (2018). The study is precisely about technological innovations of lupine to improve health and nutrition. The author considers that *chochos* could be the answer to nutritional and food requirements of the world population because of the high nutritional value and sustainable production.

While the nutritional facts of *chocho* are greatly considered, another studied issue about *chochos* is quite the opposite: the anti-nutrient substances which in some cases are toxins and are not so appreciated since they do not provide substantial health benefits; nevertheless as they do possess chemical properties, they can be used in the field of medicine and pharmacology or as pesticides and insecticides (Fernández, 2017).

Lupines contain bitter alkaloids and there are preliminary studies on their toxicity suggesting that a lethal dose for infants and children is 10 mg/kg bw and for adults is 25 mg/kg bw (Carvajal-Larenas, 2016). However, these alkaloids can also serve medical purposes such as the treatment of hypocholesterolemic, antiarrhythmic and immunosuppressive activity. Ciesiolka et al. (2005), based on in vitro studies, suggested that hypocholesterolemic activities are associated with stimulation of low-density lipoprotein receptors by a protein component of the lupin seeds. The study also showed pharmacological properties such as a decrease of arterial blood pressure of rats. Many pharmaceutics and cosmetic uses for lupin seeds have been described since the sixteenth century (Aguilera and Trier, 1978).

Lupine plants can often be found in the border of roads growing as wild plants. Andean farmers plant lupine in protective fences to function as a natural repellent plant against pest and diseases of other crops. All plants of the *Lupinus* genus contain alkaloids. The total concentrations range can vary from 0.01 to 4%, depending on plant species and part of the plant (INEN, 2004).

While there is no agreement about the origin of the *Lupinus mutabilis*, the study of Blanco 1982 (cited by Olortegui et al., 2010) consider it the only American species of the genus *Lupinus* that has been domesticated and cultivated as leguminous. *Chochos*, produced in the rural Andean zones have been considered a rustic plant, preferred by indigenous communities. This is why those had not been very popular until recently, when a recovery of the local production and a return to cultural identity and heritage of traditional crops have upgraded products as pseudo-cereals like quinua (or quinoa), amaranth, chia, and chochos.

Nowadays the traditional Ecuadorian "ceviche", a cold seafood soup, has seen fish and shrimps replaced by chochos, making up the popular dish "cevichocho", made of tomatoes, onion, lemon juice and *chochos*. This dish is greatly appreciated by vegetarians and vegans. As "cevichocho", a wide number of new dishes are being prepared with *chochos* and are an important part of the modern national cuisine.

INEN Norm 2 390:2004 establishes the specifications for the lupin debittered grain. The norm defines the debittered grain as an edible clean and humid product that has undergone a thermic-hydric process of debittering. Its color is white-cream, with a characteristic flavor and taste, free of strange odors and bitter taste (INEN, 2004).

Chochos are cultivated in the moorland and specifically talking about Ecuador, there is a high vulnerability of erosion. Approximately 48% of the lands in Ecuador present this condition (.

Conducting and experiment of upcycling *chochos'* water was a challenge due to the short time assigned for this to be done. Nevertheless, the coming section explains the methodology and the experimental design to reduce and benefit from this activity.

# 3. Methodology

I conducted a research that started with a literature review about *chochos*, which lead me to the webpage of INIAP where I read a report about the properties of the *chocho* water alkaloids, in which the dangers of the toxins contained is highlighted (Villacrés et al., 2009). The extremely bitter taste of the seeds made me realize about how useful it could be to avoid the presence of insects or if it could benefit crops. The paper also talks about the nutritional facts of the *chocho*, its nutritional and medical value.

As I had just a short time to conduct an experiment, upcycling *chochos'* water to spread plants and protect them from insects could not provide enough data and outcomes to report on. Therefore, for this particular project I engaged in an experiment to see the possibilities of upcycled chochos' water to breed new seeds, even though from the literature people are reluctant to use water directly on seedlings because of the toxicological properties of its alkaloids (Jarrín, 2003).

One of the upcycling uses of the water obtained from the hydration of *chochos* could be watering plants, therefore the first aim of this particular project was to see if it could help the germination of seeds. First, the water of hydrating the *chochos* should be obtained for the experiment.

The second step was to learn about the process to hydrate and debitter the *chochos* As mentioned above, *chochos* are a traditional product. While nowadays it is possible to buy them hydrated at supermarkets, few years ago it was necessary to do it yourself. My primary source was my grandmother who has debittered *chochos* for many years. She explained the process to hydrate them to me.

*Chochos* are boiled with plenty water during around 20 minutes, then the water has to be discarded. Then they remain in water, changing it daily for seven days. The *chochos* I used came from the Andean moors of Chugchilán, in the Cotopaxi province (Figure 1).

*Figure 1.* Chochos *being grown in Chugchilán.*

The third step was to develop the seedlings, and I decided to do so from various legumes found in the Andean region where *chochos* also grown, to see how water used to debitter *chochos* could have an effect on different types of plants, as well as to see if the water from hydrating *chochos* could be used to water seeds.

## 3.1 Experimental design

The experimental process was divided into two parts: 1) Hydrating of *chochos* and 2) Seeding.

After gaining more knowledge about how to hydrate the *chochos* (Figure 2), I started that process. On the first day, I put the *chochos* in water and boiled them for about 20 minutes, then put the water aside. Then the water was changed every day for a period of seven days. I used 50 grams of dried chochos and approximately 500 milliliters of water per change. The water from all the changes was saved in bottles and later used to water the seeds.

*Figure 2. Dried chochos*

With the *chochos'* water I was able to plant wheat (*Triticum*), barley (*Hordeum vulgare)*, pea (*Pisum sativum)*, broadleaf plantain (*Plantago major)*, and chocho (*Lupinus mutabilis)*; and water them with two types of water in order to compare the outcomes: 1) Potable tap water and 2) Water used to hydrate the *chochos*. (Figure 3)

*Figure 3. Hydrated chochos*

For the seeding process I used wheat, barley, pea, broadleaf plantain, and chocho. I had ten large pots, five for each type of water. Inside of them were placed 10 paper-roll tubes where I planted 1 seed per paper-roll tube. The pots where placed in a tray and kept in my living room along with the graduated cylinder. I measured 10 ml of each type of water and poured it on each paper-roll tube when watering the plants. I watered them every two days.

### 3.2 Process diagram

Figure 4 shows the process diagram of the whole experiment undertaken. It starts with the *Lupinus mutabilis* plant. The *chochos* are dried by the sun, a farmer sells them. Then the process of my experiment begins by following the procedure of debittering and hydration of the *chochos*. I boiled them and then changed the water every day for seven days. After having the chochos hydrated I had stored in a plastic bottle the chocho´ s water which was later used to water the plants. With paper-roll tubes I created 10 spots in a pot in which I planted the different types of seeds and watered the plants with 10 ml of water every two days. After 5 days I could compare the results.


*Figure 4. Flowchart of the experimental design*

## 4. Results and Discussion

On the experiment that I preformed I had two water conditions to water the seeds. The first water condition was potable tap water and the second water condition were the waters used to hydrate the chochos. After five days results were compared from the two different water types. I watered the plants three times during those five days with 10 ml of water. Results from both conditions were similar. For the first water condition (potable tap water) there were 11 wheat (Figure 5), 5 barley (figure 6), 8 pea (figure 7), 9 chocho (figure 8) and none for broadleaf plantain (figure 9). Whereas for the second water condition (waters used to hydrate chochos) there were 10 wheat (figure 10), 3 barley (figure 11), 6 pea (figure 12), 9 chocho (figure 13) and none for broadleaf plantain (figure 14).


*Figure 5. Wheat sprouts, water type 1*


*Figure 6. Barley sprouts, water type 1*


*Figure 7. Pea sprouts, water type 1*


*Figure 8. Chocho sprouts, water type 1*


*Figure 9. Broadleaf plantain sprouts, water type 1*


*Figure 10. Wheat sprouts, water type 2*

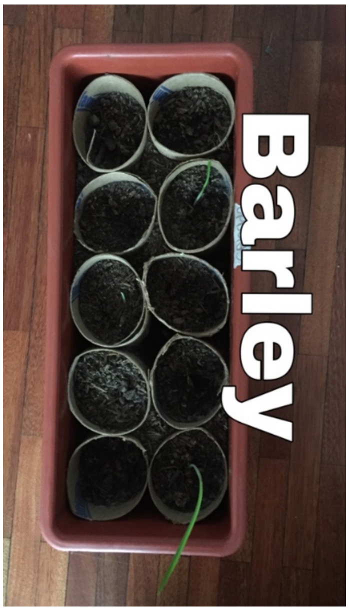


*Figure 11. Barley sprouts, water type 2*


*Figure 12. Pea sprouts, water type 2*


*Figure 13. Chocho sprouts, water type 2*


*Figure14. Broadleaf sprouts, water type 2*

| | # of sprouts | |
|---|---|---|
| **Plants** | **Potable tap water** | **Debittered chocho water** |
| Wheat | 11 | 10 |
| Barley | 5 | 3 |
| Pea | 8 | 6 |
| Chocho | 9 | 9 |
| Broadleaf plantain | 0 | 0 |
| Mean | 6.6 | 5.6 |

*Table 1. number of sprouts per water condition and mean of germinations*

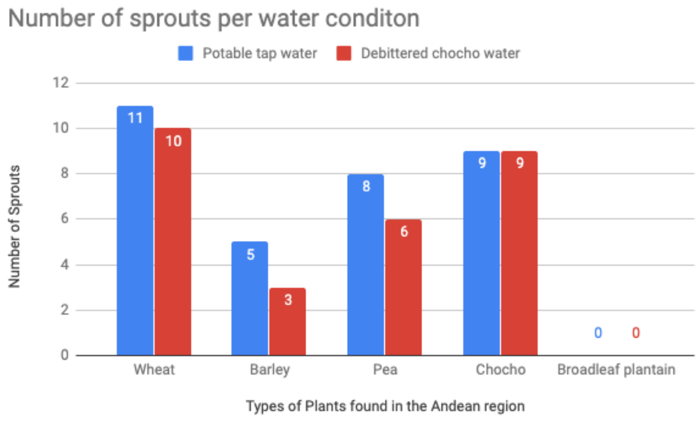


*Figure 15. Graph, number of sprouts per water condition*

Figure 15 and Table 1 demonstrate the relationship between the spouts in the different types of plants found in the Andean region in relationship with the two water conditions. There is also a mean of germinations in figure 15 where it is seen that for potable tap water there was a mean of 6.6 germinations and for debittered chocho water there was a mean of 5.6 germinations. This two numbers are close to each other which suggests that the two water conditions may have the same effect on germination of plants.

In addition the pH testing on the chocho's water came to be around 4,8 and 5,8; this means that the water is slightly acidic, but not enough to affect the sprouting of seeds. On the other hand the pH of potable water I used was of 7.1 which means that it is neutral.

With the experimentation I got favorable results with both water conditions, which lead to the topic of linking up sustainable sanitation, water management and agriculture. The water obtained from the hydrating process of chochos can be used in the same crops and in that way completing the water cycle by giving the crops back the water with some of the chocho's nutrients. With this study the processing chocho industries may be inspired in order to make a change and reduce water, towards closing the water loop.

The results suggest that both type of water work (potable and debittered chocho's water) for the germination of seeds during a five day experimentation process. However, Jarrín (2003) states that on the germination trials on seedbeds, the chocho's water didn't have a negative effect on the sprouting although, there was a noticeable decrease in size as the concentration of alkaloids was higher. So effectively the concentration of alkaloids can influence in the growth and germination of seeds, but the concentration of alkaloids changing the water daily during the debittering process is not that high and therefore it could be used for seedling. As water type 2 has a similar efficiency as water type 1, it is appropriate to reuse the debittered chocho's water obtained since it helps reducing the amount of water disposed and leads to close the water loop, the water returns to the crops of the same species. In addition, it contributes to SDG 6 (Sustainable Development Goals) which is clean water sanitation. It helps reducing the industry's water footprint as well as preventing contaminated water full of alkaloids into the local sewer systems and nearby water bodies, instead using it for the sprouting of new seeds.

## 5. Conclusions

The nutritional benefits of consuming chochos are not discussed in this study, but as its value is extremely high and good for health it encourages its consumption and the way this product may also help crops to develop and upcycle water.

Chochos are important beans cropped in the Andean region, particularly the *Lupinus mutabilis* Sweet specie, but in Europe in the Mediterranean coast of Spain and Italy is well extended the production and consumption of *Lupinus albus* known as "altramuz" that has a similar hydrating process (Huyghe, 1997). White lupin (Lupinus albus L.). Field Crops Research. 53. 147-160. So upcycling unembittered water is not exclusive to our region but can be done elsewhere. Because of the high nutritional components of this bean, it could be thought to enter other markets and its hydrating process would be the same.

Now talking about germination in different plants found in the Andean region, the experiment conducted showed that it is little less and as effective as potable tap water, meaning that it can be used in home garden or in a bigger scale such as large plantations, maily focusing on the Andean region since the plants used for the experimentation were from there.

## 6. Recommendations

Future experiments could be conducted to test if debittered chocho water affects the growth of plants, but so far, in a 5 day testing it did not show negative results. Different concentrations and ways of storing the debittered water could be tested and analysed to watch for chemical variations in its composition, in order to know how long the water could be stored and still be used to water plants and germinate seeds. Further experiment could take place where the alkaloid concentration is monitored close to see which variables affect the seeds and soil.

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