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FOOD SCIENCE AND TECHNOLOGY

FOOD AND ANCESTRAL GASTRONOMY

ANTHROPOLOGICAL ANALYSIS OF AFRICA AND ASIA

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ABSTRACT

The evolution of humanity developed largely thanks to food. After the man discovered the fire, the cooked food allowed it to have a wide cranial cavity and that the spine acquired a lordotic curvature. Also, the culture of the people has been forged based on the diet to which they had access. For all this it is essential the study of ancestral food and cuisine, to understand the food anthropological evolution of the world. In this study, aspects of the ancestral food and gastronomy of Africa and Asia were analyzed and its main culinary creations were investigated. Africa stands out for its fermented foods (boerewors, dumpling, melktert, umcombotsi, emahewu and buganu), its products based on barley (kita, dabo and genfo), and its meat products (melfouf, merguez and kofta or kebab).

Asia stands out for its fermented soybeans (thua nao), its fermented soy-based products (gochujang, kanjang and doenjang), rice-based drinks (rice beer), flat breads (lavash, katyrma, jupka or yufka, according to region) and coffee. This demonstrates how food has largely forged the history of these continents. Nowadays, it is essential to carry out this type of research since, due to globalization, all traditions, culture and legacies are being lost in time. Putting into context the importance that these foods have had throughout the history of each country, shows that they must continue to remain as a standard for future generations.

Keywords: Food anthropology, culture, history, tradition.

INTRODUCTION

Anthropology is the science that studies the sociocultural, biological, archaeological and linguistic aspects of society or group of people throughout history to the present, analyzing and interpreting the similarities and differences between different communities.

The introduction of anthropology as a science to our world has increased the amount of studies and research on social life, customs, culture and physical aspects. Each field of study has variations in time and space, so an analysis based on living societies and their behavior patterns must be performed to understand and reconstruct each of the basic foundations of behavior in the past (Goodman, 2015; Stewart, 2017).

The anthropological perspective explains that cultures are interdependent since there was always communication between communities. This caused that the knowledge and resources shared by areas of enormous amplitude were extended, with this it can be affirmed that the human being did not build his culture in isolation, it did it interacting with others to a lesser or greater extent (Marcus, 2015).

Currently, interest in the anthropology of food and its influence on the sociocultural life and physiology of a society has increased. Eating is a necessity, not only to survive but also to have a good state of physical and mental health.

The complexity and openness of the subject has made human food an object of study from different branches such as biology, medicine, sociology, psychology, etc. Gastronomy is a field that enjoys the contact between nature and human culture, and has adapted to all types of environment and locality.

The influence it has within societies varies according to their cultures and customs, since all societies have mechanisms for food production, distribution and consumption (Caglar, 2015; Fernandez, 2015).

Since the origin of the man, the way to know the nutritional content of food has been sought, however, the lack of prior knowledge and the implementation of magical or religious beliefs encouraged to create ideas, traditions, legends and fables, which led to the creation of eating habits that could not take advantage of most nutrients from food and that caused the extinction of societies that could not find effective solutions for proper nutrition (Strauss, 2015). This field mediates a reciprocal reaction of nature and culture, this happens because food provides nutrients and proteins that directly affect the level of energy with which the physical activities of an individual within a community are carried out (Mallett & Sutisno, 2016).

Over time, factors such as globalization, capitalism and multiculturalism have influenced all societies, creating questions between tradition and identity. With this, changes in mentality, culture and customs have emerged, notably changing the national cuisine of cities and countries, and as a consequence the loss of their traditions and the importance this represents to a society (Faubion, 2015).

This effect strengthens traditions as a way of claiming the specific cuisine of each society. All this anthropological analysis can be done through a revaluation of the food knowledge of each culture. For this reason, food consumption, production, distribution and preparation of these are the reflection of who we are, which means that they are the reflection of our social identity. The human's relationship with food, including aspects of supply, circulation, manipulation, customs and ideologies, are essential aspects for the study of food anthropology (Medina, 2019).

To understand the principle of food culture, the ancestral foods of each community must be taken into account, since it is these that defined the culture of the ancestors, who took advantage of them to produce them frequently because they endured certain climatic, terrestrial and extra-terrestrial conditions. The indigenous communities based the evolution of their culture on food, they adopted their food preferences according to the ease of cultivation, but the worldview, beliefs and perceptions, represented the fundamental pillar for their consumption and veneration, so they set many foods as sacred or

censored, based on whether they were attributed medicinal or nutritional benefits (unprovable) or if they caused any adverse health effects (Ayora-Diaz, 2015; Counihan, 2001).

Ancestral foods have been very popular in today's society. These not only provide flavor and nutritional contribution, but also carry a historical burden that results in the culture and traditions of the people. Ancestral foods have the ability to communicate a legacy, they are a series of images that come to have a protocol of behaviors and procedures, carry a series of signs and symbols that express meanings that make up the cultural identity (Fraser, Frausin, & Jarvis, 2015).

The presentation and context of food have a psychological influence on the brain of the human being through sensory codes. To explain it, Picallo (2009) mentions that through the senses (taste, sight, touch, smell, and hearing) the brain interprets the information sent by food. These interact by sending chemical signals to the brain, who will determine what will stimulate it more, thanks to this, cultures around the world forged their history, customs and traditions based on their senses and the results they had after a sensory and mental analysis.

For all the above, the objective of this research is to show the main foods and culinary creations of countries in Africa and Asia, to understand their food anthropology and how these foods represent the culture and tradition in these continents.

METHODOLOGY

For this research, a bibliographic review was carried out in the following databases: SciencieDirect, Scopus, Springer and NCBI. Only documents that were published between 2011 and 2019 were selected. Only articles published in English were chosen. The search was based on the following descriptors: anthropology, food anthropology, gastronomy, African food, Asian food, African cuisine and Asian cuisine. A bibliographic review was also carried out in Google Scholar with the same descriptors and articles were selected from 2001 to 2011. Research and review articles, encyclopedias sections and books were included (Figure 1).

The bibliography was chosen based on the following criteria:

a) Relevance of the topic
b) Only articles in English
c) Articles that identify food history in Africa and Asia. Studies with repeated themes were analyzed and the most relevant one was chosen based on the established criteria.

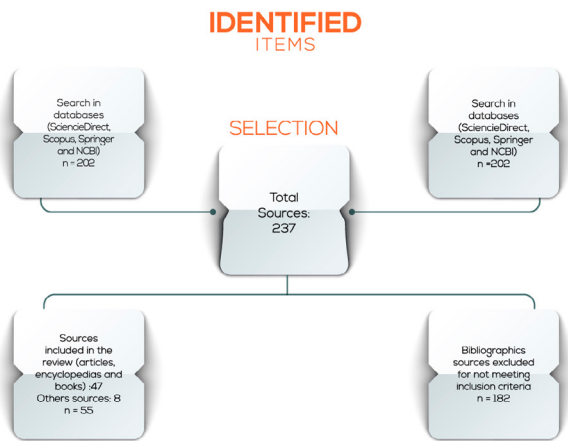

Figure 1. Flow chart of the bibliographic search and delimitation of information.

AFRICA

The culinary culture varies depending on each society, due to its origins and external influences. An example of this is African cuisine, unique for the fusion of food and culinary customs of local ethnicities with foreign influences. Oktay and Sadıkoğlu (2018) comment that the countries of the African continent have had centuries of European colonial dominance, by remaining for a long time under the influences of the governments of Holland, Germany, France, Spain, Belgium and Great Britain. The culinary culture of these countries was adapted to the African territory, along with the cultures of the Indians, Malay and Pakistanis, who were taken as slaves from Asian countries.

One of the traditional dishes of African culture that demonstrates the combination of cultures is the boerewors, a type of pork sausage or meat widely consumed in South Africa. This sausage has French and Dutch influence, in addition to the use of condiments from India and Malaysia such as coriander, pepper and garlic. There is also the dumpling, whose origin is Asian, but thanks to the migration of the inhabitants of that area, its presence extended to the African territory, where the recipe was adapted to the ingredients that existed at that time and in those locations. Also, another of the famous millenary preparations is the melktert, ancestral dessert influenced by the Indian and Malay culture, which is served on the fifteenth day of Ramadan (Lucky & Akande, 2018; Mathenjwa, Hugo, Bothma, & Hugo, 2012; Oktay & Sadıko lu, 2018).

Another example about the crossroads of cultures and how food anthropology can be studied is in Zimbabwe, cassava is consumed as a traditional food, however, this product has an American origin and was introduced to Africa in the 16th century (Shigaki, 2016). The African food culture has many adaptations of foreign foods within its community and as in other countries, the consumption of bread, beer and other products

are present almost daily in the diet.
Next, we will analyze the main examples of ancestral foods that have a historical connotation and have undergone changes due to different events that have allowed them to be considered national heritage of each country.

Fermented foods in Swaziland

Fermentation is an ancient and millenary technique used for the preservation of food in many communities. In the Kingdom of Swaziland (a state located in South Africa) varieties of products are prepared through this practice. Due to its various benefits, it is especially attributed to the concentration of various nutrients that comprise it, the destruction of anti-nutritional compounds such as tannins and to inhibit the development of microorganisms due to the low pH level. Among the most outstanding products are: Umcombotsi (alcoholic beverage), which is obtained from the mixture of water with cornmeal, germinated sorghum without grinding, brown sugar and several species that are cooked to gelatinize the starch and ferment between 25°C and 30°C by 72 hours. Emahewu (low alcohol drink), is one of the most common drinks found in African homes, made from corn and water to obtain a soft porridge that is fermented at room temperature, sometimes they add sugar or a mashed potato. Buganu (marula wine), is made with the ripe fruits of the marula tree (Sclerocarya birrea), the pulp along with water and sugar is fermented for three days. All these drinks are sifted before serving. The problems that can occur during the artisanal production of these fermented products are due to the mishandling of materials and the lack of food safety (Golomski, 2016, 2018; Simatende, Gadaga, Jabulanie, & Siwela, 2015; Simatende, Siwela, & Gadaga, 2019; Tamang, Holzapfel, Shin, & Felis, 2017).

Barley-based products in Ethiopia

One of Africa's star raw materials is barley, which is known as "king of crops" as it is the most cultivated and harvested product in several countries, including Ethiopia. This food is recognized as an important part of the socio-economic and cultural life of the Ethiopians since, in some measure, it prevents hunger during periods of food shortage, occupying

an important position in the food security and sovereignty of this country. Its magical-religious influence creates a power conferred to the point by the community, who believe that barley possesses supernatural powers to heal or beneficially influence people's health. In addition, it is a food that can be developed in adverse environments and stored for almost 25 years due to its low water activity (MacGregor, 2003).

For the elaboration of products with barley, their grains must go through a complex processing. This consists of husking, grinding, sifting and roasting the grain to get the ideal flour. Among the main dishes consumed in Ethiopia are kita, dabo and genfo bread (Mohammed, Seleshi, Nega, & Lee, 2016).

The kita bread is made with barley flour mixed with water and salt, it is instant bread that is widely consumed for the ease of processing, in addition to serving as an emergency food due to its reduced production cost (Satheesh & Fanta, 2018).
The dabo, is a honey bread similar to the kita, although thicker since nowadays yeast is added for the fermentation process. This bread is baked on both sides and it is customary to consume it with coffee, in a ritual that represents Ethiopian reciprocity and hospitality (Shewayrga & Sopade, 2011).

Genfo is a traditional ceremonial dish, it is a mixture of flour, usually of barley, corn and wheat, all mixed with water to obtain a kind of porridge, after 20 minutes of cooking, species and melted butter are added. It is normally consumed at breakfast and special celebrations such as weddings or birthdays. In Ethiopia there is a belief that genfo is a sacred dish, capable of helping postnatal mothers with the production of breast milk and as a replacement for milk as such. In addition, it is believed that it has nutritional properties that strongly benefit the growth and development of children between 6 to 24 months (Mezgebo, Belachew, & Satheesh, 2018; Mohammed et al., 2016)

Meat products of North Africa

Roman historians and archaeologists demonstrated that, at the beginning of humanity, humans survived by hunting, with meat being their main source of food. For its consumption, certain cooking techniques were carried out to preserve the greatest amount of meat, avoiding its rot or deterioration, using primitive processes such as curing, smoking, sun drying and fermentation. In the countries of North Africa, Islam predominates, so that their religious beliefs allow only the consumption of "halal" food, which refers to the allowed food from animals that have been treated with respect and slaughtered so that their suffering is minimal. Initially, the food base in North Africa consisted of agriculture and the domestication of animals such as cattle, sheep, goats, camels and poultry. Pork is a prohibited food under Muslim beliefs. Among the most consumed meat products in North Africa are melfouf, merguez and kofta or kebab (Gagaoua & Boudechicha, 2018; Riesz, 2018).

Melfouf is a product made with roasted lamb liver, seasoned with salt, pepper and red pepper, usually served with bread or tortillas. It is specially prepared in the religious holiday "Eid Al Adha", which means "the festival of sacrifice", where a lamb is given as an offering to sacrifice and honor God for saving the life of Ishmael, son of the prophet Abraham. Merguez is a sausage prepared based on lamb, beef or poultry, seasoned with spices and chili, which gives it a flavor that, in many occasions is quite spicy, it is usually served fried or roasted to prepare sandwiches or Accompanied with couscous. Kofta or kebab is a meat product that has become a staple food in the countries of North Africa. It is of Eastern origin and has Turkish influence for the spices with which it is seasoned, traditionally it is served with pita bread, tahini or with cooked rice (Cagri-Mehmetoglu, 2018; El Ayachi, Daoudi, & Benkerroum, 2007; Gagaoua & Boudechicha, 2018).

ASIA

Asian food and culinary creations have always sought to create different

universes every time they are prepared, always accompanied by a mixture of vegetables, spices, nuts and various types of meats. It represents one of the best gastronomies in the world, encompasses many countries that have an ancient history, which very rarely can be found on the planet, thus, countries such as Japan, China, India, Vietnam, Thailand and the countries that constitute the middle East, these countries are the ones that contribute the Arab influence at the preparation moment. One of the ingredients that all these countries share is the condiments and spices that provide flavor and intense smell to the dishes of each town (Harmayani et al., 2019), which in turn have found in the vegetable kingdom an ideal ally to share the pleasure of eating with the mysticism of the bioactive compounds they possess. Thus, it has been possible to attribute to these dishes medicinal powers that although until a few years ago they were nothing more than beliefs, nowadays it has been possible to demonstrate their nutritional role, especially antioxidant (Horng & Tsai, 2012; Joshi & Visvanathan, 2019).

Throughout the years, Asia has seen how food has entered into all kinds of events, so we can see that, in all wars, uprisings, legends, etc., there is always some kind of food or gastronomic dish. One of the main dishes we can find throughout the continent is soups with noodles or rice. Asian society is and has been very fond of seafood, so we can find creations such as sushi (rice vinegar), and to elaborate this we will need to know basic terms such as maki (wrapped in seaweed), nigiri (portion of compact rice oval shape to add pieces of seafood), uromaki (inverted maki), oshizushi (square mold for vinegar rice), gunkan (arc-shaped nigiri or seaweed basket), temaki (seaweed cone) and sashimi (raw fish without rice). Within the most important of the fish-based cuisine we will have dishes accompanied by tuna, salmon and the controversial puffer fish, we can also find a variety of seafood, where the shrimp stands out (But, Wu, & Shaw, 2019; Hajeb & Jinap , 2015; Lipoeto, Lin, & Angeles-Agdeppa, 2013).

Depending on the importance of food for the Asian continent, the following are some of the most relevant ancestral foods and preparations for the study of Asian food anthropology.

Jang: Fermented soybean ancestral products

Asia and specifically Korea have a great relationship with soy, its use dates back approximately 4000 years before Christ. The origin point of this millenary grain is Manchuria (Dongbei Pingyuan, a historical region in northwest China, constituted by Liaoning, Heilongjiang and Jilin), and since then it has become a great source of protein for the entire continent. Its production worldwide is very extensive, in Asian countries it is used as a source of food, while in Western countries also as food for animals and for the development of non-food products. In Korea, the use of fermented soybeans goes beyond a simple raw material that accompanies any dish, since its potential content of essential and non-essential nutrients has been demonstrated and has become considered a functional food. Among the best-known culinary preparations are: Kanjang, the country's most traditional fermented soy sauce, there is evidence of its consumption since ancient times, how traditional ingredients only used fermented soybeans, salt and water, nowadays you can find the mix with corn, wheat and other cereals. Doenjang, is fermented soybean paste (in Korean it means thick soybean paste) is obtained after fermentation of many soybeans, in the kitchen it is mixed with other sauces and normally mixed with anchovy paste to enhance its flavor, is always present when preparing pork belly (samgyeopsal). Gochujang, this is a spicy sauce made from a mixture of glutinous rice with spicy chili powder, along with soybean paste, this preparation is left to ferment in clay containers for long periods of time (including years), in some villages Barley, jujube or pumpkin is usually added. These products are used in many garnishes and occupy an important place in the daily life of the people who consume them (Burgess, 2014; Shin & Jeong, 2015).

There are ethnic groups in Asia, whose diet is based largely on fermented soy products, these groups are known as "Fermented Soy Jang Culture". The inhabitants of these ethnic groups have developed different fermentation techniques to have soy products, liquids, thick or mixed. The fermentation to which soy is exposed is carried out by some fungi or bacteria such as Baciillus sp. The countries that have food where mushrooms are used for their process are Korea, Japan and Indonesia (in Indonesia

the only product of this style is the famous tempeh, which is a cake with a firm texture and strong flavor, which is used as a substitute for meat, especially on the island of Java). While some of the countries where bacteria such as bacillus are used to cause fermentation are India, Nepal and Cambodia, although we can also find these types of preparations in Japan, Korea, Bhutan, Thailand, Cambodia, Laos, etc. (Lee & Kim, 2018).

In general, these fermented soy products are obtained from soaking soybeans in water (germination), with subsequent fermentation in baskets or vessels for several days, months and even years, with temperatures around 25°C to 40°C. The soybean seed contains a high amount of proteins, it can be used in its natural state, or decomposed to be a source of nutrients from peptides and amino acids resulting from enzymatic decomposition by different processes in its development that in turn will develop new chemical structures that will allow new flavors, aromas and textures. There are clinical studies that show the incidence of significant consumption of these fermented soy products with health benefits, especially in ailments such as constipation, obesity and to combat diabetes and cancer (Lee & Lee, 2014; Shin & Jeong, 2015).

Rice-based drink

The rural ethnic population of Asia depends exclusively on nature for its survival. Traditional rice beer or sake is an indispensable part of the socio-economic and cultural life of indigenous communities such as Tripura (state of the Republic of India). Its production and use has a long way in the history of communities and is associated with festivities such as marriages, festivals, funerals and various rituals. Rice beer recipes vary depending on the alcoholic strength, diversity of aromas, flavor, essence, sugar levels and other raw materials used (in general 13 different types of plants are used, depending on the region) (Ghosh et al ., 2016).

Rice beer is a quality drink with nutritional contribution. In its preparation, the only basic and irreplaceable ingredient is rice flour, the rest of the ingredients vary according to the regions where this drink is made. It

is considered a beverage specially prepared to benefit health since the plants that compose it have several bioactive compounds. However, its recipe and preparation are not specified anywhere, as are many Asian recipes, so it is important to register its preparation for better production results and increase the shelf life of the product (Okuda, Iizuka, Xu, & Wang, 2019).

The standard methodology for rice beer production is to cook the rice and spread it on a surface to cool it quickly. The plant leaves are added and mixed until you get a homogeneous mass that is covered with banana leaves so that the vapors can leave the container for 3 days. After this, water is added and it is ready for consumption, the alcoholic degree will depend on the fermentation time and the amount of sugars (Ghosh et al., 2016; Longkumer, 2016).

Flat bread (lavash, katyrma, jupka or yufka)

The flat bread term encompasses a variety of breads that have in common that their thickness is a few millimeters, they are on the list of the intangible cultural heritage of humanity since 2016. Originated in rural society, in a different context to the current situation, its birth is very ancient, there are findings of these breads in Mesopotamia, ancient Egypt, Sumeria and other nearby civilizations, and they were probably the first processed foods of humanity. They were always present in the geographical areas of nomadic tribes, which represented their subsistence in terms of economy. Flatbreads are present in most daily meals in many villages in Asia, in various celebrations, especially at births and are increasingly appreciated in western countries. . (Pasqualone, 2018).

These breads show numerous advantages over the traditional ones, it is obtained from cereals (wheat is not included), pseudo-cereals are generally used or flour from some legumes is also added, the use of these raw materials allows the development of local agriculture and its sustainability. Its preparation does not depend on sophisticated ovens, they are still produced in the same way as many years ago, in metal cooking plates, stone or mud ovens, sunk in the ground and in cauldrons. Today

they are also produced in modern industrial lines. They are usually dehydrated by a second thermal process to prevent mold growth and thus have a longer shelf life, these breads do not have the traditional yeast fermentation. They are usually served as if they were a plate where other foods are placed, it is also used as a spoon or fork and it is possible to take food portions from a container with flat bread. This makes flatbreads very popular and also traditional in West Asia, Central Asia and in some Mediterranean areas, especially in the Indian subcontinent (India, Pakistan, Bangladesh, Nepal and Bhutan) and the Arabian Peninsula (Mir et al., 2014; Wani, Sogi, Sharma, & Gill, 2016).

Coffee, (cultural heritage)

Coffee is part of the daily life of much of humanity, in several parts of Asia it is one of the main drinks par excellence. There are several data on the etymology of the word, it is related to Kaffa, Soha region and former province of southwestern Ethiopia, considered as the main center of origin of the coffee plant. From Ethiopia this grain would travel to Yemen where it began to be grown on a large scale. It is also related to the word kahve which means coffee drink obtained by boiling (Yılmaz, Acar-Tek, & Sözlü, 2017).

Due to different roasting procedures where the chemical structure of volatile compounds is formed, there are numerous varieties of coffee and therefore the use of different temperatures and times will result in considerable organoleptic changes. Coffee is characterized by its caffeine content, for example, Turkish coffee has a higher concentration than other varieties grown around the world. Due to its phytochemical components such as alkaloids, coffee bean stimulates the cardiovascular and cerebral system (Lim, Zwicker, & Wang, 2019).

The coffee from the Asian part of Turkey, is made from a mixture of high quality Arabian coffee beans and a medium roast, the way of brewing is different from other coffee drinks because copper coffee boilers are used to boil (Lim et al., 2019), which have a long handle that makes it more

comfortable to keep it straight in the flame. The base of these coffee makers is large, so it allows the interaction of fire with the entire surface, another feature is a peak with a large diameter, which provides a perfect size to pour into the cup without spilling, the coffee from Turkey is considered cultural heritage (Yılmaz et al., 2017).

Thua nao: fermented soybeans

Thua nao is one of the proud of Asian culinary culture, it is a very traditional fermented food in Thailand, where its origin is attributed. They consume it mainly in the northern part of the country.

This product is considered a protein supplement and is also used as a condiment (flavor enhancer), it is consumed as a paste to which salt and spices are added. There are two types of thua nao, dry and fresh. There are similar products in other countries, these are known as kinema in India, chongkukjang in Korea and natto in Japan. These fermented alkaline foods are found in the traditional diet in many of the Asian countries (Chukeatirote, 2015).

The raw materials for its elaboration are soy, water and natural microbes of the Bacillus sp genus. It is made by fermenting all the ingredients in banana leaves for 2 or 3 days at room temperature, and then dried in the sun, by losing moisture, it can be stored at room temperature for several months. This is a product that comes from an alkaline fermentation where soy proteins are hydrolyzed in ammonia, amino acids and peptides, causing an alkaline increase in pH between 8 and 9. All this enzymatic activity favors the formation of new chemical compounds that will be related to the aroma, flavor, texture, and appearance. By this change of pH, the product will be harmless since it will not allow the growth of many pathogenic bacteria, but the growth of some Bacillus strains, especially B. subtilis, B. licheniformis, B. megaterium and B. pumilus (Chukeatiro, Dajanta, & Apichartsr, 2010; Inatsu et al., 2006).

CONCLUSIONS

Studying the origin of each civilization allows us to understand the importance and relevance that foods have had so that they can develop. Food anthropology teaches us how gastronomy has played a fundamental role in shaping the history of peoples. In this investigation we can find the main ancestral food and culinary creations of the African and Asian continents, which are part of their cultural heritage.

Africa has had to live with many European countries throughout history, this combination has been given by countless factors that currently have the majority of the countries of the continent in poverty, despite the richness of their land.

Food and gastronomy were not left out of these events, and the culture and food history, along with the gastronomy of these peoples, was modified and forged with the exchange of many products, which, to some measure, enhanced many of the customs that they had.

African countries stand out for the millenary consumption of products obtained from the alcoholic fermentation of different cereals to obtain drinks with a greater or lesser degree of alcohol.

Other millenary customs are the elaboration of different types of products from barley (mainly breads) and the elaboration of meat products based on lamb, beef and poultry.

Asia is a millenary continent par excellence; its lands are marked with centuries of tradition. Every event that has had its history has involved many foods and how to prepare them. In turn, these foods have been granted, in addition to nutritional properties, medicinal and magical qualities, which has taken their cuisine to a level of mysticism unique on the planet. Stresses its food history with the preparation of culinary creations with condiments and species, aromatic plants and seafood.

The Asian continent throughout history stood out for the consumption of fermented soy products, in most countries this millenary grain

has been consumed for centuries and has been given countless procedures to obtain different gastronomic varieties.

The flatbreads are another of the emblems of the continent since in all its regions they are consumed for their importance and legacy. We can also mention the importance of rice-based drinks and the traditional coffee that is present in people's daily lives.

It is important to understand how food can continue to form the culture of each people and their development should be taken care of and encouraged with their different culinary recipes.

Losing this heritage would represent the loss of identity of the new generations of each region, for this reason, this type of studies should continue to be carried out in all continents and countries of the world.

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FLOUR CARROT

(Arracacia Xanthorrhiza)

TO IMPROVE THE TEXTURE OF CHILLED SAUSAGES

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ABSTRACT

White carrot flour has been recognized as an ingredient in the meat industry, due to technologies properties and nutritional benefits. In the first instance, the white carrot flour was evaluated for hydration properties and structural characteristics.

The substitution of white carrot flour by wheat flour in chilled sausage is valuable information with respect the behavior rheology that imply add this ingredient in the formula convectional This study evaluated the substitution of 50%, 100% and 200% of flour carrot by wheat flour and after analyzed the behavior rheology with respect to module G' and G''. Therefore, the analysis of properties hydration and structural of white carrot flour as a functional ingredient in chilled sausages allows substitution of white carrot flour by wheat flour.

Keywords: White carrot flour, hydration properties
structural properties, rheology properties, chilled sausages.

INTRODUCTION

Carrots are important crop since its root can be industrialized and distributed around the globe. The root carrot has been incorporated in meat products to improve properties of the texture of foods (Kim & Paik, 2012). There are different colors that the carrot can present such as white, yellow, orange, red, purple or very dark purple. Among these color carrots, white carrots highlight due to its high content of starch that in hence the properties of meat foods as sausages. The production of white flour carrot is not widespread in food industry (Londoño-Restrepo, Rincón-Londoño, Contreras-Padilla, Millan-Malo, & Rodriguez-Garcia, 2018). This is attributed to the lack of information regarding the correlation between the white flour carrot structure, hydration properties and rheology behavior. Although the consume of wheat flour affect at digestive systemic denominated celiac disease (Lucendo, 2011). Therefore, there is a need to incorporate into the literature studies that consider the structural and hydration properties of the white carrot flour for sausage production to replace the use in wheat flour.

The use of wheat flour is an ingredient that giving rise to a viscoelasticity network in matrix process food for the presence of substrate (arabinoxylan) and the enzyme (endoxylanase) (Lucendo, 2011) . On the other hand, the white carrot belongs to Arracacha variety and it is (Arracacia xanthorrhiza) presents a low gelatinization temperature and retrogradation tendency, with high water absorption capacity and paste clarity; these food properties are highly desirable for the food industry (Castanha et al., 2018).

It is relevant to highlight the application of the white flour carrot for future commercialization as an ingredient in chilled sausage. Consequently, this work aims to evaluate the structural, hydration properties and behavior rheology of white carrot flour to substitute the wheat flour.

METHODOLOGY

2.1 Elaboration of white carrot flour

White carrots (Arracacia xanthorrhiza) were purchased in different markets in Guayas, Guayaquil (-2.2265789, -79.8872438). They were washed with water and sanitized by immersion in peracetic acid (80%) for 10 min. The carrots were manually peeled and cut into 5 mm slices. Slices of white carrot were dried in the oven at 50 °C for 8 hours and after were ground to 250 µm for analysis this methodology was adapted according to reported by (Chattong & Apichartsrangkoon, 2009).

2.2 Hydration properties of white carrot flour

Water activity, water holding capacity (WHC) and swelling power (SP) were determined in the carrot flour. These hydration properties were carried out according to the methodology given for proposed by (Cornejo & Rosell, 2015).

2.3 Structural properties of white carrot flour

The crystallinity pattern was performed by X-ray diffractometer model X´Pert PRO (PANalytical, Boulder, United States). The samples were equilibrated at 100% relative humidity chamber by 24 hours. The conditions used in diffractomer were 30 Ma and 40 Kv, a diffraction angle (2θ) range of 4 -40 ° with a 0.05 ° step size by 2 s.

The equation of Rabek (1980): was used to determine the relative crystallinity (RC)

$$RC\ (\%) = (Ac/(Ac+Aa))*100 \qquad \text{Eq1.}$$

Ac represents crystalline area and Aa the amorphous area. The software using for this test was OriginLab Corporation, Northampton, USA, this methodology was realized according to (Campuzano, Rosell, & Cornejo, 2018).

2.4 Elaboration of Chilled Sausage

Raw Materials: beef meat, pork meat, wheat flour, red wine, powder garlic, salt, peeper black. The formulation of the chilled sausage was performed in the pilot plant of Universidad Agraria Ecuador (Guayaquil, Ecuador) using the formulations shown in Table 1.

Table1.
Chilled Sausage formulations containing 50%, 100% and 200 WFC

Ingredients	Percentage in each formulation (w/w)			
	Control[a]	50% WCF	100% WCF	200% WCF
Pork meat	60.255	60.255	60.255	55.255
Water	31.470	31.470	31.470	31.470
NaCl	1.244	1.244	1.244	1.244
Garlic	0.623	0.623	0.623	0.623
Sodium Nitrite	0.311	0.311	0.311	0.311
Sodium Phosphate	0.311	0.311	0.311	0.311
Red Wine	0.786	0.786	0.786	0.786
WF[b]	5.000	2.500	-	-
WCF	-	2.500	5.00	10.00

[a]Control=0% of WCF (White Carrot Flour), WF(Wheat Flour)

The process to obtain chilled sausage was mixture reached 4 °C. The meat mixture did not exceed 10°C. The mixture was stuffed into 26 mm cellulose casings. Samples were hand linked and heat process at 75 °C, until inner temperature product was 70 °C. Samples were separated from casings by hand and were vacuum packed and stored at 4 °C for 24 until analysis.

2.5 Rheology Properties

The rheology properties were evaluated on a controlled stress Kinexus PRO rheometer (Malvern Instruments, Worcestershire, United Kingdom) considered as parameter: under strain control mode at 25 °C. Apparent viscosity was established by increasing the shear rate (0.0001 to 450 s-1) in 15 min. The frequency considered to linear region was of 1 Hz and shear strain from 0.1 to 100%. The (G') and (G'') were determined in a range of the frequency from 0.01 to 10 Hz. This process was adjusted to methodology as reported by (Chattong & Apichartsrangkoon, 2009).

1.5 Statistical Analysis

The statistical analysis was carried out in chilled sausage for triplicate. The analysis were made using Statgraphics Centurion 16 (Statistical Graphics Corporation,2014 UK). The samples of chilled sausage were evaluated with the viscoelastic parameters the storage modulus (G'), loss modulus (G'') and determinate significant differences by analysis of variance (ANOVA).

2. Results and discussion

The WCF was evaluated for hydration properties (Table 2). The moisture content and water holding capacity are comparable at reported by (Barrera Victor, Brito Beatriz, 2004) .The water absorption index (WAI) is related with the content of fiber 2.25 ± 0.21 reported for white carrot flour arracacha .(Londoño-Restrepo, Rincón-Londoño, Contreras-Padilla, Millan-Malo, & Rodriguez-Garcia,2018) that comparated with orange carrot (Dacus carota) is higher , this characteristic generate an ability to trap water within the cell matrix , it allows bind water (Robertson & East-

wood, 1981).

Table 2.
Water Absorption Index , Water holding capacity and swelling power

PARAMETERS [a]	SAMPLE WCF
Moisture (%)	75.8 3 0.26
WAI (g/g)	0.44 3 0.04
WHS (g/g)	5.61 3 0.66
SP(ml/g)	4.75 3 0.08

[a]Values represent the mean of 3 replicates with their standard error

The starch granules have been related to the swelling power. The micelle of starches granules network related to the amylase content of the flour. The white carrot flour granules were spherically variables sizes with equatorial lengths between 80 and 100 μ and transverse from 42 to 50 μ is presented in ***Fig 1.***

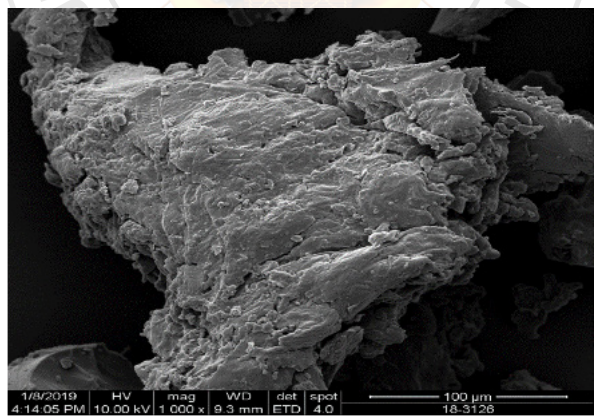

Fig1. White Carrot Flour (Scanning Electronica Microscopy) SEM

The shape and structure of the WCF were mainly polyhedral. In addition, some granules covered by sacks of fiber appear and in smaller ones (proteins) attached, granules with little protuberances are observed. The analysis of the white carrot flour shown for X-ray diffraction of WFC. This ***Figure 2.*** indicates that it is type B, with the most representative peak at angle 21° followed by angles 20° and 18 ° 2q respectively. The patterns of X-ray diffraction of WCF is comparable with the type of diffraction model previous findings in wheat four starch (Blazek et al., 2009).The relative crystallinity (RC) for WCF was 14.66% was calculated according to Eq1. This result implies that WFC is more amorphous than crystalline, considered the relation between the term of amylopectin with the crystallinity (Buléon, Colonna, Planchot, & Ball, 1998). This structural must be considered in the boiling process, where can produce amylose lixiviation due to partial gelatinization of extern layer, for this reason, the loss of amylose could contribute to keep the remaining amylopectin (Campuzano et al., 2018). The addition of carrot flour increased the water binding capacity, this finding is supported by the content insoluble fiber due to water binds to insoluble polysaccharides by hydrogen, ion and/ or hydrophobic interaction (Pietrasik & Janz, 2010).

Regarding the swelling power, it is directly proportional to the temperature. If there is an increment of temperature, the mobility of the starch molecules increases. Consequently, the granule becomes more porous (Han, Cho, Kang, & Koh, 2012). This leads to the phenomenon known as starch gelatinizes. It starts with the hydration of the amorphous parts, followed by swelling and distortion of the crystalline region reported by (Simonin, Guyon, Orlowska, de Lamballerie, & Le-Bail, 2011), the process applied as elaboration with addition of carrot dietary improves water-binding capacity (Grossi, Søltoft-jensen, Christian, Christensen, & Orlien, 2012). Addionally, the water retention in meat can be affected by degradation of proteins (Huff-Lonergan & Lonergan, 2005). The properties hydration suggest the impact in developed of ingredients of meat products related to texture. Alvarado-Ramirez et al., (2018), showed sensory acceptability with a range of 6.10 3 0.20, that in qualitative scale represents “like slightly”.

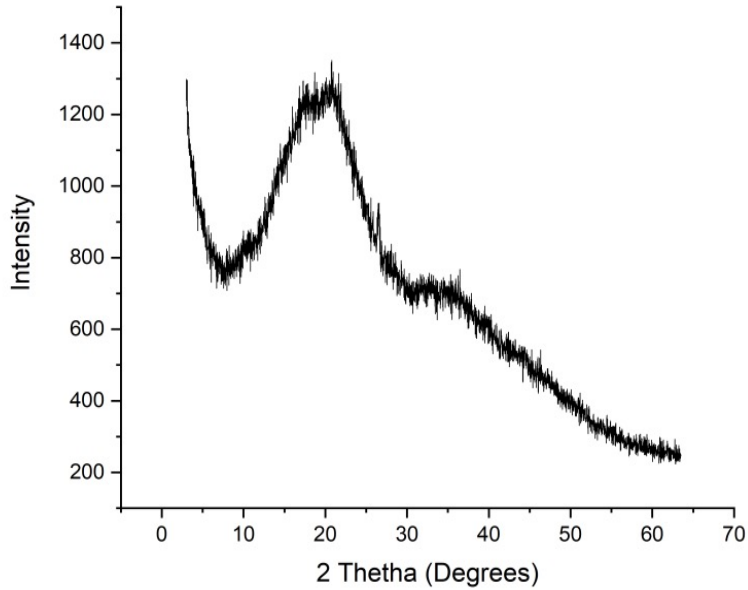

Fig2. White Carrot Flour X-Ray

The arracacha starches present properties that are related with the structure of the starch molecules in the varieties such as (Arracacia xantorrihiza) yellow the gelatinization of temperature in onset is a range of (54.9-55° ± 0.5 °C), peak temperature (58.9-59.1 ±°C) and conclusion temperature (71.9-73.9 ±0.5). Additionally, starch granules present cracks and fissures on their surface; this may facilitate WHC (Table. 2) in the structure.

Consequently, their gelatinization lower temperatures agree with the amorphous structure as reported in ***Fig 2.*** In the case of arracacha starches, the long-branched chains of amylopectin may hinder to extend the molecular association after cooling, contributing to the low retrogradation tendency. In this context, the arracacha starches show a high interest in industrial application, considering also starch pasting properties can be useful in application of meat products that required highly viscosity and refrigeration (Grossi et al., 2012, Castanha et al., 2018). The behaviour rheology is determined by viscoelastic measurement of storage G´, loss G´´) modulus are among parameters considered by research in previous reports in sausage (Choe, Kim, Lee, Kim, & Kim, 2013). White carrot flour was added to a formulation of chilled sausage replacing WF in 50%, 100% and 200% by WCF. The viscoelastic measurement of storage G´

and loss G´´ were parameters considered to analyze the rheology behavior of chilled sausage ***Table 2.*** The substitution of 200%, 100% and 50% of carrot flour by wheat flour don't significance difference in the behavior in the viscous and elastic component. The values of viscous module G´´ are lower that elastic module G´, in consequence the rheology behavior is elastic, that characteristic is attributed to convectional sausage elastic and hardness (Balestra, Bianchi, & Petracci, 2019).

Table 2.
Rheological properties on chilled sausage

	VISCOELASTIC PROPERTIES	
SAMPLE	G′ (Pa)	G″ (Pa)
CONTROL	18943.30 ± 17.56[b]	83925.00 ± 8.89[a]
50% WFC	120809.00 ± 23.43a	34219.00 ± 74.59[b]
100%WCF	120850.00 ± 150.0[a]	34246.70 ± 225.46[b]
200%WCF	120809.00 ± 23.43[a]	34219.00 ± 74.59[b]
P-value	0.000	0.000

CONCLUSIONS

The studies of structural and properties hydration in carrot flour are important to correlation the viscoelastic characterization of chilled sausage. In consequence, the addition of carrot flour at 50%, 100%, and 200% showed that module G'' is lower than elastic module G. This indicates the predominance of the elastic component with respect viscous component

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PROPOSAL FOR THE PRODUCTION OF A REFRESHING DRINK USING GUAYUSA LEAVES

(Llex guayusa)
and native guanabana leaves
(Annona muricata)
flavored with lemon essence.

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ABSTRACT

This research proposal is based on a worldwide problem in which a trend of consumption, tastes and preferences of the population that ingests non-alcoholic beverages arises. A product that is in the middle of a controversy because it is unhealthy and poor in micronutrients, was developed a drink based on guayusa leaf (Llex guayusa) and native soursop leaves (Annona muricata) with three treatments:
(T1, T2, T3) which contain 75% and 25%; 50% and 50%; 25% and 75% of guayusa and soursop leaves respectively.
A sensory evaluation was performed using a hedonic scale by a panel of 30 untrained evaluators who rated from 1 (I really like it) to 4 (I dislike it), the characteristics evaluated were: color, smell, taste and texture of the three treatments. The results showed that the T1 treatment (75% and 25% content of guayusa and soursop leaves, respectively) presented the greatest sensory acceptance. The product belonging to this treatment was subjected to physical-chemical and microbiological analysis taking as reference the NTE-INEN 2304: 2016 and NTE-INEN 2337: 2008 regulations to ensure its quality and safety. We conclude that the refreshing drink, after physical chemical and microbiological analysis, is within the parameters of the regulations mentioned above.

Keywords: Innovative, stimulating drink, guayusa, soursop, lemon.

INTRODUCTION

The World Health Organization (WHO) echoes something that is visible in urban societies of the 21st century and is overweight in the population, a phenomenon that has been expanding since the 1980s. In Ecuador, the National Health and Nutrition Survey warned that in 18 of the 24 provinces, including Quito and Guayaquil, there is a prevalence of excess weight in adults (between 18 and 60 years old) above 60%, which means that 6 out of 10 Ecuadorian adults suffer from obesity (Ministry of Public Health, 2013).

The consumption of natural products grows considerably worldwide and Ecuador is not far behind. In the last decade, a trend has emerged, which has gained more and more strength over the years, related to leading a lifestyle as healthy as possible through the consumption of products that contribute positively to health and allow having a better quality of life. (Quality Assurance & Food Safety, 2015).

According to Andrade and Flores (2008) this is not a fad, rather it is an evolution of the consumer thanks to the fact that there is more information on how to raise awareness in the population by many people who choose to take care of themselves, especially through food.

The future of society brings a new concept of healthy eating based on simplicity with special benefits for the body, both in the food itself and in the preparation methods (Quality Assurance & Food Safety, 2015). Finally, these food preferences have generated an impact on the industry, which is currently forced to change and innovate in all its facets, from the selection of raw materials, supply chain management, to production processes. (Lupo, 2014).

Guayusa belongs to the Aquifoliaceae family and is recognized with the Castilian name of guayusa in most localities of Ecuador. It is a perennial tree native to the Amazon region, where it is wild, but it is also present in certain subtropical places of the Andean region in a cultivated state (Jørgensen and León-Yanez 1999). In general, individuals of this species

reach an average size of up to 10 m in height, have a diameter at chest height (DBH) of 50-80 cm, have an irregular crown and have dense foliage (Garcia Barriga 1992).

The guayusa-based drink is not only an infusion, it is a product that competes in the energy drinks market, due to its high content of elements such as caffeine in variable amounts, superior to those of coffee and tea; it also contains theobromine and minor amounts of theophylline. Due to the amount of caffeine that the plant contains, its consumption contributes to the stimulation of the skeletal muscles, increases the waking state and increases the ability to exert physical effort (Correa & Bernal, 1989).

The guayusa-based healthy drink is exported from the Ecuadorian Amazon (Runa, 2014) and with the Andean Development Corporation financing a project to strengthen production in the Ecuadorian Amazon indigenous population (CAF, 2011).

Guayusa is endowed with a caffeine-rich composition of approximately 2%, belonging to the group of plants with energizing properties; Regarding other studies carried out using solvents, they indicate that the most important constituents of the species are the following: methylxanthines, quinones, theobromine, theophylline, tannins, steroidal compounds, lactonasterpenics, coumarins, flavonoids, triterpenic saponins and essential oils. The presence of purine alkaloids, triterpenes that are derived from chlorogenic acid, riboflavin, nicotinic acid, choline, pyridoxine and isobutyric acid, has also been found (Melo, 2014).

Annona muricata, commonly known as soursop, is the other ingredient in this drink (Patel and Patel, 2016). The composition of the leaves of the Annona muricata plant, the study of its active ingredients, its biological activity against different types of cells, including its toxicology. All this, in order to determine if there is scientific evidence of its benefits and impact on the human body, and that supports a potential recommendation for use in the treatment and prevention of disease (Tilburt and Kaptchuk, 2008).

Scientists have long investigated this species and conducted countless studies to determine the plant's components, discover its active properties, and confirm its chemical effect on the human body. (Coria et al., 2016) Within these investigations,

Phytochemical evaluations of Annona muricata leaves have been carried out and the presence of different Phyto-constituents has been demonstrated. (Coria et al., 2016). The main compounds (phyto constituents) of these are detailed below: Alkaloids, Megastigmans, Flavonols, Triglycosides, Phenolic, Cyclopeptides, Minerals: K, Ca, Na, Cu, Fe, Mg, Essential Oils, Acetogenins (ACGs), Other elements and essential nutrients (Fadaeinasab et al., 2015).

One of the treatments that was given to the leaves was dehydration, which is currently one of the oldest ways of preserving food and aims to eliminate much of the moisture from the products. Dehydrated foods maintain a large proportion of their nutritional value if the process is carried out properly (Krokida & Philippopoulos, 2005).

The purpose of this research is the development of a refreshing drink combining dehydrated guayusa leaves and soursop leaves, thus giving a very high quality energizing product and taking advantage of its high mineral content.

METHODOLOGY

Location

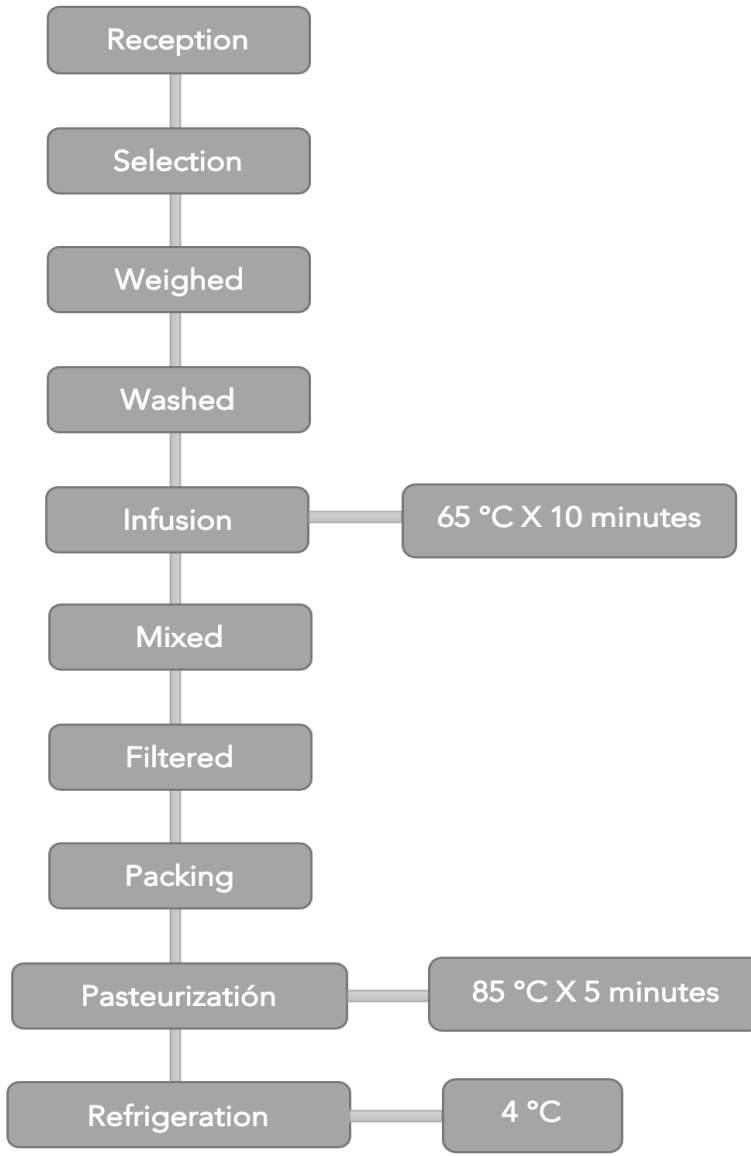
The product witht the different treatments was elaborated in the pilot plant of the Faculty of Agrarian Sciences, at the Universidad Agraria of Ecuador, Milagro campus, whose geographical location is the following 2 ° 14'45 '' south latitude and 78 ° 55''41 ' 'west longitude.

Obtaining the product

The production process is briefly described (Figure 1), guayusa and guanabana leaves were selected following the steps of quality and food safety, washing was carried out using a sodium hypochlorite solution (50 ppm concentration), then rinsed with distilled water (Juran & Gryna, 1999).

The leaves were subjected to an adiabatic dehydration process for 5 hours at a temperature of 62 ° C. Then we proceeded to the next step, which was the infusion for 10 minutes at a temperature of 65 ° C so that the leaves release all their aromatic essences that characterize each one of them, such as guayusa and soursop. We proceeded to mix the rest of the ingredients such as sugar, lemon essence and stabilizer, then the product was filtered using a 10-micron thick sieve. Finally, this was packaged in a 200 ml glass bottle of content and pasteurized at 85 ° C for 5 minutes. The product was stored under refrigeration at 4 ° C until use.

Figure 1. Flow diagram of a refreshing drink.



Authors, 2019.

Product formulation

The three treatments were developed, where the variables were the quantity of guayusa and soursop leaves (Table 1). Three repetitions were performed for each product, maintaining the same conditions and complying with the quality parameters, considering the content of soluble solids, acidity, pH and the regulations of BPM (Good Manufacturing Practices) and food safety. For the statistical analysis of the data, the randomized complete block design (RCBD) was used.

Table 1. Guayusa and Soursop drink formulations

COMPONENTS	PRODUCT		
	T1 (%)	T2 (%)	T3 (%)
Water	63	63	63
Sugar	15	15	15
Guayusa leaves	15	10	5
Soursop leaves	5	10	15
Lemon essence	1	1	1
Stabilizer	0,5	0,5	0,5
Citric acid	0,5	0,5	0,5

Authors, 2019.

Sensory Evaluation

Sensory elaboration allows us to measure the acceptance of the product with greater acceptance of the three formulations or treatments carried out. This work was carried out by 30 untrained panelists. The evaluators were students of Agricultural of both sexes, aged between 19 and 25 years of age. Each panelist was given a 250 ml bottle of water to rinse any residue between each tasting, and a sample of each bottle containing 50 ml and an evaluation form were also delivered. The evaluated properties were color, flavor, texture and odor. The data obtained from the sensory evaluation were

examined using the one-factor analysis of variance (ANOVA) and the Tukey test at 5% probability using the statistical software InfoStat version 2017.

RESULTS

Different concentrations of guayusa leaf and guanabana leaves were used, maintaining the same amount of lemon essence (T1, T2, T3), with the intention of offering a product that presents a variety of organoleptic characteristics that are attractive to the consumer and in this way, encourage the increase of their consumption. seeking to take advantage of the attributes that the guayusa and native soursop leaves give, such as their astringent and bittersweet flavor as well as their intense and complex aroma combined with the essence of lemon for its slightly bitter flavor.

The values of the means, the standard deviation and the coefficient of variation (***Table 2***) of the four evaluated sensory characteristics of the beverages were presented. Product T3 (25% guayusa leaves and 75% soursop leaves) presented the highest deviation coefficients and the lowest averages of the four evaluated characteristics, compared to the remaining two products. In contrast, the T1 product (75% guayusa leaves and 5% soursop leaves) presented the lowest deviation coefficient averages and the highest average of the four characteristics evaluated by the sensory panel.

Table 2. Mean, standard deviations and coefficients of variations of the evaluated characteristics.

Parameters		Drink		
		T1%	T2%	T3%
Color	Mean	4.00	4.00	4.00
	Deviations	0.00	0.00	0.00
	Standard	0.00	0.00	0.00
	CV			

Flavor	Mean	3.80	3.17	2.83
	Deviation	0.41	0.53	0.59
	Standard	10.71	16.76	20.90
	CV			
Smell	Mean	3.57	3.03	2.43
	Deviation	0.63	0.67	0.73
	Standard	17.55	22.04	29.92
	CV			
Texture	Mean	3.90	3.17	2.47
	Deviation	0.31	0.65	0.78
	Standard			
	CV	7.82	20.45	31.46

Authors, 2019.

The levels of association presented by the sensory characteristics evaluated were analyzed ***(Table 3***). A high correlation was observed between the odor and flavor variables, a similar situation occurred with the texture, odor and flavor properties. These results allow us to infer that the drinks in which treatment 1 and treatment 2 correspond had a more pleasant taste for the semi-trained judges, which also have a more pleasant smell. In the same way, those drinks that exhibited a better texture generally showed a very pleasant smell and taste.

Table 3. Correlation matrix of the evaluated characteristics.

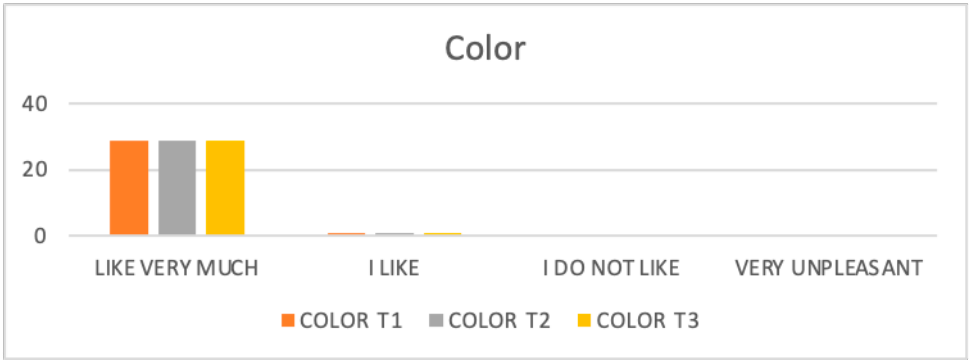
	Color	Flavor	Smell	Texture
Color	1	0.48	0.46	0.58
Flavor	0.73	1	1	0.10
Smell	0.75	0.03	1	0.13
Texture	0.61	0.99	0.99	1

Authors, 2019.

Organoleptic Analysis

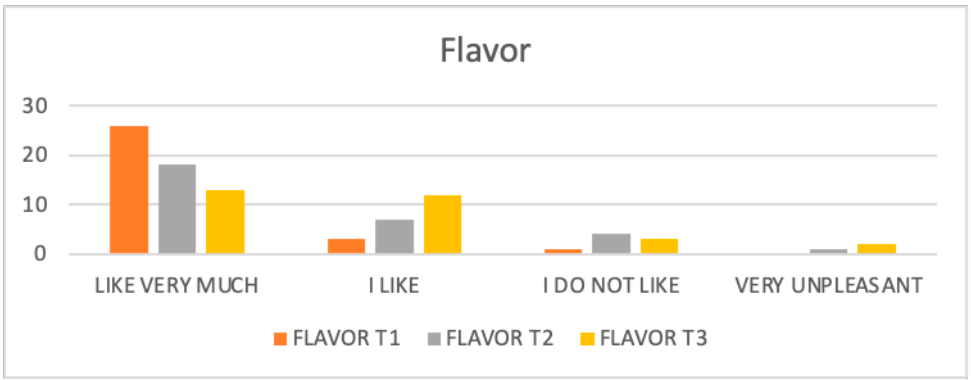
Figure 2, 3, 4 and ***5*** show the results of the sensory evaluation carried out by 30 semi-trained judges. The refreshing drink with native guayusa and soursop leaves has a good acceptance mainly in the characteristics of flavor, smell, color and texture; while in taste and smell there is a significant difference between treatment 1 and treatment 3.

Figure 2. Sensory evaluation of color.



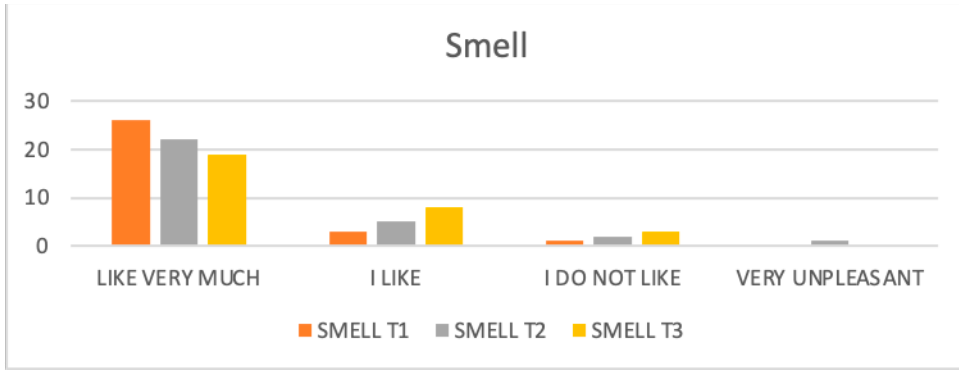
Authors, 2019.

Figure 3. Sensory evaluation of flavor.



Authors, 2019.

Figure 4. Sensory evaluation of smell.



Authors, 2019.

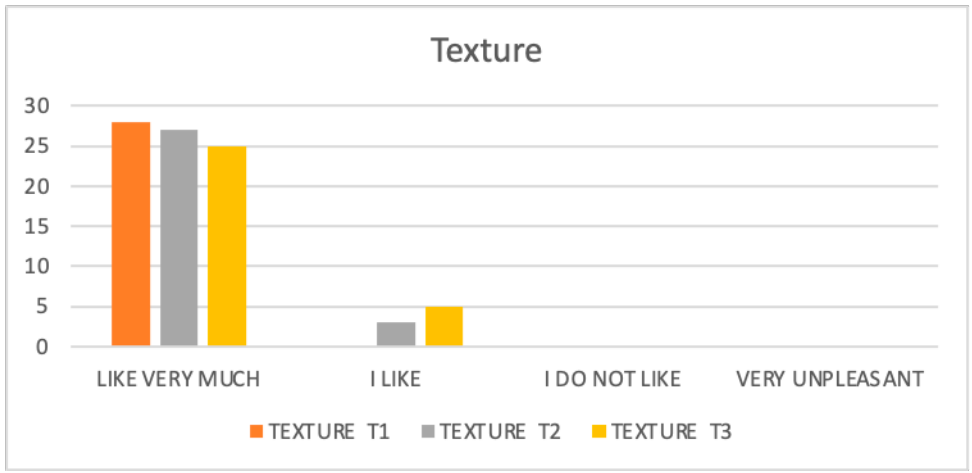


Figure 5. Sensory evaluation of texture.

Authors, 2019.

Table 4. Physical-chemical results of the product with the highest acceptance (T1).

Parameters	Unit	Results	Requirements	Standards of References
Total soluble solids	°Brix	6.6	5-7	CODEX STAN 247 NMX-F-1982 NTE INEN 380
pH	pH	2.34	Min. 2.0 Max. 4.6	INEN 0389
Acidity (expressed as citric acid)	g/100ml	0.094	0.1	NTE INEN ISO 750

Authors, 2019.

The samples analyzed for the physico-chemical parameters are within the ranges of the reference standard can be seen in Table 4.

Table 5. Microbiological results of the T1 product.

Parámetros	Requirements NTE INEN 2337:2008	Results
Total Coliforms	<3 UFC/ml	<2.8 UFC/ml
Fecal Coliforms	<3 UFC/ml	<0,8 UFC/ml
Aerobic Mesophilic	Max. 10 UFC/ml	$0.7x10^{1}$ UFC/ml
Molds and yeasts	10 UFC/ml	$0.5x10^{1}$UFC/ml

Authors, 2019.

The samples analyzed in the microbiological parameters are within the ranges of the reference standard can be seen in **Table 5**.

DISCUSSION

The guayusa leaves and native soursop leaves drink T1 had a pH of 4.24. This value was similar to previously reported data, for example, pH values ranging from 3.13 to 4.20 in beverages have been determined using different forms of elaboration in addition to concentrations of guayusa leaves (Bolade, Oluwalana, & Ojo, 2009); while soft drinks produced from the soursop leaf have shown pH values of 2.0 to 3.89 (Nassareddin & Yamani, 2005). The high levels of acids observed in drinks using both raw materials, is attributed to the existence of organic acids such as acetic, malic, citric, and tartaric, given by the use of lemon and guayusa essence (Singh, Ganeshpurkar, Narwaria, Raí , & Pal, 2011); While formic acid such as acetic, oxalic, succinic, tartaric and malic are components of the calyces of the guayusa leaf (Ibrahim, Hasan, & Khalaf, 2015), the presence of these compounds provide the food with a considerable antimicrobial action (Gould, 1994).

The result of the total soluble solids (SST) for the drink T1 starting at 6.6 ° Brix, these keep certain distances with similar studies carried out previously, it can be mentioned that in guayusa drink, SST values have been found that vary from 8.20 to 11.21 ° Brix (Fasoyiro, Babalola, & Owisibo, 2005). The content of soluble solids quantified in Brix grade constitutes a quality parameter widely monitored in the fruit and juices producing industry, since they provide approximate content of sugars present, although it is also composed to a lesser extent of soluble pectin's, organic acids and amino acids (Verma & Joshi, 2000).

The product with the highest sensory acceptance by the evaluator panel was T1, consisting of 15% guayusa leaves and 5% native soursop leaves. The high trend could reflect the relative lack of knowledge of the combination of guayusa leaf and guanabana leaf among the evaluation participants, therefore, some of its organoleptic characteristics may not be as attractive, compared to other leaf species. They are more consumed and have more acceptance in the local population, such as the green tea leaf, chamomile and anise. This behavior is revealed in a study carried out in the province of Guayas, city of Guayaquil, where 85% of 500 people surveyed are unaware of the offer of products based on guayusa leaves and soursop leaves (Jácome, Saltos, Gonzales, & Valdiviezo, 2011).

CONCLUSIONS

From this research work it can be concluded that the acceptance of the drink through a sensory panel made up of semi-trained people, of the three drinks obtained. In general, the degree of acceptance of the three drinks was quite satisfactory, with the drink from treatment T1 standing out with 15% guayusa leaves and 5% soursop leaves in its composition.

The physical-chemical and microbiological results of the soft drink are within the allowable limits of the INEN 2304: 2016 and INEN 2337: 2008 standards.

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AGRICULTURE

Comparative Study of Trichoderma strains for Controllyng Moniliasis

(Moniliophthora roreri) of Cocoa (Theobroma cacao L.)

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ABSTRACT

At present, the demand for cocoa beans as a raw material for the production of chocolate is continually increasing. However, the production and quality of them require proper management of diseases such as moniliasis, caused by the fungus Moniliophthora roreri, capable of causing considerable losses in the yield and quality of the beans.

The propose of this research was to evaluate the antagonistic effect of a complex of three Trichoderma strains (T. harzianum, T. viride and T. koningii) for the biological and environmentally-friendly prevention of moniliasisin the cocoa pods. This experiment was carried out in the Cumandá canton, province of Chimborazo, with both treatments applied: T1 (Trichoderma complex), and T2 (absolute witness). In each treatment, 15 trees were evaluated -The experiment was composed of a total of 30 trees or experimental units. The data were statistically analyzed based on the Student's T-test to verify the significant effects of treatments. Variables of severity and incidence of the disease (%), internal pod damage (%), symptoms (%), yield (kg/dry/tree) and an economic analysis were determined to evaluate the cost/profit ratio of each treatment. The results allowed to conclude that with the application of T1, the percentages of hardness, incidence, symptoms and internal damage of pods caused by M. roreri reduced; likewise, the increase in yield and the cost/profit ratio could evidence.

Keywords: antagonists, chocolate, phytopathogens, grains, yield

INTRODUCTION

The cultivation of cocoa (Theobroma cacao L.) has a significant importance in Ecuador's economic, social and ecological aspects. INIAP (2015) considers that the commercialization of cocoa beans generates foreign exchange and raw material for national industry, in addition to creating work opportunities for many families involved in agroproductive chains. In addition, cocoa constitutes the habitat of numerous species of flora and wildlife.

At present, small producers are those who exercise the greatest cocoa productive activity, depending solely on this crop for their livelihood (Ramirez, 2014).

Currently, the resistance of organisms in agriculture has grown considerably, one of the main reasons is the indiscriminate use of chemical fungicides. Likewise, another negative effects caused by the inappropriate use of these fungicides is, without a doubt, pollution and toxicity of the environment (Ponciano, 2012).

Hernández et al. (2014) state that the use of antagonistic species for controlling various diseases in the cultivation of cocoa provides positive effects for both the environment and the plant health. The biological control of phytopathogens has aroused great interest due to the severity of the ecological impacts caused by the progressive application of agrochemicals in the crops of interest.

One of the most common antagonists for controlling moniliasisis Trichoderma harzianum, producing changes at the structural level such as cell disintegration, therefore, the objective of the present work is an excellent alternative as a management component for phytopathogenic fungi (Hammer, Martinez and Morán 2017).

Literature review

The history of cocoa in Ecuador has the first reports in the Guayas

river basin. In the seventeenth century, there were small areas dedicated to growing cocoa beans, which spread along the banks of the Daule and Babahoyo rivers. For this reason, Ecuadorian cocoa was called "cacao Arriba" in international markets (Pinto, 2011, p. 30).

In Ecuador, cocoa is produced in 23 of the 24 existing provinces. The highest concentration of the crop is located in the coastal provinces (Los Ríos, Guayas, Manabí, Esmeraldas and El Oro). Ecuadorian farmers are increasingly opting for this crop because of the stability in international prices in recent years.

The moniliasis directly affects the production and quality of the cocoa beans and is caused by the fungus Moniliophthora roreri. Its inadequate control causes great economic losses for the farmer and it is considered one of the most severe diseases and easy to spread. Krauss and Hidalgo (2013) mention that the biological control of moniliasis is possible with Trichoderma spp., discovering positive results by reducing the populations of the pathogen and its incidence.

Moniliasis (Moniliophthora roreri)

This disease manifests itself with different symptoms according to the age of the fruit at the time of being attacked (Alarcom, 2012). It occurs in all regions where the crop is grown in Ecuador, causing considerable damage and loss.

It is believed that the reproduction of M. roreri is asexually performed by conidia, because its perfect (sexual) state is not known exactly. It should be noted that conidia are the structures capable of causing infection (Sánchez, et al., 2015).

During the dry season there is the highest index of spores in the environment, however, certain humidity conditions are necessary for the beginning of the infection period, because their germination is favored by a light film of water and at an optimum temperature of 24 ° C (Correa, Castro and Coy, 2014).

M. roreri infection in cocoa pods can occur at any age with the same severity. The symptoms of the disease are in the form of wilting, necrotizing and deformation in young pods (Suárez, 2003). It also produces premature maturity

ending with the maceration and rot of the pods.

In general, the spreading of the fungus is caused by wind, rain and to a lesser extent by insects. Recent studies show that sporulation densities of M. roreri reach 44 million spores per square centimeter (Gallego, et al., 2016). The main source of inoculum to start the moniliasis infestation is the spread of spores.

Use of antagonists

Recent studies have shown that the use of antagonists has positive effects controlling fungal diseases, this action is used as a form of biological control of pathogens. Cano (2011) points out that the microorganisms most used in agriculture are Pseudomonas, Bacillus and Trichoderma. The latter is the most used for the control of several pathogens of importance for agriculture (p.18).

Trichoderma harzianum

The genus Trichoderma has several species that exert control in phytopathogens such as M. roreri with various modes of action such as: competition for nutrients or space, antibiosis, modifying environmental conditions or more directly through mycoparisitism (Benitez, 2008).

Trichoderma harzianum mycoparasitism consists in the production of toxic enzymatic secretions that cause decay and death in the pathogenic fungi that inhabit the soil and plants. As well as the production of volatile chemicals, antibiotics and antifungals that inhibit the growth and reproduction of fungi (Chiriboga, et al., 2015).

Trichoderma viride

This antagonist adapts to several habitats, but preferably those soils with a high content of organic matter or decomposing plant wastes, also in crop residues especially in those that are attacked by other fungi. Leal, et al., (2014) report that no study has been presented to prove parasitism in any plant; However, it is capable of parasitizing, controlling and destroying many fungi, nematodes and other phytopathogens, which

attack and destroy many crops.

The mode of action of Trichoderma viride consists on inhibiting the growth of phytopathogenic fungi by generating rupture in the walls of the fungus, penetrating it through the hyphae and acquiring its nutrients; simultaneously produces antibiotics such as tricodermin that cause an effect of fungistasis on the pathogen (Acosta, 2015).

Trichoderma koningii

Several studies have shown that the antagonistic capacity of Trichoderma koningii will depend on the specificity of the isolated strain. Arias (2014) states that it is possible that there are isolates that are more efficient for the control of one pathogen than for another; in such a way that this specificity should be measured, and in case of having situations of this type it is recommended to use mixtures of antagonistic strains, in order to control the action of pathogenic populations (p.18)

METHODOLOGY

An experimental study was conducted in which treatments with three strains of Trichoderma, (T. harzianum, T. viride and T. koningii) were evaluated at a concentration of (fifty billion viable spores per gram) plus an absolute control, to determine if the application of these strains effectively decreased the incidence of moniliasis in the cocoa pods. The data obtained from the experimental units was collected out under a non-random sampling, where at the beginning of the trial 30 cocoa trees were chosen within the study area.

The independent variables were represented by the application of the three strains of Trichoderma (T. harzianum, T. viride and T. koningii), while the dependent variables evaluated were symptoms, disease severity, disease incidence, internal damage, yield in dry cocoa / tree.

The symptoms were evaluated in 10 random cocoa pods for each experimental unit, for which it was necessary to use a magnifying glass (10x) to determine the presence of the pathogen based on the following ordinal scale; zero (0) was equal to the healthy pods and one (1) to the diseased pods affected by M. roreri at 62, 77, 92, 107 and 122 days after the application of the treatments. With the severity of the disease, the fruit was classified according to the symptoms by using a qualitative scale to assess the damage of the fungus. In order to determine the percentages of damage caused by M. roreri. The external incidence of the disease was evaluated as a percentage of the incidence in each ear of each experimental unit, at 62, 77, 92, 107 and 122 days after the application of a complex of three Trichoderma strains. The internal damage of cocoa pods affected by M. roreri was evaluated, separating healthy grains from patients and expressing their weight in percentage and these evaluations were performed at the time of harvest. The dry weight / tree yield to obtain this variable proceeded to ferment and dry the harvested cocoa beans, which were adjusted to 7% humidity and measured in kilograms of dry cocoa per tree. Two crops were made, at

122 days and 137 days after the first application. The economic analysis was based on the benefit / cost ratio of each treatment under study. The treatments studied are detailed in Table 1.

Table 1. Treatments under study to control moniliasis.

No	Biofungicide	Spore content / gram	Dose
1	T. harzianum, T. viride and T. koningii	$5x10^{10}$	200 g/ha
2	Absolute witness		No application

Once the data was obtained, an analysis was carried out based on the Student t test to verify significant effects of each treatment. The experimental unit consisted of a cocoa plant, in which the incidence of Moniliophthora roreri and crop production were evaluated.

RESULTS

Disease severity (%)

Figure 1 shows the efficiency obtained after the application of T. harzianum, T. viride and T. koningii (T1) compared to treatment 2 (without application). Where it is observed that the percentage of disease severity decreased with the application of the Trichoderm complex, with an initial average of 9.51% to 5.89%. While it increased considerably in cocoa pods in which biofungicide was not applied (treatment 2) and averages of 21.99% to 24.38% were obtained.

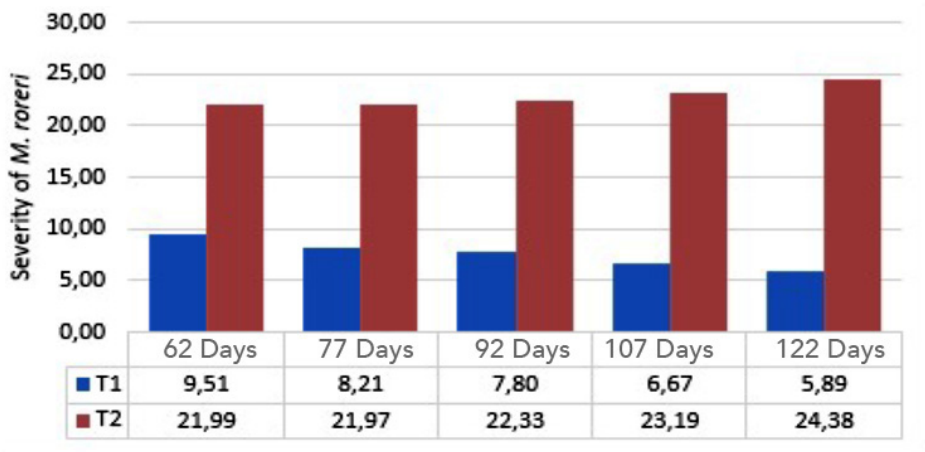

Figure 1. Severity of M. roreri at 62, 77, 92, 102 and 177 days of the evaluation.

Disease incidence (%)

Figure 2 Allows us to interpret that with the application of the Trichoderma complex, the incidence percentage of M. roreri decreased effectively in cocoa pods in relation to the time of application with an initial average of 13.50% to 5.33%. While the control treatment increased the percentage of incidence of the disease.

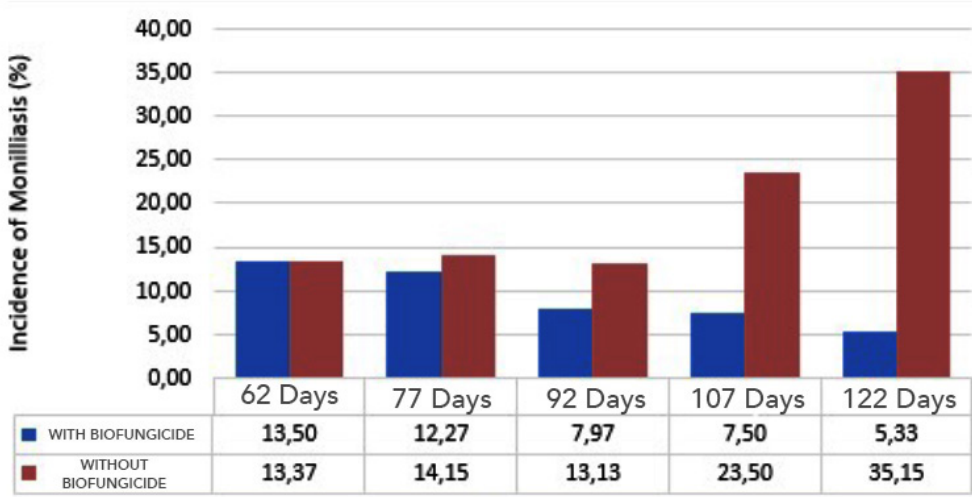

Figure 2. Incidence of the disease according to the time evaluated

Internal damage of pods (%)

The data obtained in the internal damage of the pods at the time of harvest are presented in Figure 3. According to the Student t test there were significant differences between the treatments. The highest average internal damage was obtained by the control treatment or without application of the biofungicide (T2) with a percentage of 70% of damaged grains due to moniliasis.

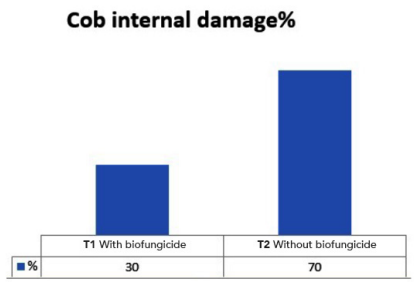

Figure 3. Internal damage of cocoa pods (%).

Symptoms of healthy fruits and diseased fruits

This variable consisted of grouping healthy fruits by means of the scale (0) healthy fruits and (1) diseased fruits for which a proportion of the total healthy fruits was made over the total fruits evaluated at 62, 77, 92, 107 and 122 days after the application of treatments. According to Student's t-test, the presence of statistical differences was determined, where treatment 1 (with biofungicide) obtained the highest percentage of healthy fruits with an average of 73.32%. Treatment 2 (without biofungicide) reached an average of 36.68% of fruits without symptoms of moniliasis. The highest percentage of fruits with symptoms of M. roreri was obtained by treatment 2 (without biofungicide) with 61.32%. The symptoms of the disease decreased with the application of biofungicide (T1), obtaining an average of 26.68% of diseased fruits.

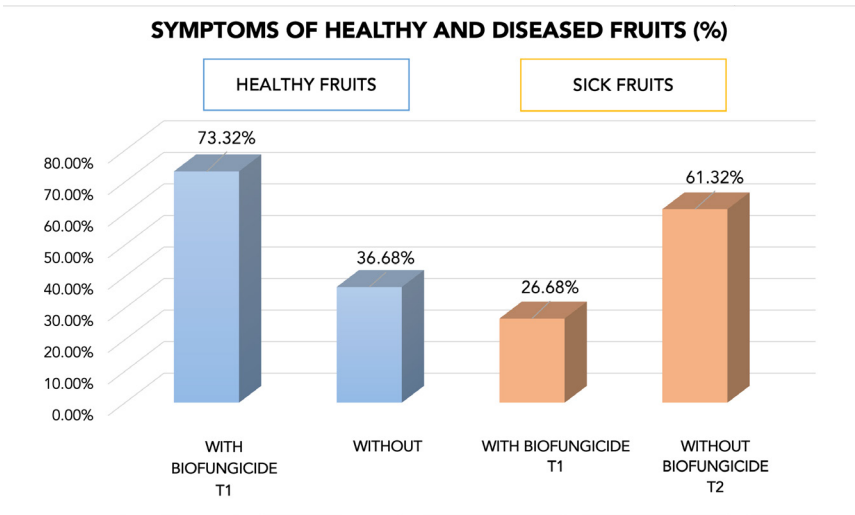

Figure 4. Symptoms of healthy fruits and diseased fruits in percentage.

Dry / tree weight yield

The Student's T test analysis for the dry cocoa yield per tree, showed significant differences between treatments with and without biofungicide application (T. harzianum, T. viridae and T. koningii). Treatment 1 (with

biofungicide) obtained the highest yield with an average of 1.49 kg, while treatment 2 (without biofungicide) reached an average of 0.99 kg of weight.

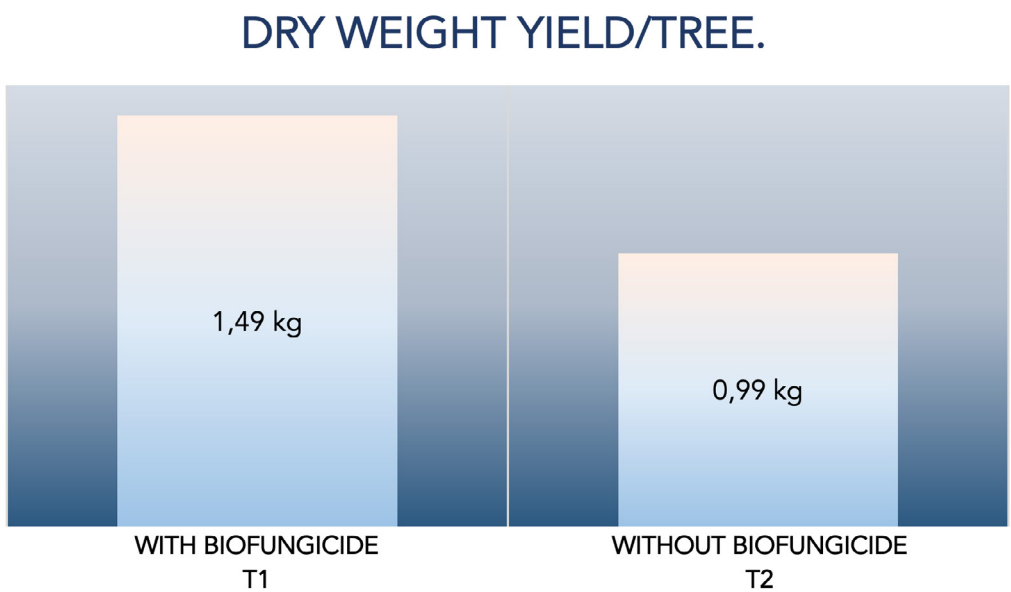

Figure 5. Dry weight yield / tree of each treatment.

Economic analysis

Table 2 specifies the economic analysis of the trial, for which a 5 % adjustment was made in the cocoa yield in the evaluated treatments. The total income was obtained according to the current price of dry cocoa at 7% humidity ($100 / quintal). The fixed cost was determined according to the production cost for a cocoa plantation established in one hectare.

With the obtaining of these data, the cost/profit ratio of the experiment was calculated, where the highest RBC was 1.21 corresponding to the treatment with application of biofungicide (T2), which indicates that this

treatment offers greater profitability for cocoa cultivation.

Table 2. Average damage due to Moniliasis(%).

COMPONENTS	T1 (WITH BIOFUNGICIDE)	T2 (WITHOUT BIOFUNGICIDE)
Yield (quintal/ha/year)	45.39	32.50
5% adjusted yield	43.13	30.88
Gross income (%)	4313	3088
Fixed cost ($)	1918	1918
Variable cost ($)	30	0
Total cost ($)	1948	1918
Net profit ($)	2365	1170
Cost/profit ratio	1.21	0.61

D I S C U S S I O N

This research agrees with the studies carried out by Martínez and Reyes (2013), who detected in their essay on the effect of certain Trichoderma species on the control of moniliasis that T. harzianum decreased the symptoms that attack cocoa pods, while T. viridae degraded phytotoxins produced by various pathogens that affect crops. In addition, they confirmed Trichoderma's ability to produce a regulatory factor for plant growth and agricultural land improvement.

Carvajal, et al., (2012), confirmed through their study that fungi of the genus Trichoderma, such as harzianum, koningii and viridae parasitize the hyphae and mycelia of M. roreri and M. perniciosa in cocoa, which is possible through the production of metabolites called Trichodermin, viridin, richotoxin and enzymes such as glucanase, chitinase and cellulase

that allow it to exert its effect on cell walls and thus significantly reduce the severity and incidence of moniliasis.

The experiment conducted by Brito, Salaya, López and Gómez (2017) regarding the isolation of M. roreri presented positive results to verify the antagonistic capacity of the genus Trichoderma. Through microscopic observations, Trichoderma structures were demonstrated acting on the spores of M. roreri until they were deformed and caused their death, making clear their antagonistic power over this phytopathogen.

Solis and Suárez (2012) obtained positive results with the application of a Trichoderma complex, with the purpose of suppressing the development or incidence of M. roreri in cocoa pods. Applications were made monthly during the rainy season. During the evaluations significant differences were found when obtaining a smaller number of pods sporulated with M. roreri. With the use of Trichoderma (viridae, harzianum and koningiopsis) the production of healthy pods increased between 16 and 20 % in relation to the control. These studies agree with the results of this research.

CONCLUSIONS

The application of Trichoderma harzianum, viridae and koningii effectively reduced the percentage of severity and incidence of M. roreri in cocoa pods.

The internal damage of pods obtained the lowest percentage with the application of the Trichodermas complex compared to the absolute control or without application.

The presence of moniliasis symptoms was verified, which appeared in 61.3 % of the pods without biofungicide application, while for the biofungicide treatment only 26.6 % of fruits affected were obtained.

The economic analysis determined the profitability of applying the biofungicide, which allowed to obtain a better yield and therefore a higher profit/cost ratio.

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BIOLOGICAL CONTROL OF ANTHRACNOSE COLLETOTRICHUM GLOEOSPORIOIDES

(Penz. & Sacc.) in red dragon fruit (Hylocereus undatus (Haw.) Britton & Rose by antagonistic microorganisms in Cerecita Guayas - Ecuador

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ABSTRACT

The cultivation of red pitahaya in Ecuador has a great economic potential. It is a fruit with organoleptic characteristics appealing to national and international markets. As it is a non-traditional crop or recently exploited in the country, the research for the treatments of different diseases are scarce.

That is why this research was based on studying the effects of the use of antagonistic microorganisms independently and in combination to control the disease known as Anthracnose. The evaluated microorganisms were Trichoderma spp. and Bacillus subtilis. The trial took place at Cerecita site in the province of Guayas-Ecuador at "Voluntad de Dios" farm. The test was carried out by implementing a completely randomized block design (CRBD) with four treatments and five repetitions, obtaining as results that the T2 treatment consisting of the combined use of Trichoderma spp and Bacillus subtilis had an important control in the disease, matching the conventional T4 treatment with the use of agrochemicals. In addition, the T2 treatment showed the highest fruit yield expressed in Kg / Hectares.

Keywords: Bacillus subtilis, biofungicide, phytosanitary control, trichoderma.

INTRODUCTION

Cacti are a group of plants that are characterized by being an important source of food, they adapt to adverse edaphoclimatic conditions and also generate an ornamental interest. Within the family of cacti, a genus with a high economic and productive potential was found which is known as Hylocereus, whose species have a variety of fleshy fruits that are commonly known in some regions as "pitahayas" (Legaria, Alvarado and Hernández, 2005).

According to Ramalho et al. (2018), Pitahaya is a fruit that is considered as "exotic" in many countries, and has become a promising crop because of its taste and its particular external shape, which attracts the attention of the markets and becomes a crop profitable. Because it is a recent crop, studies to manage its production are necessary.

In Ecuador, this non-traditional crop is distributed in the provinces of Pichincha, Morona Santiago, Loja, Guayas and Los Ríos. The country is promoting fruit in international markets generating government projects to make exports viable and thus obtain commercial and economic benefits (Huachi et al., 2015). The production of pitahaya in Ecuador varies every year as there are two well-marked climatic seasons, the dry season and the rainy season. In the last mentioned climatic conditions favor the development of diseases, for which farmers seek viable alternatives for the health care of crops (Cabrera et al., 2018).

To take advantage of the commercial opportunity of the Pitahaya it is important to deal with the pests and diseases of the crop in order to obtain the expected benefits. This article presents an alternative in the management of the Anthracnose disease. The ICA manual (2012) entitled "Phytosanitary management of the cultivation of pitahaya" describes the anthracnose caused by the fungus Colletotrichum gloeosporioides (Penz.) Penza. & Sacc. which attacks the fruits and the

rod, strong incidents in Colombia of up to 16.6% are reported (Araujo and Medina, 2008). This disease consists of small circular spots of brown color, which in advanced stages necrotic the tissue causing perforations and causing injuries in the fruits and in the penca, thus reducing the leaf area that generates the photosynthetic process of the plant.

An alternative for the control of the disease known as anthracnose is the use of antagonistic microorganisms, so the objective of this research is to evaluate the use of two microorganisms. Trichoderma spp and Bacillus subtilis applied individually and combined in the treatments. Both microorganisms have benefits when they are applied to crops, but the detailed research is limited in the case of pitahaya for which this one was posed in order to obtain relevant data for dissemination to the scientific community.

Literature review

In the cultivation of pitahaya considered an unconventional crop and of recent exploitation and commercialization, the research regarding this cultivation in Ecuador is scarce, especially in terms of control of pests and diseases, however, there are relevant studies in the biological control of anthracnose with the use of the microorganisms mentioned in other regions and in other crops, as a clear reference of the benefits of applying these alternatives in our research.

In the case of the first Trichoderma spp. is a genre noted for being the most studied for the biological control of fungal diseases in agriculture. There are several species that can be used and some of them have characteristics or mechanisms of action that inhibit the development of pathogenic microorganisms responsible for crop diseases. The greater the effectiveness of this mechanism of action against the pathogen, the possibility of becoming an efficient method for the biological control of diseases that until now are treated using chemical products will increase (Infante et al., 2009).

On the other hand, the genus Bacillus is a bacterium that is widely distributed, it is studied for its main mechanisms of action, which consist of the excression of substances as a result of its metabolism such as:

Toxins, antibiotics, siderophores, lytic enzymes, also it causes a systematic resistance in the plant. Focusing on its capacity as a biological controller, it has been implemented in the formulation of biopesticides (Villareal et al., 2018).

The use of biofungicides has shown to have such good results as that of synthetic chemical fungicides, coming to compete directly with the results in the control of diseases such as the case of anthracnose, in addition the advantage that antagonistic microorganisms have is that they become effective in stimulating the defense mechanisms of the plant that, in combination with the appropriate products, can be successful in the management of anthracnose (Landero et al., 2016)

In Venezuela, a study on the use of Trichoderma harzianum and Bacillus subtilis for the control of Colletotrichum gloeosporioides in Mangifera indicates as detailed by Sanabria, Santander and Hernández. (2012) determined that, once the degree of severity of the disease was evaluated, the best used treatment for its trials was the combined use of the antagonistic microorganisms, checking in this way the potential use to control this disease.

In the obtained results in the research of Gaviria et al. (2013), it is concluded that with the use of products whose active ingredient were microorganisms of the genus Trichoderma, a strong degree of mycoparasitism was achieved and rapid colonization in the culture media, which leaves an antecedent of its potential utility as biological controllers of C. gloeosporioides.

METHODOLOGY

This experimental work was carried out through a Completely Random Block Design (CRBD), which has a total of four treatments as described in ***Table 1***, carrying out a total of five repetitions. Given the type of research, the statistical test that was adjusted to the analysis was Tukey with a defined probability of 5% for the evaluation of the research variables.

Table 1. Description of the treatments to use in the experimental test.

Treatment	Description	Doses	Frequency of Application (days)	% Doses
T1	Trichoderma spp.	2.025 g	1-15-30-45	100
T2	Trichoderma spp. + Bacillus subtilis	1.52gr + 5.06 cc	1-15-30-45	75
T2	Bacillus subtilis	6.75 cc	1-15-30-45	100
T4	Cuprifun	1.69 cc	1-15-30-45	100

As shown in ***Table 1.*** the doses were adjusted according to the recommendation of the used products. The applications were divided into four occasions as indicated by the frequency of them and the evaluations were also carried out in the same time interval (every 15 days) obtaining three groups of data: at the beginning, in the middle and at the end of the treatment with a duration 45 days in total.

T4 consisted in the application of a product called Cuprifun of synthetic

origin whose active ingredient is copper Naphthenate.

An initial parameter of the variables of interest against the treatments and their response in the crop yield was established, for this, the average of the five repetitions was analyzed, obtaining as sampling results at the beginning, middle and end of the treatment.

The present research focused on the variable of the percentage of incidence of the disease (Anthracnose) measured in both flowers and fruits. In the flowers, the number of present flowers in each plant was evaluated and in the fruits, the quantity of fruits that presented symptomatology of the disease was evaluated. Having as response variable to the treatment in the crop yield estimated in kg / Hectare in each of the treatments.

The distribution of Experimental Units (EU) is based on the randomness of the blocks. The test was carried out in Cerecita canton in the province of Guayas, in a property located at Km 51 via Guayaquil-Salinas in the farm "Voluntad de Dios" whose coordinate is 2 ° 21'09.7 "S 80 ° 15'35.9" W

RESULTS

In ***Fig. 1***, the data for each of the repetitions within the treatments are observed. The first result indicates that the number of flowers per planttt did not show a significant difference between treatments T1, T2, T3, with the exception of T4, which shows a lower number of flowers per plant in the pitahaya, so that it is considered that all the other delimited pieces of ground have a similarity.

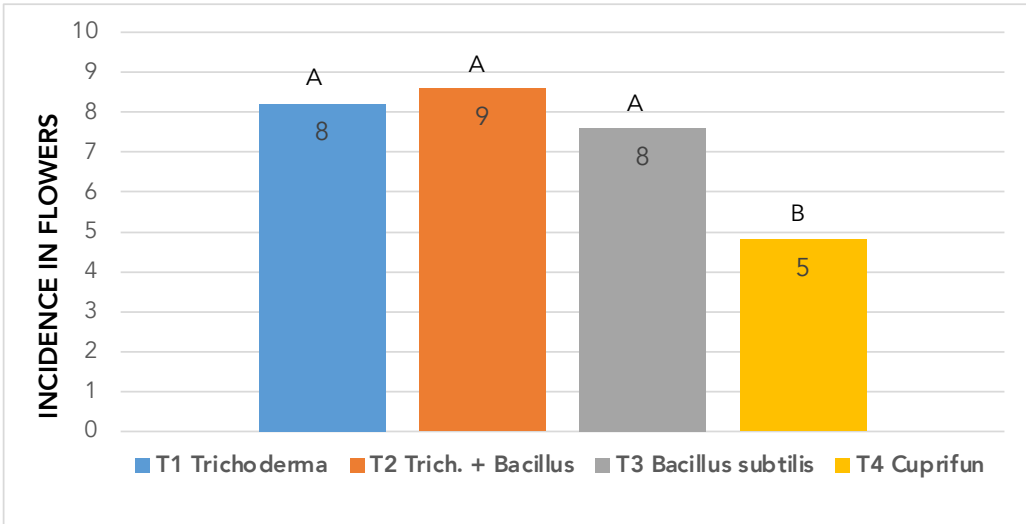

Fig. 1 Total Average of flowers/plant per treatment.

The number of flowers per plant present in each of the plots was similar in each treatment. The clear difference was in the T4 treatment with the use of Cuprifun, it might be because the implementation of this product affects the flowering process of pitahaya, which will directly affect the yield.

The percentage of the incidence of flower anthracnose per plant at the beginning, middle and end of treatment is shown in ***Table 3***. T2 had a lower presence of the disease compared to other treatments, although T2 had a lower presence of the disease, however, it is not statistically representative according to the Tukey test shown in ***Table 3***.

Table 2. Percentage of incidence of Anthracnose in flowers per plant.

TREATMENT	INTERVAL			Σ	TOTAL AVERAGE
	BEGINNING	MIDDLE	END		
T1 Trichoderma	31%	34%	36%	101%	33,67%
T2 Trichoderma + Bacillus	25%	23%	22%	70%	23,33%
T3 Bacillus subtilis	34%	37%	39%	110%	36,67%
T4 Cuprifun	32%	28%	27%	87%	29,00%

Table 3. Tukey test for the percentage of incidence of Anthracnose in flowers per plant.

TREATMENT	MEANS	n	E.E.	
T1 Trichoderma	0,15	5	0,3	A
T2 Trichoderma + Bacillus	0,15	5	0,3	A
T3 Bacillus subtilis	0,14	5	0,3	A
T4 Cuprifun	0,11	5	0,3	A

In the case of the incidence of Anthracnose by fruit the results displayed that two of the treatments T2 and T4 showed significant differences compared to treatments T1 and T3, and that there were also significant differences between them considering the sample collection intervals. The highest incidence of the disease on fruits occurs in the T3 treatment with the use of Bacillus subtilis and the lowest incidence occurred in the T2 treatment with the combined use of Trichoderma spp. + Bacillus subtilis even if without a noticeable difference compared to the conventional T4 treatment as can be seen graphically in ***Fig. 4.***

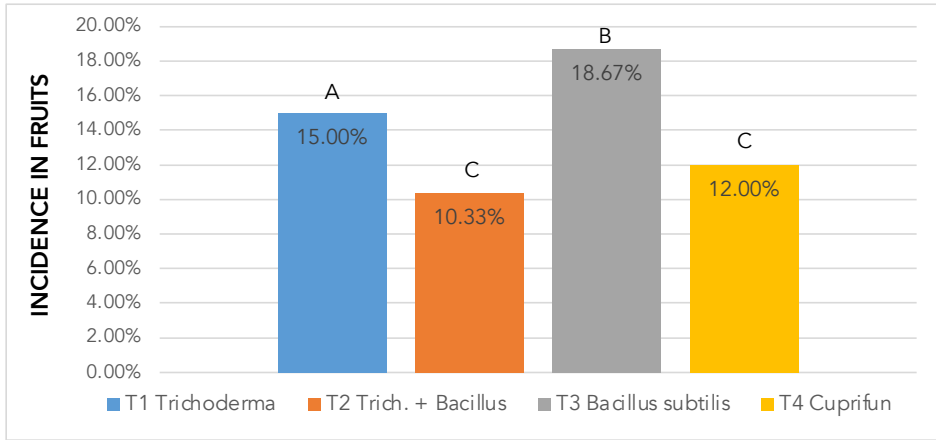

Fig. 4 Total Average of the incidence of Anthracnose in fruits per plant in the different treatments.

Finally, as shown in the results of the analysis of crop yield in Kg / Hectare, the data collected from each of the treatments and their respective repetitions are summarized, observing graphically through ***Fig.5***. that the treatment with the highest yield was T2 with the combined use of Trichoderma spp. + Bacillus subtilis followed by the conventional treatment T4 Cuprifun, which despite having controlled the incidence of the disease in a similar way to T2, in performance, a significant difference is demonstrated, therefore, the treatments of lower yield were T1 and T3 respectively .

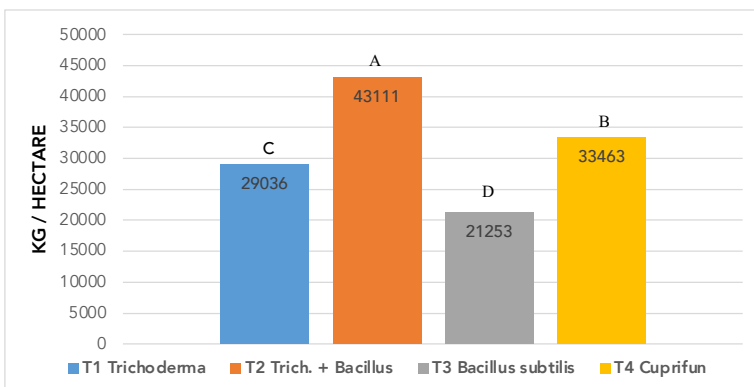

Fig. 5 Performance of the crop in Kg/Hectare

The study shows how treatments infer in the incidence of the disease, and observe that anthracnose manifested itself in different ways in each of the treatments.

As soon as the crop yield, it was obtained as a statistically significant result that the T2 treatment had a higher yield in Kg / Hectare compared to the other treatments, the second one with the highest yield was T4.

DISCUSSION

In the incidence of anthracnose, clear differences were found, the individual use of these microorganisms are not efficient compared to conventional treatment or T4, but the combined use generates a positive synergism as corroborated by Cano (2011) since it statistically matches conventional treatment without affect the flowering process of the crop.

There are several factors that affect the optimal production of flowers in pitahaya plants, according to Manzanero et al (2014), these factors can be: droughts, sun exposure, humidity, fertilizer use and agrochemicals. It is clear that the optimization of pitahaya production must be related to the use of alternatives that improve the conditions of crop development.

Although T2 and T4 are statistically similar with respect to crop yield, it is worth mentioning that the use of microorganisms for the control of phytosanitary diseases tends to generate different opinions because organic products cannot compete with chemical products, but we can argue that it is possible that the use of organic products may outperform the chemicals currently used for the management of diseases such as anthracnose as demonstrated in this research.

In the yield, the differences are clear, it is known that the use of microorganism stimulates the plant's self-defense system in addition to secrete beneficial substances in them, which brings with it positive results when evaluating the overall yield of the plantation (Corrales et al., 2017). The T2 treatment was the one that presented 23.40% more performance compared to the T4 which is conventional.

The total yield of the T2 treatment is interesting because it presented a value of 43111 Kg per hectare, which is an above-average yield in this variety that is 40,000 Kg per hectare.

Although pitahaya is currently managed in a conventional mode with the use of synthetic and agrochemical fertilizers, the use of microorganisms can have a beneficial participation in crop yield becoming a justifiable alternative to adopt in the ways of controlling various diseases, among them the anthracnose.

CONCLUSIONS

The T2 treatment consisting of combined use of Trichoderma harzianum plus Bacillus subtilis and the T4 treatment consisting of the use of an agrochemical called Cuprifun, presented the best result in terms of controlling the incidence of the disease known as anthracnose whose causative agent is Colletotrichum gloeosporioides.

Although the combined use of Trichoderma harzianum and Bacillus subtilis showed a control of the incidence of anthracnose in a similar way to the conventional treatment with the use of an agrochemical, the use of biological controllers can positively influence biostimulant factors to the net yields within the crop, so that they provide a multiple action between fungicide and biostimulant for the cultivation of red pitahaya.

The success in the presented performance by the T2 treatment is related to the number of flowers per plant compared to the T4 treatment, and it is concluded that, as a result of producing more flowers, the crop yields were higher.

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ACCELERATION OF THE PRODUCTION OF ORGANIC FERTILIZERS

from cocoa residues through the use of hydrolytic fungi in laboratory

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ABSTRACT

In Ecuador, it is necessary to utilize the harvest residues from the cocoa crop because they are not properly used later. The use of hydrolytic fungi can help accelerate the process of organic matter decomposition. In this study the effect of hydrolytic fungi on the production rate of organic fertilizers from cocoa residues was evaluated. A completely randomized experimental design was carried out with a 3 x 4 factorial arrangement, with 12 treatments and 3 repetitions. In the trial, three doses of Trichoderma harzianum were applied on three different organic substrates and compared with the absolute control. The best ones were dose 1 (0.051g/m^3) and dose 2 (0.5g/m^3) of the fungus. They accelerated the decomposition of cocoa residues (pod, leaves and husk) in a shorter time; however, in dose 3 (1g/m^3) and in the control, no action was observed on the acceleration of the decomposition of these residues. The experimentation conditions of the composting process using hydrolytic fungi to degrade cocoa residues achieved a medium with favorable temperature and pH to accelerate decomposition in the elaboration of organic fertilizers. It was observed in this study that the treatment composed by Husk + Trichoderma harzianum stood out with a benefit/cost of $ 1.78; while it was lower in the treatments with pods and leaves, with $ 1.05, respectively.

Keywords: Theobroma cacao, decomposition, crop residues, Trichoderma harzianum.

INTRODUCTION

The use of organic fertilizers in agriculture is a practice that has been gaining acceptance in recent years due to all the benefits it contributes, such as the improvement of the soil physical, chemical and biological conditions, among others (Cotching, 2018).

Ochoa (2008) states that the soil cannot produce its food by itself; that is why organic fertilizer becomes a life source for soil microorganisms. As it is known, it has millions of microorganisms that transform minerals into assimilable elements for the plants. These fertilizers are environment-friendly because their ingredients are natural; they increase the organic matter content of the soil and are low-cost. Trichoderma has been used at present in ecological agriculture for the control of root diseases, organic matter degradation and plant protection (Collado et al., 2019). It generates a relation with the plant roots to obtain a benefit in exchange for returning a positive effect to the plants (Silva et al., 2019). That is the reason for the massive use as inoculant to strengthen the plant and this fungus generally adapts well to increasingly aggressive and damaged soils (Oskiera et al., 2017).

In cocoa production zones there is no adequate assessment in programs on waste management after harvests. That is why these technological processes such as fertilizer elaboration are important, because they allow to treat rationally the organic waste and preserve the nutrients that are in these residues to be used later in agriculture. This technique consists in the biological decomposition under controlled aerobic and thermophilic conditions to obtain mature compost in the required time, through the use of organic waste (Banco Central del Ecuador, 2012).

The residues from the cocoa forest constitute a large source of organic matter that, through mineralization, generate a high amount of nutrients for plants, among other services. The cocoa residues, mainly the pods, are slowly degraded under natural conditions, especially due to the high content of cellulose

and other carbonated compounds, increasing the carbon content for which they require the addition of nitrogen sources that allow a better balance of the C/N ratio (Venkatesh & Anshumali, 2019).

Most soil microorganisms are primary decomposers, like Trichoderma which acts degrading the organic and inorganic substrates, releasing nutrients and energy through enzymatic systems, within a variety of huge microspaces. These organisms constitute the basis of multiple organic preparations (Piedrabuena, 2007).

Cruz (2000) states that, in Azuay, Cañar, Loja and Tungurahua, the production system implanted under the arguments of the "Green Revolution", based on monoculture with high technology, encouraged the indiscriminate use of chemicals, causing erosion, salinity, compaction and edaphic contamination, reducing the harvests and product quality, destroying most agricultural soils. Due to the above-mentioned facts, the objective of the research was to evaluate the effect of hydrolytic fungi on the production rate of organic fertilizers from cocoa harvest waste, under laboratory conditions.

METHODOLOGY

Essay management

The trial was conducted in the soil laboratory of the Agricultural University of Ecuador.

Microcomposting boxes were elaborated with Flex Foam 15 cm long, 15 cm wide and 30 cm long. They were lined with black polyethylene plastic and in order to make it more resistant it was packed with duct tape; plywood was placed as base for the box to provide more support on the bottom and it was perforated to drain the water.

For degradation to occur more easily, the fruit shells were crushed to a measure of 5 mm, the leaves were crushed to 1 cm and the husk already comes with the crushing process.

The quantity that was put to decompose in each treatment was two 10-cm layers of fruit shell and one 10-cm layer of manure. The same procedure was carried out with the husks and leaves. The respective dose of the fungus was added; for such purpose, a conversion was made to determine the correct value of the doses to be applied.

The essays were weekly irrigated, leaving them at field capacity so that the fungus could act under optimum conditions. Samples were taken, the first one at 30 days and then every week until the compost was entirely degraded.

Manure and cocoa waste layers were alternated; an organic product based on the fungus Trichoderma harzianum was applied on them, according to the treatments outlined in the study. The 12 treatments were weekly evaluated to guarantee an optimum environment for the fungus. The samples were taken from the central part of the boxes. The cocoa husk was purchased at the Agroscopio company, located in Guayaquil. The shells and leaves were collected from the La Florencia farm of the Milagro canton, with the UTM coordinates: X 656344.3, Y 9764051.9. The cattle manure was obtained

in the Patricia farm located in the Lomas de Sargentillo canton, with the following UTM coordinates: X 656344.3, Y 9764051.9. The product based on Trichoderma harzianum was purchased at the store AGRITOP, located in Guayaquil Km. 3 Samborondón road.

Experimental design used

The experimental design was complete randomized with 3 x 4 factorial arrangement, with 12 treatments and 3 repetitions. The variables were evaluated through a variance analysis to determine the results of the treatments with a 5 % error.

Twelve treatments were carried out (***Table 1***) to determine the combination for fastest decomposition.

Table 1. Description of the evaluated treatments, doses and applied product

TREATMENT	WASTE MATERIAL FACTOR (A)	DOSES / TREATMENT FACTOR (B)	QUANTITY RESIDUES	PRODUCT TO BE APPLIED	DOSES / COMPOSTING FIELD
T1: A1B1	Husk + manure	0.051 g/m3	30 cm	Trichoderma harzianum	0.13 g/m3
T2: A1B2	Husk + manure	0.5 g/m3	30 cm	Trichoderma harzianum	1.33 g/m3
T3: A1B3	Husk + manure	1 g/m3	30 cm	Trichoderma harzianum	2.66 g/m3
T4: A1B4	Husk + manure	-	30 cm	Absolute control	-
T5: A2B1	Pod + manure	0.051 g/m3	30 cm	Trichoderma harzianum	0.13 g/m3
T6: A2B2	Pod + manure	0.5 g/m3	30 cm	Trichoderma harzianum	1.33 g/m3
T7: A2B3	Pod + manure	1 g/m3	30 cm	Trichoderma harzianum	2.66 g/m3

T8: A2B4	Pod + manure	-	30 cm	Absolute control	-
T9: A3B1	Leaves + manure	0.051 g/m3	30 cm	Trichoderma harzianum	0.13 g/m3
T10: A3B2	Leaves + manure	0.5 g/m3	30 cm	Trichoderma harzianum	1.33 g/m3
T11: A3B3	Leaves + manure	1 g/m3	30 cm	Trichoderma harzianum	2.66 g/m3
T12: A3B4	Leaves + manure	-	30 cm	Absolute control	-

The following dependent variables were measured:

Decomposition time; color; apparent density; humidity, content of macro- and micronutrients and free carbonates.

Decomposition time

The decomposition time was measured in a time of 3 months and the first evaluation was done after one month and later, weekly.

Physical aspects

Color

For measuring the color, Munsell color chart was used, because the final product should show a dark brown, almost black, color

Apparent density

The method based on measuring a volume of the organic fertilizer and determining the corresponding mass, was used, then the following formula was applied:

$$D = \text{Weight} / \text{Volume}$$

Moisture

It was determined through the gravimetric method.

Chemical aspects

The laboratory analysis of the organic fertilizers were performed after they were ready (around two to three months depending on the fertilizer type) to determine the nutrients they contained. ***Table 2*** shows the methodologies used.

Table 2. Methodologies used in the determination of the chemical analyses

DETERMINATION	METHODOLOGY
Soil organic matter	Walkey Black (1943)
NH_4	Kjendall (1883)
P	Colorimetry
K, Ca, Mg, Zn, Cu, Fe, Mn	Atomic absorption
S	Turbidimetry
B	Colorimetry
pH	Potentiometry

Free carbonates

Free carbonates were measured only on samples of organic fertilizers which had pH higher than 7.8.

Moisture in humid sample and in dry sample

For the humid sample: Fifty grams of organic fertilizer were weighed with an accuracy of 0.001 g, they were transferred to a capsule and placed in stove at 100 °C (during one hour or more) or until constant weight was obtained between two successive weighing moments. After the indicated time, the sample was removed from the stove and was put to cool. Afterwards, it was weighed in the analytical scale and the weight was recorded.

Calculations:

%Moisture= (Humid Weight – Dry Weight) / Humid Weight *100

For the dry sample: The samples were air-dried, then 50 g were weighed and transferred to a capsule and the same analysis that was done for determining the moisture of the humid sample, was followed.

Apparent Density

The surplus sample from what was left to determine moisture was collected. It was deposited in a plastic test tube and the volume it occupied and the corresponding mass were determined. The sample was carefully deposited in the recipient, moving the test tube lightly for the particles to settle.

Calculation:

Density is determined by the formula: D = Weight / Volume

Free carbonates: qualitative method

Fifty grams were taken from the sample in which pH was equal to or higher than 7.8 and transferred to a 100-150 ml beaker. Drop by drop of the 5 % HCl solution was added. When the acid was added it was observed whether gas (CO_2) emissions occur, which could produce effervescence or foam in the container.

Macro- and microelements

Compost samples were taken to be carried to the soil fertility laboratory of the National Autonomous Institute of Agricultural Research (INIAP) and to the laboratory of the Agricultural University of Ecuador for their respective interpretation.

Temperature

The thermometer was placed at the center of the sample at a reasonable depth and the temperature measures of each sample were obtained.

Color

In order to determine color the sample was placed on a card and it was spread with a spatula to have a better vision and the color of each compost sample with its respective determinations was observed through Munsell chart.

R E S U L T S

Decrease was observed in the compost volume at the end of the process (two to three months according to the residue type); the recovery percentage obtained from compost was: husk, 90 %, leaves, 66.6 % and pod, 33 % ***(table 3)***.

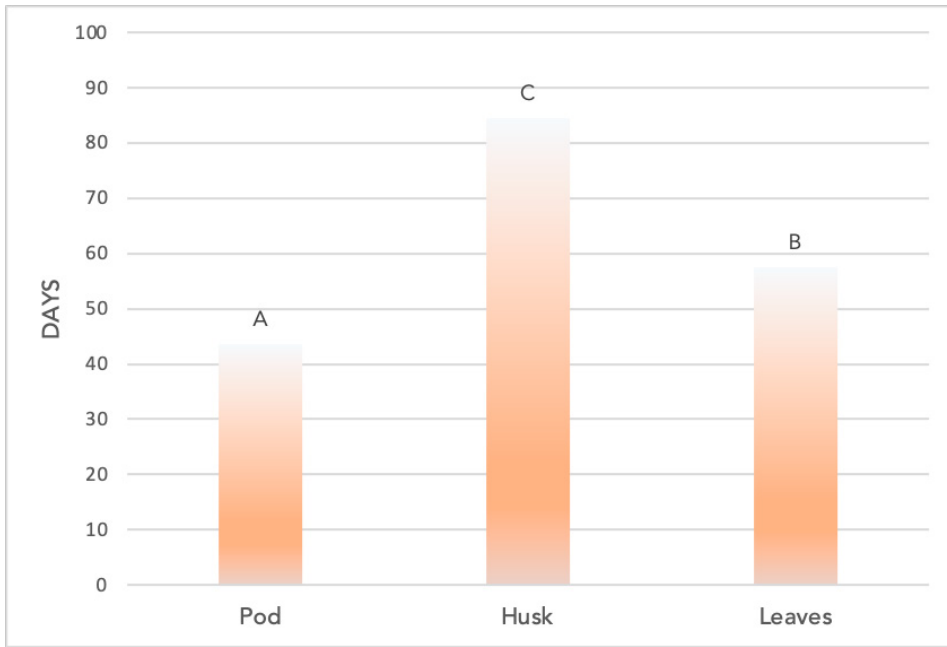
Table 3. Organic matter recovery

	HUSK	LEAVES	POD
Initial Quantity	30 cm	30 cm	30 cm
Final Quantity	27 cm	20 cm	10 cm
Recovery	90 %	66.6 %	33 %

Decomposition time

According to the data obtained through Tukey's test at 5 %, figure 1 shows the average times of elaboration of the compost. According to the variance analysis statistical significance was found among the means of the residues. The pod compost was the one that took less time to decompose with an average of 43,50 days; while the one that took longer was husk with an average of 84,50 days.

Figure 2 shows that the fungus Trichoderma significantly influenced the decomposition rate of the organic residues; however, the highest dose was not the most effective one. The most logical explanation is that the fungus rapidly colonized the plant material making the dose used insignificant.



Means with a common letter are not significantly different ($p > 0.05$)

Figure 1. Elaboration time of the pod, leaf and husk composts.

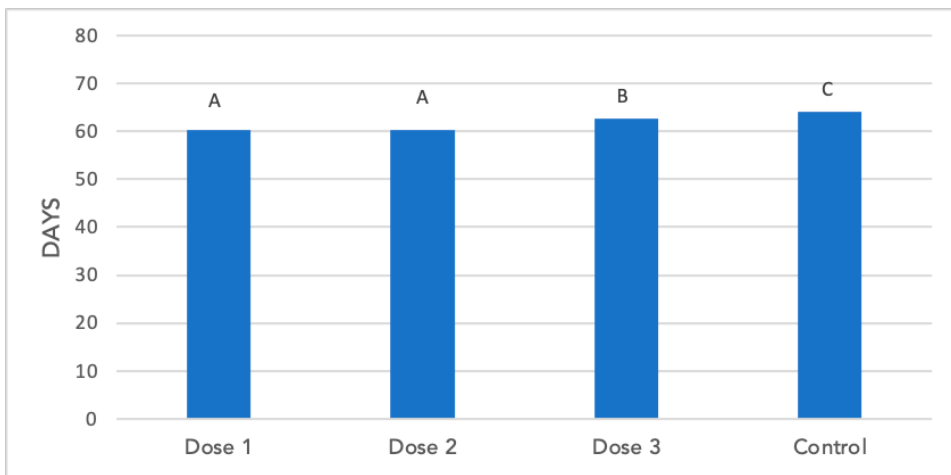


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Figure 2. Decomposition time of the cocoa pod, leaf and husk residues. Physical aspects

Temperature

The temperature obtained weekly (5^{th}-9^{th}) shows that it has high temperatures over 50 °C, the husk until reaching ambient temperature, but it took longer to decompose; while the leaves and pod were more rapidly decomposed and they obtained temperatures not higher than 40 °C, until reaching ambient temperature (***figure 3***).

The pod reached high temperatures of 50 °C, because of having presence of carbon; while the pod reached temperatures lower than 40 °C due to its water holding.

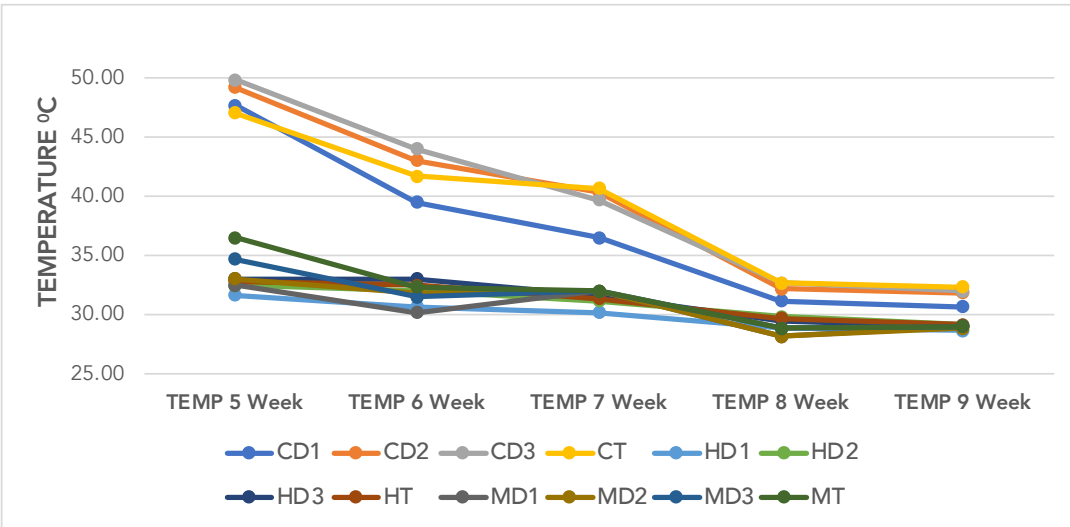


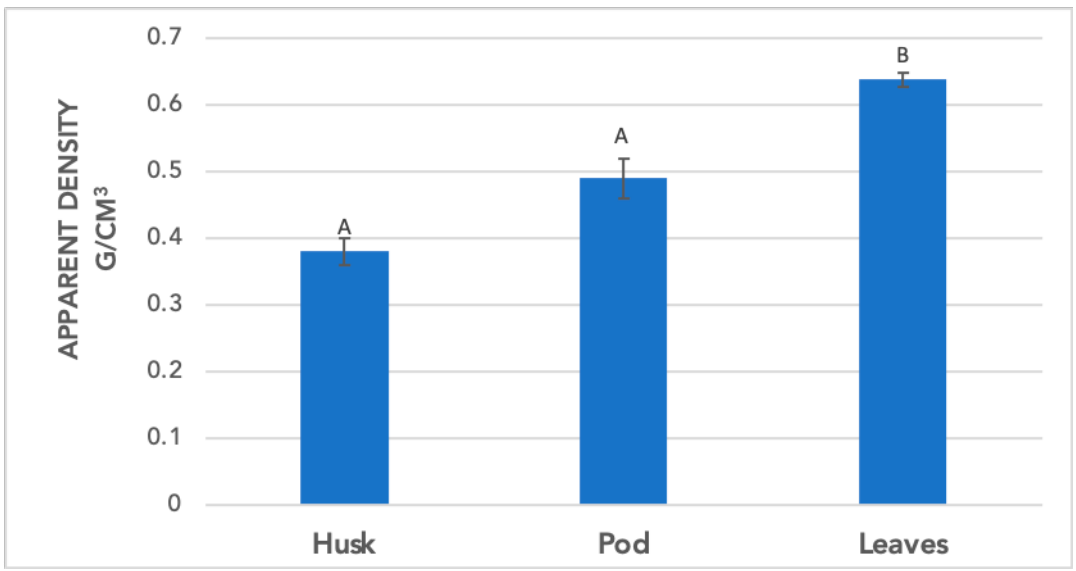
Figure 3. Dynamics of temperature fluctuation of organic fertilizers based on husk, leaves and pods.

Apparent density

According to the data obtained through Tukey's test at 5 %, figure 4 shows the averages of apparent density. According to the variance analysis statistical

significance was found among the means of the leaf, husk and pod residues, the two last ones had the lowest density average (0.38 and 0.49); while the leaf showed very high average (0.64).

The effect of the doses was not significant on the apparent density of the organic fertilizers.



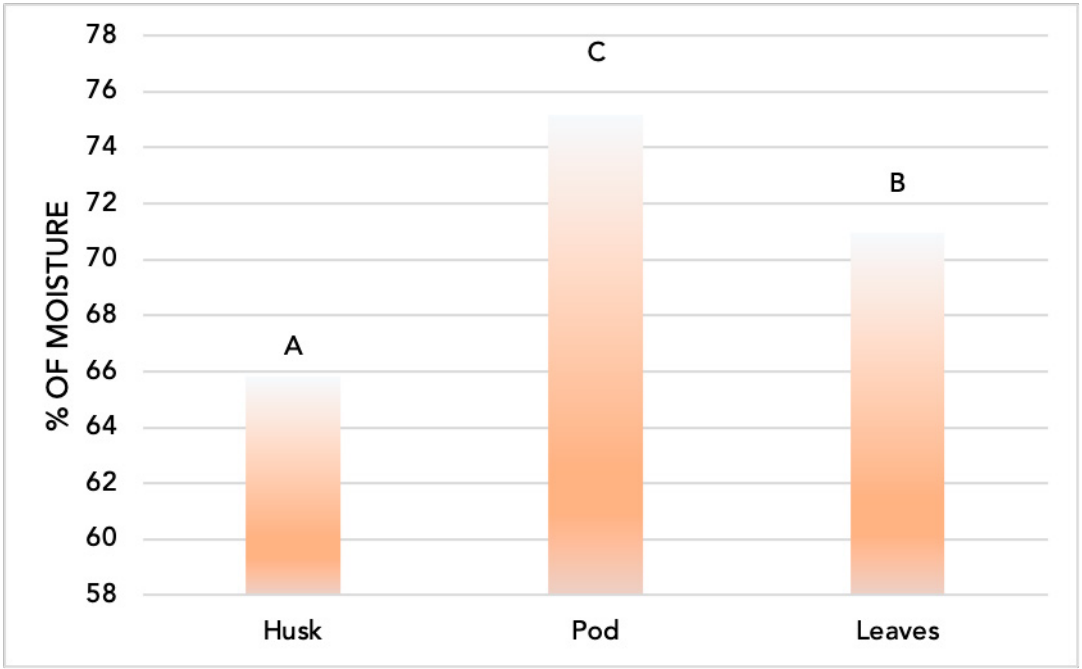
Means with a common letter are not significantly different ($p > 0.05$)

Figure 4. Averages of the apparent density of organic fertilizers based on husk, leaves and pod.

Moisture in humid sample

According to the data obtained through Tukey's test at 5 %, figure 5 shows the moisture averages in humid sample. According to the variance analysis statistical significance was found among the residue means: the pod was the one with the highest average quantity of moisture content with 75.17

%; the one with the lowest content was husk, with 65.84 % and the leaf had an intermediate performance with 70.97 %. The effects of the Trichoderma doses were not significant on the moisture percentage.

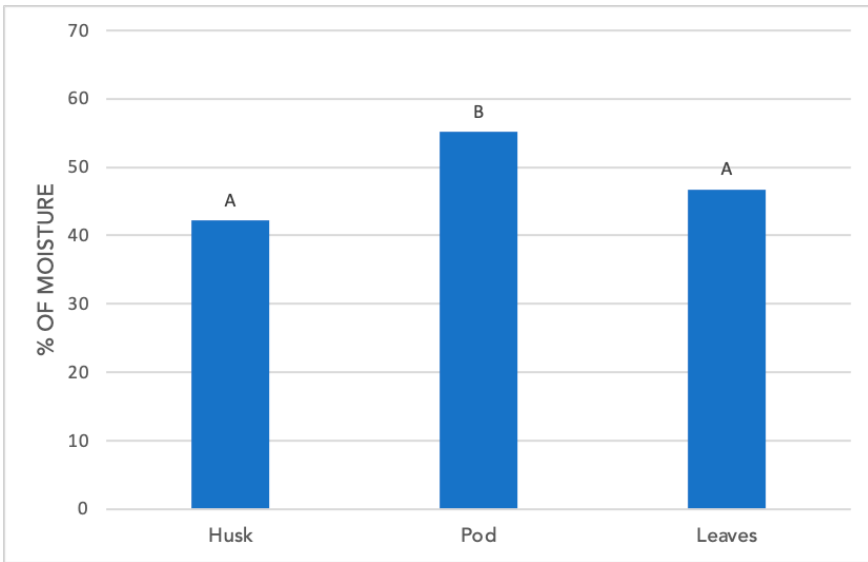


Means with a common letter are not significantly different ($p > 0.05$)

Figure 5. Moisture averages in humid basis of organic fertilizers based on husk, leaves and pod

Moisture on dry basis

According to the data obtained through Tukey's test at 5 %, figure 6 shows the averages of moisture on dry basis. According to the variance analysis statistical significance was found among the residue means: the pod was the one that had the highest average quantity of moisture loss in sample dried under air with 55.18 %; husk had the lowest loss with 42.22 %; while in the leaf 45.77 % was obtained.



Means with a common letter are not significantly different ($p > 0.05$)

Figure 6. Averages of moisture on dry basis of organic fertilizers based on husk, leaves and pod.

Color

As can be observed in table 4, the color obtained in the cocoa husk was dusky brown; while the cocoa leaves had a brownish black color and the cocoa pod had a black color when decomposition ended. It was observed that the three residues had the optimum color of compost.

RESIDUES	COLOR	
Husk	5YR 2/2 Dusky Brown	
Leaves	5YR 2/1 Brownish Black	
Pod	N1 Black	

Table 4. also shows the differentiation of the tonalities obtained in each organic fertilizer.

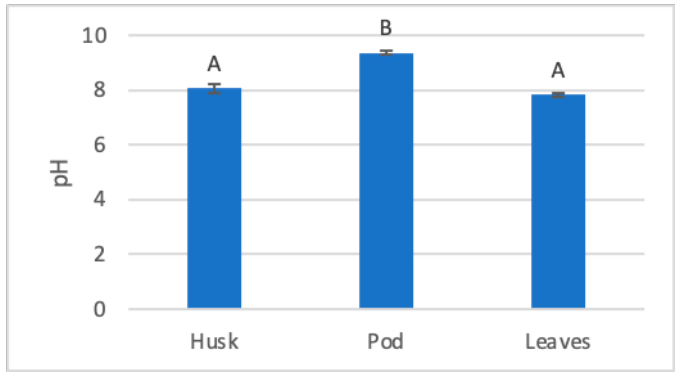
Table 4. Color of the organic fertilizers based on husk, leaves and pod

Chemical aspects

pH

According to the statistical analysis, as can be observed in figure 6 about the pH of the compost samples, through Tukey's test, the cocoa pod has pH >9, the husk has pH >8 and the leaves, pH >7. In other studies it has been proven that the optimum pH for compost is between 7 and 8; the results obtained in this study proved that the leaves and husk are in this range. Nevertheless, the pod was over 9, which decreases its quality as organic fertilizers and restricts its use (Román, Martínez, & Pantoja, 2013).

The effect of the Trichoderma doses was not significant on this variable.



Means with a common letter are not significantly different ($p > 0.05$)
Figure 6. Averages of pH of organic fertilizers based on husk, leaves and pod.

Table 5 shows that the content of ammoniacal nitrogen, phosphorus and copper was higher in the fertilizer obtained from husk, and was among the best ones regarding the content of potassium, magnesium and zinc; nevertheless, it was below in the calcium, iron and manganese content. The above-explained facts reflect that the fertilizer of cocoa husk is a considerable source of nutrients, surpassing those obtained from cocoa pod and leaves.

Table 5. Result of the analysis of the chemical compounds present in the obtained fertilizers

	%	ppm							
	N-NH4	P	K	Ca	Mg	Cu	Fe	Mn	Zn
Pod	1.98^{a}	4007.00^{a}	32825.75^{b}	13455.25^{b}	10048.75^{a}	27^{a}	5989.25^{ab}	890.25^{b}	121.50^{a}
Leaf	1.98^{a}	4015.25^{a}	18217.75^{a}	13620.25^{b}	10341.25^{a}	25^{a}	6605.75^{b}	919.75^{b}	129.50^{a}
Husk	2.95^{b}	6778.50^{b}	27691.75^{b}	10427.75^{a}	9770.00^{a}	35.50^{b}	5270.50^{a}	547.75^{a}	103.5^{a}

Means with a common letter are not significantly different ($p > 0.05$)

Free carbonates

This method is qualitative. The presence or absence of free carbonates is reported only in samples that have pH >7,8. With the application of HCl in the samples it could be observed that there was no effervescence; thus there is no presence of CO_2. No compost sample has presence of free carbonates.

The presence of free carbonates in organic fertilizers is considered strange and deleterious matters for the crops on which they are applied. For such reason, a good organic matter should not contain free carbonates. If organic fertilizers have free carbonates their utilization will be limited in soils with pH higher than 7 and will be avoided in crops that require pH lower than 7.

Economic analysis of the treatments in this study

The economic analysis (***Table 6***) was carried out to determine the treatment with better results regarding benefit/cost ratio. It was observed that the treatment which stood out in the study was Husk + Trichoderma harzianum with a benefit/cost of $1,78 (American dollar); while Pod + Trichoderma harzianum with $1,05 was the one with the lowest profitability. The treatment of Leaves + Trichoderma harzianum had an intermediate value of $1,47.

Table 6. Economic analysis of the obtained fertilizers

Treatments		Husk + Trichoderma harzianum	Pod + Trichoderma harzianum	Leaves + Trichoderma harzianum
Order	Detail			
Residues	sac	3	3	3
Treatment set-up	Day wage	15	15	15
Fungus Trichodermaharzianum	20g.	20	20	20
Outputs		38	38	38
Production (kg)		2.7	2.44	1.59
Sale price		7	7	7
Income for sale		67.50	40	56.00
Profit		29.50	2	18.00
Benefit/cost ratio		1.78	1.05	1.47

DISCUSSION

The purpose of the study was to observe the acceleration of the production of organic fertilizers from cocoa residues through the addition of hydrolytic fungi.

In this essay, different doses of Trichoderma harzianum were applied in the different treatments; the best doses were 1 (0.051 g/m^3) and 2 (0.5 g/m^3), which accelerated the decomposition of cocoa residues (pod, leaves and husk) in lower time; while dose 3 (1g/m^3) and the control did not show action on the acceleration in the decomposition time of these residues. Similar studies conducted by Sharma, Singh, & Sharma (2012) proved that the use of these fungi decrease the carbon:nitrogen ratio, which influences positively the acceleration of organic waste decomposition. They state that these microorganisms generate enzymes capable of breaking the polymers that make up the lignocellulose complex. An interesting result in this research is that a higher dose was not associated with a higher acceleration in decomposition. The explanation is focused on the high capacity of Trichoderma to colonize and reach high levels of CFU (colony forming units), starting from low concentrations of the inoculant (Nieto et al., 2017).

Richard et al. (2002), in their studies about the physical characteristics of compost, found that plant residues mixed with efficient microorganisms under high humidity conditions, between 60 and 80 %, in the composting process, resulted in a compost with good physical and chemical characteristics; although it is recommended that the moisture of compost should be between 50 and 60 % so that organic matter could be more rapidly decomposed (Román, Martínez & Pantoja, 2013). In this work with the compost of cocoa waste mixed with Trichoderma, moisture was achieved with a similar range (60-80 %) as the ones described by Richard et al. (2002).

To reach hygienization it is recommended to maintain a temperature higher than 55 °C during three consecutive days (Román, Martínez, & Pantoja, 2013), although this hygienization also depends on the microbiological contamination of the raw materials. According to the record of the temperature variations carried out by Borowski & Liebhardt (1983) during the compost process, it was observed that treatment 1, constituted by cocoa husk only,

does not reach the temperature (39 °C) to achieve the thermophilic stage (between 40 and 60 °C), probably as there was not an appropriate balance of necessary nutrients for the microflora to multiply and be activated for a long period. Yet, in treatment 5, constituted by cocoa husk and efficient microorganisms, the thermophilic stage is reached very fast, exceeding 60 °C; while in the treatments of cocoa husk with dose 1 (0.051 g) and dose 2 (0.5 g) of Trichoderma harzianum, they did reach the thermophilic stage because they surpassed 50 °C. The activity of fungus decomposition could be observed with higher presence. On the other hand, the treatments with pods with dose 3 (1 g) and the control, obtained temperatures lower than 35 °C; this means that the decomposition process did not reach the thermophilic stage.

For apparent density, Epstein (2011) in his study obtained that treatment T3: coffee residues with Trichoderma spp. it was 0.6 $g.cm^{-3}$, which was optimum for composting. The other treatments were above the established values. However, the data obtained in this study reveal that the husk treatments doses 1 and 2 had lower apparent density value (0.34 $g.cm^{-3}$) because the low apparent density values found are related to the organic carbon content in the different obtained products; while the control leaf treatment showed high density (0.7 $g.cm^{-3}$).

For Peixoto (1988), compost pH should be kept over 7,0 to 8,0 at 42 days. This performance of pH indicates a good performance of microorganisms in the compost. In this study it is proven that the husk and leaf treatments are in this same pH range and the efficiency of the fungus in this compost decomposition process is demonstrated.

CONCLUSIONS

The experiment conditions of the composting process using hydrolytic fungi for the degradation of cocoa waste, achieved a medium with favorable temperature and pH for the acceleration of decomposition to elaborate organic fertilizers.

It was proven that the decomposition time of organic waste can be accelerated using the fungus Trichoderma in doses of 0.051 g/m^3 and 0.5 g/m^3 under laboratory conditions, and these doses can be used in home microcomposters.

The time for decomposing the pod was an average of 43.50 days and the husk was the one that took longer to decompose, with an average time of 84.50 days. Although husk took longer there was a better reaction of the fungus in this organic residue. The treatments with husk doses 1 and 2 were the ones that recorded better physical and chemical characteristics of compost, which constitutes a good alternative to utilize home waste and create sources of improvements to recover agricultural soils.

It could be observed that the application of the Trichoderma harzianum doses does not influence the quantity of micro-and macronutrients in the treatments; however, the quantity of micro- and macronutrients depends on the residue type which is used for composting.

With the obtained results it was observed that Husk + Trichoderma harzianum stood out with a benefit/cost of $1,78; nevertheless, Pods + Trichoderma harzianum had $1,05.

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Effects of Sulfur and Silicon on Moniliophthora roreri and Ferrisia virgata in Cacao

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ABSTRACT

This experimental work was carried in the Banco de Arena campus, Milagro, Guayas province, in a 5-year-old established *Theobroma cacao* crop. The general objective of this research was to evaluate the effect of micronized sulfur and liquid silicon on *Moniliophthora roreri* and *Ferrisia virgata* in cocoa. The experiment consisted of four treatments, including the control, each one evaluated through eight repetitions, for which 32 experimental units comprised by a cacao plant, using a replicated latin square design. The treatments were: T1: micronized sulfur; T2: liquid silicon; T3: sulfur + silicon, and T4: witness. The variables evaluated were the number of healthy and diseased pods per tree, symptoms of moniliasis and *cochinilla* (cochineal disease), level of infestation, damage of moniliasis, yield per tree and a benefit-cost analysis. The analysis of variance and the Tukey test at 5% probability were used for statistical evaluation. Among the results, it was obtained that T3 (micronized sulfur + liquid silicon) had higher statistical averages in terms of dry weight per plant and yield in kg/ha (3198,12). For each dollar invested the gain was $1,61 whereas T1 had $ 1,47 in return. The study allowed to make a recommendation regarding the use of the aforementioned products in the Banco de Arena area: the combined effect of sulfur and silicon was the best treatment to control both pests.

Keywords: Micronized sulfur, cocoa, yield, liquid silicon

INTRODUCTION

Ecuador, due to its circumstances and its fortune in biological resources, is one of the largest producers of fine aroma cocoa, derived from the National variety, whose flavor has become the best for centuries in the world market. Refined chocolates use this seed for their manufacture. In addition, this grain stands out for its purity, flavor, and fragrance (Tapia, 2014).

Cocoa is a profitable crop in Ecuador and provides jobs for a large part of the communities in urban and rural areas. CCN 51 cocoa symbolizes one of the most significant items in the country, establishing 5 % of the national distribution, making it one of the traditional commercial interest crops in the province of Los Ríos (Sanchez and Garcés, 2012).

In Ecuador, there are 490,000 hectares of cocoa distributed across the provinces of Guayas, Los Ríos, Manabí, Esmeraldas, and El Oro. 15 % of the national production comes out of Guayas. Ecuadorian cocoa is exported worldwide: the United States buys approximately 50 % of the production; European countries 35 %, including Holland and Germany, and lastly, Mexico. These countries represent about 90 % of the cocoa sales produced in the country (Espinoza and Arteaga, 2015).

Pests and diseases have caused a low production of Ecuadorian cocoa, as well as in the Union of Cocoa Farmers Organizations of Ecuador (Unocace), in 927 producers comprising approximately 4 000 hectares of cocoa surface, they record losses of 45 % in their production in the year 2016 (Reyes, 2016).

Literature review

Agricultural work for cocoa cultivation in Ecuador has a distinguished history in the native and global economy. However, diseases are one of the most limiting factors for cocoa production. The International Cocoa Organization had indicated that the production of this crop is not stable because of several factors, including diseases and insect pests that cause

losses in the 30 % of world production of cocoa (Sánchez, 2015).

Nevertheless, cocoa can withstand threats caused by insects because both harmful and beneficial insects coexist in large crops. Pollinators and predators and parasites of harmful insects are considered beneficial (Cortázar, 2017).

Moniliasis (*Moniliophthora roreri*)

Moniliasis is a disease that generates great losses in cocoa cultivation, reaching up to 100% when weather conditions are conducive and trees are highly susceptible to the disease. For more than a century, products based on inorganic salts and other compounds of natural origin had in the controlling phytosanitary problems (Ochoa et al., 2015).

This disease attacks only cocoa fruits and is one of the most important factors in crop yield. It causes losses ranging between 16 % and 80 % of production. Since supposedly high temperatures are favorable for the spreading of moniliasis (Estrella and Cedeño, 2012), the severity of the damage caused by the disease varies according to climate and the location of the crop.

Typical symptoms for this disease are known by the appearance of a dense powdery mass (spores of the fungus) on the infected cocoa pods, which change successively from ash to brown (Carrera, 2016).

The incubation period of the fungus is three to eight weeks, depending on the climatic circumstances, age of the fruits and the susceptibility of the cocoa varieties. The survival of the pathogen begins in crop residues (infected cobs) and in the old cobs that remain long attached to the plant, if they are not eliminated (Onofre, 2016).

Cochineal (*Ferrisia virgata*)

Small insects with flaccid body, succivorous phytophagous habits; they are easy to reproduce and develop colonies; located in any host plant weakening or killing them, either sucking their sap, injecting them with toxic or spreading viruses (Ramos and Serna, 2004).

Ferrisia virgata can produce several overlapping generations each year. Females lay their eggs in groups, which are located under the body in waxy fibers. The range of eggs is 109 to 185 per generation and may exceed 500. The oviposition period takes 20 to 29 days. The incubation period takes about 3 to 4 hours

(Peck, 2001).

They live in groups in preserved parts of plants such as leaf armpits or under loose bark. A female can deposit 300 to 500 wrapped eggs as in a cotton bag. After oviposition, the female dies (Gerson, 2015).

The infestations of *F. virgata* remain grouped around the shoots, leaves and terminal fruits, sucking the sap of the plant, causing yellowing, wilting and drying of the plants and premature leaf drop and fruit abortion (Kaydan, 2012).

Sulfur

Sulfur acts as a defense against pests and diseases. Plants have a variety of secondary metabolites and several of them have sulfur in their structure. These compounds can be in active or inactive form, the latter can be activated through the energy of enzymes when there is damage from a pathogen (Intagri, 2017).

Silicon

Silicon allows plants to counteract the effects of biotic and abiotic stress, helps in the growth and development of the plant and reduces disease attack. Several works indicate its essentiality in grasses, where in the form of hydrated oxide it agglomerates in the wall, expanding its impermeability and resistance to fungal damage (Bonilla, 2013).

METHODOLOGY

The experimental design in this research included four treatments. Each treatment was applied to 32 trees in a previously established five-year-old crop with 1111 trees per hectare. were evaluated in the production stage. In order to identify the best treatment controlling fungal disease and insect pest, the comparison of averages was performed using the Tukey test at a 5% probability.

The independent variables considered were micronized sulfur and liquid silicon, while the dependent variables evaluated were number of healthy cob and diseased cob, symptoms, level of insect infestation, damage, yield per tree and cost benefit analysis (CBA).

Data collection on the number of healthy and diseased ears started by classifying them as healthy or diseased. Symptoms were evaluated by observing the ears that showed signs of the disease. Infestation levels were taken using a table according to the number of insects seen in the ears. The damage was observed according to the condition of the disease on cocoa fruits. The yield was measured for each treatment and then converted into kg / ha. The CBA was calculated based on the total budget, obtaining the benefits of the best treatment on the evaluated variables.

The treatments constituted the levels of each of these products, as well as an absolute reference control. The treatments studied are detailed in ***Table 1***.

Table 1. Study treatments

No	Treatments	Dose	Applications (Days)
1	Micronized Sulfur	1 kg/ha	1 - 30 - 60 - 90 - 120
2	Liquid Silicon	1 l/ha	1 - 30 - 60 - 90 - 120
3	Micronized Sulfur + Silicon	1 kg/ha - l/ ha	1 - 30 - 60 - 90 - 120
4	Absolute witness	No treatment	

The design used was a Latin square composed of the four treatments mentioned in ***Table 1***, where each experimental unit consisted of a cocoa plant. In order to increase the accuracy of the test, the experiment was performed in duplicate, obtaining a total of 32 experimental units.

The coefficient of variation was greater than 35 %, for this reason, it was necessary to make an adjustment in each of the data, this allowed reducing the coefficient of variation.

RESULTS

Number of healthy and diseased pods

The total averages of healthy and diseased pods indicated that treatments 1 and 3 presented a high number of healthy ears, while the control consisted mostly of diseased fruits (***Figure 1***).

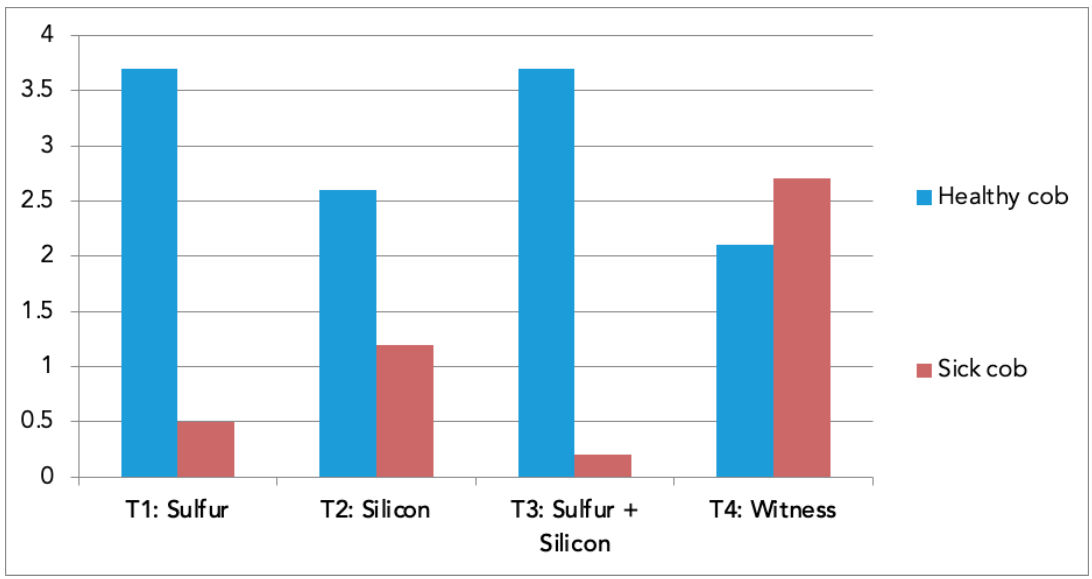

Figure 1. Average of healthy and diseased cob.

Symptoms of moniliasis

The percent of infection recorded every 30 days shows that the control obtained a high percentage of infection, while the T3 comprised of Micronized Sulfur + Liquid Silicon expresses favorable results, reducing the symptoms at 125 days after its application (***Figure 2***).

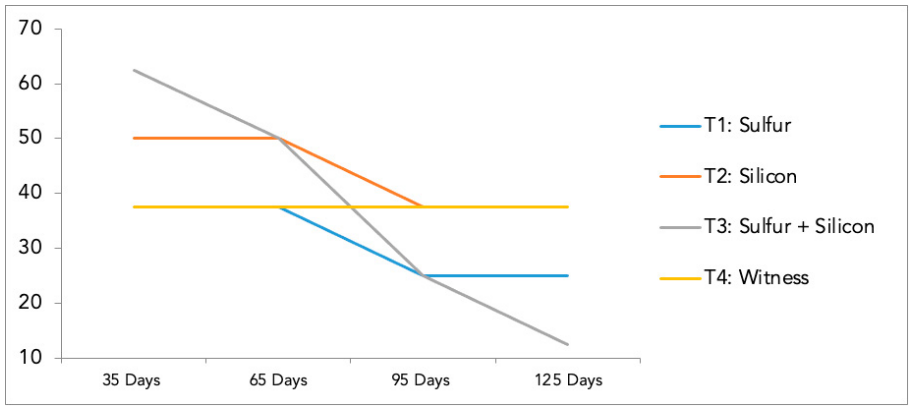

Figure 2. Symptomatology of Moniliasis.

Symptoms of cochineal disease

The symptoms of this insect remained high in all evaluations for the control, while in the other treatments the symptomatology decreased. T3 presented the largest reduction which favored its averages until reaching 10% at 125 days of its application (Figure 3).

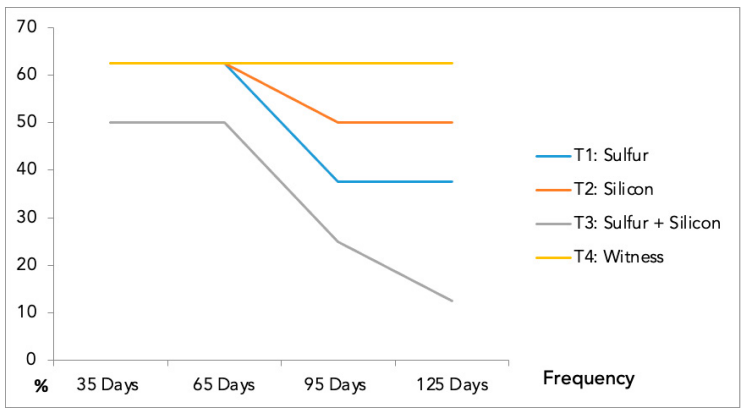

Figure 3. Cochineal symptomatology.

Cochineal infestation

The variable was taken according to a scale valued in null, low, medium and high, showing that Sulfur + Silicon represented by treatment 3 shows better results, obtaining zero and low in said procedure.

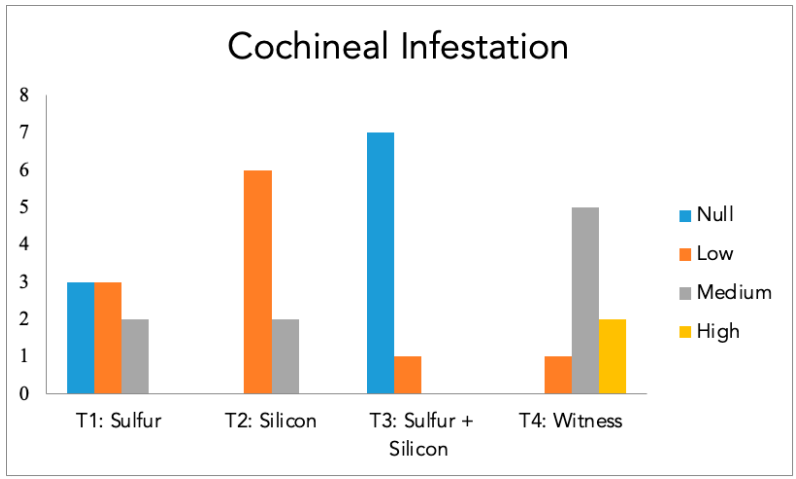

Figure 4. Insect infestation.

Moniliasis damage

As can be seen in the following table, no significant differences were detected in the first two evaluations; however, at 95 and 125 days there were significant differences between treatments 1 (Micronized Sulfur) and 3 (Sulfur + Silicon). According to the Tukey Test at a 5 % probability, treatment 3 expressed a low percentage of damage with an average of 3.7.

The damages due to moniliasis in each of the evaluations carried out, presented a relatively high coefficient of variation (greater than 35 %), variables to which an adjustment was made, using the arcosine function in each of the data. This allowed reducing the coefficient of variation as seen in ***table 3***.

Table 3. Average damage due to Moniliasis (%).

		AVERAGES			
No	**Treatments**	**35 days**	**65 days**	**95 days**	**125 days**
1	Micronized Sulfur	34,6 a	31,8 a	19,6 b	12,0 bc
2	Liquid Silicon	44,7 a	40,1 a	32,7 a	25,5 b
3	Sulfur + Silicon	38,0 a	33,6 a	13,7 b	3,7 c
4	Witness	30,3 a	37,7 a	47,1 a	55,1 a
	Cv (%)	38,6	43,19	50,08	57,23
	Cv Adjusted data (%)	22,93	27,27	13,89	14,25

Yield per tree

The results of the analysis of the yield per tree showed that in the first evaluation carried out, no significant differences were detected -However,

at 125 and 150 days there were significant differences between treatments. According to the Tukey test at a 5 % probability, treatments 1 (micronized sulfur) and 3 (sulfur and silicon) presented higher yields (***Table 4***).

The performance in each of the evaluations carried out, presented a relatively high coefficient of variation (greater than 35 %), averages to which a logarithmic adjustment was made in each of the data. This allowed reducing the coefficient of variation as can be seen in ***table 4***.

Table 4. Average weight / tree yield (grams).

No.	TREATMENTS	AVERAGES		
		95 days	125 days	150 days
1	Micronized Sulfur	244,3 a	303,2 a	321,1 a
2	Liquid Silicon	157,7 a	180,7 ab	212,6 ab
3	Sulfur + Silicon	222,2 a	293,0 ab	333,1 a
4	Witness	206,7 a	172,4 b	160,8 b
	Cv (%)	47,15	39,09	34,82
	Cv Adjusted data (%)	9,93	8,76	8,02

Cost/profit analysis

The total income was obtained from the adjusted yield in kg / ha, considering that, at the time of the study, the current cost per pound was $0.80 and $ 1.6 per kg of dry cocoa.

All treatments under study presented profitability. However, treatment 3 (sulfur + Silicon) presented the highest profitability with a net value of $1.61, followed by treatment 1 (micronized sulfur) with a net value of $1.47 for each dollar invested, while the control had the lowest margin of profitability ($0.37).

Table 5. Cost/profit analysis

COMPONENTS	T1 Micronized Sulfur	T2 Liquid Silicon	T3 Sulfur + Silicon	T4 Witness
Yield Kg / ha	3554,1	2551,2	3997,65	1930,35
Performance adjusted Kg / ha	2843,28	2040,96	3198,12	1544,28
Fixed cost ($)	1800	1800	1800	1800
Variable Cost ($)	40	120	160	0
Total cost	1840	1920	1960	1800
Gross Income ($)	4549,25	3265,54	5116,99	2470,85
Net Profit ($)	2709,25	1345,54	3156,99	670,85
Cost/profit ratio	1,47	0,70	1,61	0,37

DISCUSSION

It was established that micronized sulfur and liquid silicon reduce the presence of Moniliophthora roreri and Ferrisia virgata in the cocoa crop; According to Furcal (2012), silicon-based products manage to accumulate a large amount of that element, this makes the cocoa pods rigid, preventing insects from entering their mouthpiece and reproductive stylet, which is consistent with this research that silicon-based treatments decreased the symptoms and damage of F. virgata in cocoa pods, confirming that silicon is a pest-insect controller.

Regarding the damage caused by M. roreri in cocoa pods, it also presented significance in treatment 3 (Sulfur + Silicon), and a lower percentage of damage to the pods was obtained due to Moniliasis. Since plants have a variety of secondary metabolites with sulfur in their structure that activates when facing pathogen harm, sulfur-based treatments worked in decreasing the damage, producing better results, with an average of 0 to 1%.

In addition, in the experiment conducted by Vélez (2018), results were similar to the ones obtained with the application of sulfur to the crop in order to control moniliasis, especially regarding the number of healthy (30) and diseased (10) pods per treatment. This showed that the incidence of the disease was reduced to 30 % when treated with the application of products based on antifungal minerals.

With respect to cocoa productivity; According to this research, treatment 3 included by Sulfur + Silicon obtained a higher yield (3997.65 kg / ha), followed by treatment 1 Micronized sulfur (3554.1 Kg / ha), coinciding with Alvarez (2008), who states that Silicon increases production and maintains high biomass accumulations, likewise, Silicon applications replace the application of fertilizers enriched with fungicides, and Calvo (2015), states that sulfur increases productivity up to 20 % and recommends the use of sulfur not as a fertilizer, but as an amendment for crops, thus corroborating that sulfur works in controlling diseases, and also increases crop yields.

In the trial, the profitability of the treatments was estimated using the benefit-cost ratio. Calvo (2015) states that the use of sulfur and silicon reduces pesticide practices that, in addition to causing damage to the environment, increase expenses for the producer, which would lead to lower production costs due to the reduction of fertilizers or fertilizers between 20

and 40%. The foregoing agrees with this investigation that the treatment with the best profitability was number 3 comprised of micronized sulfur + liquid silicon, improving its productivity and better economic performance for the producer.

Bustos (2017) states that the use of silicon as a natural activator of the immune response of plants is considered as one of the alternatives for improving agricultural production. and it also makes a contribution in the reduction of damage caused to the environment. His experiments have showed that foliar applications of silicon improve the health of cocoa pods, therefore producing an increase in the number of pods per tree and higher margins of profitability for the crop. This study had similar results.

CONCLUSIONS

Micronized Sulfur + Liquid Silicon had a positive control effect on *Moniliophthora roreri* and *Ferrisia virgata* in cocoa crop.

The number of healthy pods increased with the use of the treatments under study, unlike the control where a high incidence of symptoms was found.

Liquid Silicon applied alone to cocoa pods did not show a positive effect on crop yield, because it generated smaller increases. As for the control of insects - plague, these same applications diminished the symptoms and damage of *F. virgata.*

The economic analysis showed that treatment 3 (Sulfur + Silicon) is the most convenient, because it obtained a greater net benefit of $ 1.61, compared to the other treatments that were applied during the study.

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Presence of Native Underutilized Edible plants on Cocoa and Banana Farms

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ABSTRACT

This experimental work was carried in the Banco de Arena campus, Milagro, Guayas province, in a 5-year-old established *Theobroma cacao* crop. The general objective of this research was to evaluate the effect of micronized sulfur and liquid silicon on *Moniliophthora roreri* and *Ferrisia virgata* in cocoa. The experiment consisted of four treatments, including the control, each one evaluated through eight repetitions, for which 32 experimental units comprised by a cacao plant, using a replicated latin square design. The treatments were: T1: micronized sulfur; T2: liquid silicon; T3: sulfur + silicon, and T4: witness. The variables evaluated were the number of healthy and diseased pods per tree, symptoms of moniliasis and *cochinilla* (cochineal disease), level of infestation, damage of moniliasis, yield per tree and a benefit-cost analysis. The analysis of variance and the Tukey test at 5% probability were used for statistical evaluation. Among the results, it was obtained that T3 (micronized sulfur + liquid silicon) had higher statistical averages in terms of dry weight per plant and yield in kg/ha (3198,12). For each dollar invested the gain was $1,61 whereas T1 had $ 1,47 in return. The study allowed to make a recommendation regarding the use of the aforementioned products in the Banco de Arena area: the combined effect of sulfur and silicon was the best treatment to control both pests.

Keywords: Genetic resources, ethnobotany, local knowledge, agriculture, food sovereignty.

INTRODUCTION

Since agriculture have emerged on earth about 10 000 years ago, about 7000 plant species have been cultivated, as an evidence of the great agrobiodiversity of the planet. Today, only about 30 species contribute significantly to food worldwide. Of these ones, rice, wheat, corn and potatoes are the most exploited, and there are few plant species that support a growing population (Ministerio del Ambiente, 2017). In general, the presence and conservation of the genetic richness of underutilized native edible plants are important for a country. They are the source of unique productivity genes, nutraceutical properties and tolerance to biotic and abiotic factors. Therefore, these qualities could be used for the genetic improvement of these species, for the benefit of alimentation and the production of new useful materials. (Ayala, 2008; Bravo, Arteaga y Herrera, 2017; Franco, Peñafiel, Cerón y Freire, 2016; Ríos, Alanís and Favela, 2017).

Ecuador is one of the 20 most diverse countries in the world, with about 25 000 vascular species (INIAP 2008), 5172 useful species, 1552 of which are edibles (Balsev et al., 2008), cultivated and wild. These plants are part of the genetic resources of the country and can contribute to their sovereignty and food security (Menéndez, 2015). In addition, there is a great cultural diversity, much of it associated with the eating habits of the communities, which also contributes to the wealth country. However, it is projected that by 2030 year, the population will be 19.8 million inhabitants (INEC, s.f.) and agriculture, affected by globalization, industrialization and climate change may not be able to feed them properly.

Guayas, on the Ecuadorian coast, is one of the provinces with the greatest agricultural potential in the country. It is constituted politically by urban and rural areas, one of these is Mariscal Sucre. The economy of Mariscal Sucre is based on agriculture, about 99% of its area is intervened by cocoa, sugar cane and banana farms, specially (Concejo de planificación del GAD Parroquial

Rural Mariscal Sucre, 2015). In these farms remain underutilized edible native plants that could be suffering threats common in monocrop farming systems. The first, its displacement through an intensive and technified agriculture of introduced species with economic value. The second, the change in the dietary preferences of the inhabitants (Torres, 2010). The third, the indiscriminate use of pesticides and herbicides that in monocultures are necessary for the control of weeds, pests and diseases. The fourth, the accelerated and silent loss of local knowledge about the management and use of these species and the generational transfer of knowledge associated with their crops (De la Torre y Macía, 2008).

Under this panorama, it is imperative to know the current status of underutilized native vegetable species as food. Ethnobotany is a valuable tool for the study of these species and the threats that allow their erosion. It is defined as the study of the interactions of people with their environment in cultural and biological dimensions (Albuquerque & Alves, 2016). Its aim is to interpret the local botanical knowledge (Chan, Pat-Canche and Saragos, 2013). Therefore, several studies in the area have helped to highlight their role in biodiversity conservation and community progress (Alexaides, 2003).

The objective of this research was to know the underutilized native edible plants present in farms of Mariscal Sucre, Guayas and the local knowledge that the farmer has about their conservation and uses. We hope the results contribute to agricultural from Mariscal Sucre producer becoming aware of the need to conserve and cultivate these species and recover the local eating habits and knowledge they had to contribute to the food sovereignty of the country.

Literature Review

In Latin America, countries such as Guatemala, Colombia, and Argentina have conducted ethnobotanical studies on edible plants. Pardo and Burgos (2012) investigated the presence of medicinal and edible plants in five villages of a nature reserve in Taxisco, Guatemala, and evaluated the traditional knowledge of the local inhabitants. 60% of the registered plants were native and many of them were not only found in the forest, but also in the family gardens of the interviewees. With this work the importance of conserving

natural environments (source of medicines and food), and of the cultural wealth that the inhabitants of Taxisco inherited from their ancestors, result of their interaction between man and nature, was evidenced. In Argentina, the eating habits of Tapiete indigenous communities, northeast of the province of Salta, were studied. The plant species that these communities used, their forms of collection, consumption and storage were identified. In addition, the knowledge of the local people was cataloged. 54 native plant species were recorded. Most species are consumed raw, and the rest as beverages, condiments or flour (Montani and Scarpa, 2016).

Pasquini, Sánchez and Mendoza (2014), studied the distribution of knowledge and uses, management and production of edible plants in communities of Bolívar, Colombia. The work was developed interacting with the families of the place through the recognition of the plants. The loss of knowledge and tradition in the use of these plants was evidenced. Older people recognized more plants than they normally used. In this case, men could recognize more plants than women. Mosquera, Santamaría and López (2015) conducted an ethnobotanical study in the municipality of Turbo, Antioquia, Colombia. The objective of that research was to know the methods of knowledge transmission that older people in the sector use to teach future generations to identify edible wild plants that can complement their diet. With the help of surveys, different forms of knowledge transmission were found, but oral transmission remains the main means of passing knowledge to new generations. What worries is the lack of interest of the youngest in recognizing, preserving and valuing the resources they possess as a food source.

In Ecuador, the main research on ethnobotany of plants has been developed in the Andes and the Amazon. In the Andes, explorations have been made since the colonial period, currently, mostly in Kichwas and mestizo populations (De la Torre, Muriel y Valslev, 2006). Ecuadorian indigenous people make up 7% of the total population, have their own language and culture; among them, the Kichwas are the majority. Mestizos are Spanish-speaking people, descendants of Europeans, mainly Spaniards, with Native American (indigenous) natives, who represent 72% of the inhabitants of the country (González-Andrade,

Sánchez, Martínez-Jarreta, 2006, Organización Panamericana de la Salud, 2017).

Chavez and Pavón (2011) evaluated the native flora of the province of Imbabura, in the north of the country. They identified 112 plant species with food, medicinal, combustible, cultural, and toxic and construction uses. These results allowed systematizing the information in a software for future research. There are also studies of specific plant food species. Calva (2016) investigated the importance of Andean tubers Oca (Oxalis tuberosa), mashua (Tropaeolum tuberosum) and melloco (Ullucus tuberosus), in communities in the province of Loja, southern Ecuador. The purpose of the research was to preserve ancestral knowledge about the use, cultivation and conservation of these species and share that knowledge among the participants of the ethnobotanical study.

In the Amazonian, Clavijo and Yánez (2017) conducted a study of the use of plant resources in farmers associations of Napo, Pastaza and Morona Santiago provinces. The data taken included socioeconomic aspects and the frequency with which plants are used according to six categories of use (edible, combustible, timber, social and ritual, toxic or poisonous and medicinal). The results showed that the owners use the introduced plants more frequently than the native ones. One reason is the arrival of outsiders who contribute to the lack of the use of native. Thus, Luzuriaga (2017) presented a study done in that community in the province of Pastaza. The study highlighted the value of plant wealth as a source of innovation for community development. This research assessed the importance of local knowledge related to plant biodiversity. The need for the use of these natural resources to be carried out considering sustainability and conservation criteria was also highlighted. In the same region of Pastaza there is an updated report on edible plants in agricultural farms managed by mestizos and Kichwas. In general, most specimens were cultivated and the Kichwa community reported more variety than mestizos (Abril, Ruíz, Alonso y Aguinda, 2016).

METHODOLOGY

Study area

The study was conducted in Mariscal Sucre, rural area of Canton Milagro, province of Guayas, on the Ecuadorian coast (Geographical coordinates UTM 666016,93-9773863.68; 670297,87-9766524,14; 660479,44-9763775,08 and 661812.80-9766788.75) (Gobierno Autónomo Descentralizado, Cantón San Francisco de Milagro, 2014) (Figure 1) . It has an area of 56.47 km^2, with flat or wavy geographical features, with slopes of up to 5% and a maximum altitude of 40 meters above sea level. Its annual average temperature fluctuates between 24°C and 26°C and annual rainfall between 1400 and 1900 mm. Its territory is totally intervened by agricultural activity with cocoa crops (*Theobroma cacao* L.), banana (*Musa x paradisiaca* L.) and sugarcane (*Saccharum* spp.) mainly. 64% of its population is made up of mestizos dedicated to these tasks (Concejo de planificación del GAD Parroquial Rural Mariscal Sucre, 2015)

Sample selection

Because there is no formal record of the number of agricultural farms in Mariscal Sucre, 20 of them were worked with areas under 10 ha. The informants were their owners (***Figure 2***), who were selected according to the snowball technique (Albuquerque, Lucena & Neto, 2014).

Ethnobotanical study

In order to obtain the ethnobotanical data, a semi-structured interview was developed related to the knowledge of farmers about the location, uses and conservation of the native edible plants present in their farms. The interviews were conducted in a free, informed and consensual manner (Troncoso-Pantoja y Amaya-Placencia, 2017). The location of the plants within the farms

was performed using the technique of the tour guide (Trajano, Lima and Albuquerque, 2007), consisting of the informant leads the interviewer to the site where the plant grows.

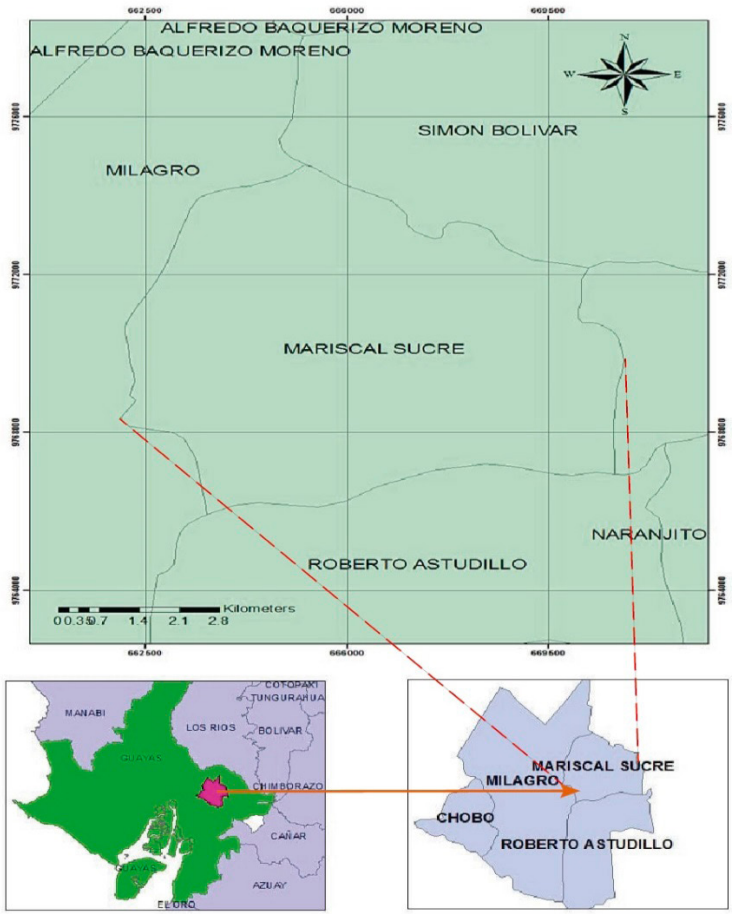

Figure 1. Location of the study area in the provincial and cantonal context of the rural zone of Mariscal Sucre

Figure 2. Farmer in the maintenance of the CCN-51 cocoa crop in his farm, located in the rural area of Mariscal Sucre, Guayas.

Sampling

Botanical samples were collected for subsequent herborization and taxonomic identification. Photographs and videos were taken. In all cases the geographical location of the specimens was recorded with a GPS. The collection of the samples did not need permits from the Ministry of Environment since they were not wild species in protected areas.

Treatments of botanical specimens

The collected samples were transferred to the Phytogenetic Resources Laboratory of the "Universidad Agraria del Ecuador". There they were herbalized and identified to the most specific taxonomic category possible, supported by the photographs and videos taken and the contrast with the Catalog of Vascular Plants of Ecuador from the Missouri Botanical Garden (Jørgensen, PM & S. León-Yánez, 1999), Red Book of the Endemic Plants of Ecuador (León, Valencia, Pitman, Endara, Ulloa, and Navarrete 2011), the Encyclopedia of Useful Plants of Ecuador (de la Torre, Navarrete, Muriel,

Macía, Balsev and Valverde, 2008) and WEB pages (García, 2011; Pautrat *et al.*, sf, and Tramil, sf.).

Data processing and analysis

With data collected in interviews and identification of the botanical material, a database was created in the spreadsheet Microsoft Office Excel 2010. Descriptive statistics was used for data analysis. Tables, frequency histograms and pie charts were used to represent the results.

RESULTS

Current status of local knowledge on the use of native edible plants in twenty farms in Mariscal Sucre

65% of the interviewees were women and 35% men. Regarding the perception they had about the type of work they did, women defined themselves as housewives and men as farmers. Four age groups were formed: 38 to 50 years (five women), 51 to 64 years (five women and three men), 64 to 76 years (three people of each sex) and 77 to 87 years (one man). According to the degree of instruction, 60% of the total informants received basic education, 35% secondary, and 5% university. 90% of the interviewees showed no interest in preserving the local knowledge of their community, only two farmers were able to identify the largest number of native species with nutritional value.

Registration of native edible plant species in the rural area of Mariscal Sucre

Twenty nine underutilized edible species belonging to 15 families were registered. The family with the highest number of species was Fabaceae (25%), followed by the Caricaceae (13%), Malvaceae and Annonaceae (12%), Malpighiaceae (7%) and, Myrtaceae and Sapotaceae (6% each) (Figure 3).

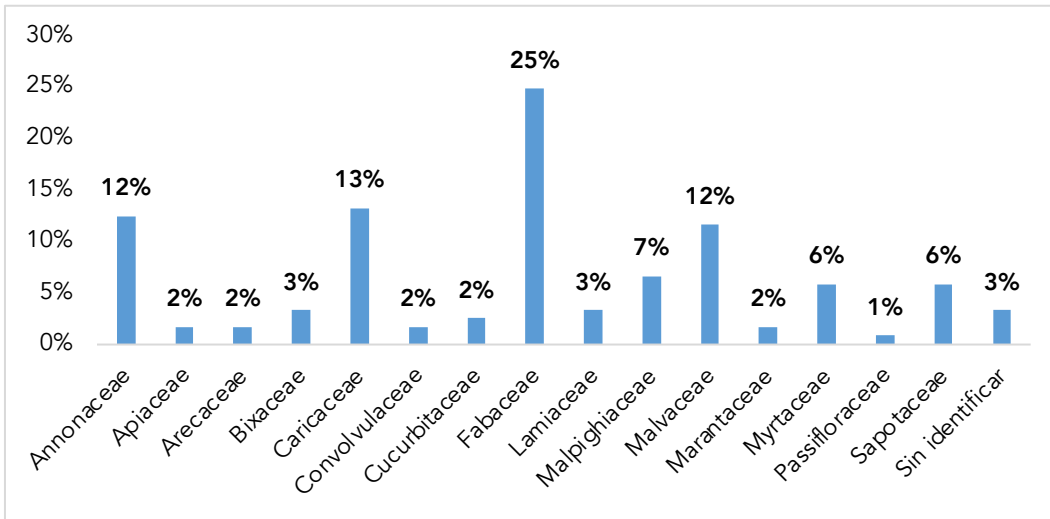

Figure 3. Botanical families according to the underutilized native food species found in farms of Mariscal Sucre, Guayas.

According to the interviewees, most of the plants under study were located in cultivated areas of their farms (63%), within their yards or gardens (30%) or both (7%) (***Figure 4***).

Figure 4. Farmer showing an achiote plan (Bixa orellana L.) located inside her farm, in Mariscal Sucre, Guayas.

Table 1. shows the native edible plants found in this investigation. Their common names, scientific names, families, growth habits, edible parts, consumption status, preparation form and consumption were recorded. According to their growth habit, 62% of the plants were trees, 18% vines, 10% herbs and 10% shrubs. The best known or most frequently used fruit trees were "chirimoya" (*Annona cherimola* Mill.), "guanábana" (*Annona muricata* L.), "guaba de bejuco" (*Inga edulis* Mart.), "zapote" (*Matisia cordata* Bonpl.) y "cereza" (*Malpighia emarginata* Sessé & Moc. Ex DC.). Little known and consumed species were found, some trees as "caimito morado" (*Chrysophyllum cainito* L.) y *"guayaba agria"* (*Psidium friedrichsthalianum* (O. Berg) Nied.), other herbaceous like "tapioca" (*Maranta arundinacea* L.) and "bedoca" (*Passiflora foetida* L.). About the edible part of the plant, 79% were fruits, 10% seeds and, tuberous root, rhizome and leaf 3.4% each. Although "tapioca" is extracted from cassava (Manihot sculenta Crantz.), in this study informants gave that name to *Maranta arundinacea* L.

90% of the edible parts of the plants are consumed fresh, 7% fresh or dry and 3% dry. According to the form of preparation, 55% do it without prior preparation, followed by chopped (18%), chopped or smoothie (3%), smoothie (18%), crushed (3%), and scratched (3%). Forms of consumption are varied, raw (81%), cooked (17%), raw or cooked (1%) and cooked, roasted or fried (1%) (***Table 1***).

Regarding the commercial value that these species have for the interviewees, 92% use it for family consumption and the remaining 8% consume and sell it. Table 2 shows the frequency of consumption of 27 plants reported in this investigation. Each value corresponds to the number of interviewed who reported consuming that species, at least once daily, weekly, biweekly or monthly. The most used species were chirimoya, guanábana, guaba de bejuco, zapote, "papaya" (Carica papaya L.) y cereza. The least consumed were caimito morado, guayaba agria, tapioca y "zapallo" (Cucurbita maxima Duchesne ex Lam.)

Table 1. Taxonomic identification, growth habit, edible part, consumption status, forms of preparation and consumption of underutilized native plant species found in coca and banana farms in Mariscal Sucre.

COMMON NAME	SCIENTIFIC NAME	FAMILY	GROWTH HABIT	EDIBLE PART	CONSUMPTION STATUS	PREPARATION FORM	CONSUMPTION FORM
Achiote	Bixa orellana L.	Bixaceae	Shrub or tree	Seed	Fresh and dry	Crushed	Cooked
Achojcha	Cyclanthera pedata (L.) Schrad.	Cucurbitaceae	Vine	Fruit	Fresh	Chopped	Cooked
Arazá	Eugenia stipitata McVaugh	Myrtaceae	Shrub or tree	Fruit	Fresh	Smoothie	Raw
Bedoca	Passiflora foetida L.	Passifloraceae	Vine	Fruit	Fresh	Without any processing	Raw
Caimito morado	Chrysophyllum cainito L.	Sapotaceae	Tree	Fruit	Fresh	Without any processing	Raw
Camote	Ipomoea batatas (L.) Lam.	Convolvulaceae	Vine	Tuberous root	Fresh	Chopped	Cooked (Roasted or fried)
Caña fístula	Cassia grandis L. f.	Fabaceae	Tree	Fruit	Fresh	Without any processing	Raw
Cauge	Pouteria caimito (Ruiz & Pav.) Radlk.	Sapotaceae	Tree	Fruit	Fresh	Without any processing	Raw
Cereza	Malpighia emarginata Sessé & Moc. ex DC.	Malpighiaceae	Shrub or tree	Fruit	Fresh	Without any processing	Raw
Chirimoya	Annona cherimola Mill.	Annonaceae	Shrub	Fruit	Fresh	Without any processing	Raw
Culantro hediondo	Eryngium foetidum L.	Apiaceae	Herb	Leaf	Fresh	Chopped	Cooked
Guaba de bejuco	Inga edulis Mart.	Fabaceae	Tree	Fruit	Fresh	Without any processing	Raw
Guaba de mico	Inga manabiensis T.D. Penn.	Fabaceae	Tree	Fruit	Fresh	Without any processing	Raw
Guaba machete	Inga spectabilis (Vahl) Willd.	Fabaceae	Tree	Fruit	Fresh	Without any processing	Raw
Guanábana	Annona muricata L.	Annonaceae	Tree	Fruit	Fresh	Smoothie	Raw
Guayaba agria	Psidium friedrichsthalianum (O. Berg) Nied.	Myrtaceae	Shrub or tree	Fruit	Fresh	Smoothie	Raw, Cooked
Guayaba amarilla	Psidium guajava L.	Myrtaceae	Shrub or tree	Fruit	Fresh	Smoothie	Raw, Cooked
Haba pallar	Phaseolus lunatus L.	Fabaceae	Vine	Seed	Fresh and dry	Without any processing	Cooked

Jirón	Sicana odorifera (Vell.) Naudin	Cucurbitaceae	Vine	Fruit	Fresh	Chopped	Cooked
Mococha	Phytelephas aequatorialis Spruce	Arecaceae	Tree	Fruit	Fresh	Without any processing	Raw
Naranjilla	Solanum quitoense Lam.	Solanaceae	Shrub	Fruit	Fresh	Smoothie	Raw, Cooked
Papaya amarilla y morada	Carica papaya L.	Caricaceae	Tree	Fruit	Fresh	Chopped, Smoothie	Raw
Pechiche	Vitex gigantea Kunth	Lamiaceae	Tree	Fruit	Fresh	Without any processing	Cooked
Tapioca	Maranta arundinacea L.	Marantaceae	Herb	Rhizome	Dry	Scratched	Cooked
Zapallo	Cucurbita maxima Duchesne ex Lam.	Cucurbitaceae	Vine	Fruit	Fresh	Chopped	Cooked
Zapote	Matisia cordata Bonpl.	Malvaceae	Tree	Fruit	Fresh	Without any processing	Raw
Guaba cubana	Unknown 2	Fabaceae	Tree	Fruit	Fresh	Without any processing	Raw
Guaba de río	Unknown 3	Fabaceae	Tree	Fruit	Fresh	Without any processing	Raw

Table 2. Consumption frequency of 27 underutilized native food plants of this research.

SCIENTIFIC NAME	LOCAL NAME	CONSUMPTION FREQUENCY				
		DIARY	WEEKLY	BIWEEKLY	MONTHLY	INTERVIEWEES WHO REPORTED CONSUMING THE SPECIES
Annona cherimola Mill.	Chirimoya		3		1	4
Annona muricata L.	Guanábana	6	4			10
Bixa orellana L.	Achiote	1	4		1	6
Carica papaya L.	Papaya amarilla y morada	8	7		1	16
Chrysophyllum cainito L.	Caimito morado				1	1
Cucurbita maxima Duchesne ex Lam.	Zapallo		1			1
Cyclanthera pedata (L.) Schrad.	Achojcha		1			1
Eryngium foetidum L.	Culantro hediondo	1	1			2
Eugenia stipitata McVaugh	Arazá	2	2		1	5
Inga spectabilis (Vahl) Willd.	Guaba machete	6	2	1		9
Inga edulis Mart.	Guaba de bejuco	4	10			14
Inga manabiensis T.D. Penn.	Guaba de mico	1	2			3
Ipomoea batatas (L.) Lam.	Camote		1	1		2
Malpighia emarginata Sessé & Moc. ex DC.	Cereza	1	7			8
Maranta arundinacea L.	Tapioca		2			2
Matisia cordata Bonpl.	Zapote	6	8			14
Passiflora foetida L.	Bedoca	1				1
Phaseolus lunatus L.	Haba pallar	2	1			3
Phytelephas aequatorialis Spruce	Mococha		2			2
Pouteria caimito (Ruiz & Pav.) Radlk.	Cauge	2	3			5
Psidium friedrichsthalianum (O. Berg) Nied.	Guayaba agria	1			1	2
Cassia grandis L. f.	Caña fístula		1			1
Sicana odorífera (Vell.) Naudin	Jirón		1			1
Solanum quitoense Lam.	Naranjilla		1			1
Vitex cymosa Bertero ex Spreng.	Pechiche	1	2	1		4
Unknown 1	Guaba de río		1			1
Unknown 2	Guaba cubana		1			1

Conservation status of native edible species according to the local knowledge of the farmers of twenty farms in the rural parish Mariscal Sucre

Farmers were consulted for the number of individuals present on their farms, of each of the 27 species presented in Table 3. The information was visually corroborated, using an arbitrary scale: many (more than ten), regular (five to ten) and few (less than five). For example, seven farms presented a small number of individuals of at least one of the following species: caimito morado, tapioca, bedoca, "caña fistula" (Cassia grandis L. f.), "jirón" (Sicana odorifera (Vell.) Naudin), "naranjilla" (Solanum quitoense Lam.) and "guaba cubana". Four with at least two species like "guaba de mico" (Inga manabiensis T.D. Penn.), "camote" (Ipomoea batatas (L.) Lam.), "mococha" (Phytelephas aequatorialis Spruce) and guayaba agria and three with "achiote" (Bixa orellana L.). Farms were also found with regular numbers of individuals, with species such as guanábana, achiote, zapallo, "arazá" (Eugenia stipitata McVaugh), tapioca and "haba pallar" (Phaseolus lunatus L.) and some with a lot of guanábana, achiote, papaya morada, papaya amarilla, "achojcha" (Cyclanthera pedata (L.)., "culantro hediondo" (Eryngium foetidum L.), "guaba machete" (Inga spectabilis Vahl) Willd.), guaba de bejuco, guaba de mico, zapote, haba pallar and guaba de río. On average, the species with the highest number of reports were papaya, amarilla o morada (16), guaba de bejuco (14), zapote (14), guanábana (19), guaba machete (9) and cereza (8); On the other hand, 21 species were named by less than six interviewed.

Table 3. Number of farms where many, regular or few numbers of individuals of 27 species under study were found[1]

Scientific name	Common name	Number of farms where the species were found[1]			
		Many	Regular	Few	Total
Annona cherimola Mill.	Chirimoya			4	4
Annona muricata L.	Guanábana	2	2	6	10
Bixa orellana L.	Achiote	2	1	3	6
Carica papaya L.	Papaya amarilla y morada	6		10	16
Chrysophyllum cainito L.	Caimito morado			1	1
Cucurbita maxima Duchesne ex Lam.	Zapallo		1		1
Cyclanthera pedata (L.) Schrad.	Achojcha	1			1
Eryngium foetidum L.	Culantro hediondo	2			2
Eugenia stipitata McVaugh	Arazá		1	4	5
Inga spectabilis (Vahl) Willd.	Guaba machete	2		7	9
Inga edulis Mart.	Guaba de bejuco	3		11	14
Inga manabiensis T.D. Penn.	Guaba de mico	1		2	3
Ipomoea batatas (L.) Lam.	Camote			2	2
Malpighia emarginata Sessé & Moc. ex DC.	Cereza			8	8
Maranta arundinacea L.	Tapioca		1	1	2
Matisia cordata Bonpl.	Zapote	4	3	7	14
Passiflora foetida L.	Bedoca			1	1
Phaseolus lunatus L.	Haba pallar	2	1		3
Phytelephas aequatorialis Spruce	Mococha			2	2
Pouteria caimito (Ruiz & Pav.) Radlk.	Cauge			5	5
Psidium friedrichsthalianum (O. Berg) Nied.	Guayaba agria			2	2
Cassia grandis L. f.	Caña fístula			1	1
Sicana odorifera (Vell.) Naudin	Jirón			1	1
Solanum quitoense Lam.	Naranjilla			1	1
Vitex gigantea Kunth	Pechiche			4	4
Unknown 1	Guaba de río		1		1
Unknown 2	Guaba cubana			1	1

Many= more than ten individuals **Regular**= between 5 and 10 individuals

Few= less than five individuals

Table 4. shows the comparison made by informants about the presence of 27 native edible species 10 years ago with the present time. According to the data provided, the most named species were papaya amarilla, zapote, guaba de bejuco, guanábana and guaba machete. 89% of the plants were in the past in greater quantity (more than 10 individuals), and distributed in the farms, including guanábana, papaya amarilla, guaba machete, guaba de bejuco, zapote, "cauge" (*Pouteria caimito* (Ruiz & Pav.) Radlk.) and pechiche (*Vitex gigantea* Kunth), which have now been displaced by other agricultural crops such as cocoa and banana, or because they produce excess shade that is not suitable for the farmer. In case of zapote, three informants said that, in addition, it was cut for firewood or coal and in the case of papaya amarilla, an informant said that he was displaced by other crops and by of ants plague. Two interviewees reported that in the past they had no mococha on their farms but currently cultivate it, the same with the naranjilla and the achojcha, in each case a farmer grows it for consumption.

Table 4. Presence of native food species, 10 years ago compared to the present time, according the farmers.

SCIENTIFIC NAME	COMMON NAME	ABUNDANCE OF THE SPECIES ON THE FARM ACCORDING TO THE INTERVIEWEES			
		SINCE 10 YEARS AGO			
		N[1]	Absent	IT WAS MORE THAN 10 INDIVIDUALS DISTRIBUTED THROUGHOUT THE FARM	IT WAS LESS THAN 10 INDIVIDUALS DISTRIBUTED THROUGHOUT THE FARM
Annona cherimola Mill.	Chirimoya	4	1	3	
Annona muricata L.	Guanábana	10		7	3
Bixa orellana L.	Achiote	6	2	4	
Carica papaya L.	Papaya amarilla	16	1	10	5
Chrysophyllum cainito L.	Caimito morado	1		1	
Cucurbita maxima Duchesne ex Lam.	Zapallo	1		1	
Cyclanthera pedata (L.) Schrad.	Achojcha	1	1		
Eryngium foetidum L.	Culantro hediondo	2		2	
Eugenia stipitata McVaugh	Arazá	5	4	1	
Inga spectabilis (Vahl) Willd.	Guaba machete	9		8	1
Inga edulis Mart.	Guaba de bejuco	14	1	12	1
Inga manabiensis T.D. Penn.	Guaba de mico	3		3	
Ipomoea batatas (L.) Lam.	Camote	2		1	1
Malpighia emarginata Sessé & Moc. ex DC.	Cereza	8	3	5	
Maranta arundinacea L.	Tapioca	2		2	
Matisia cordata Bonpl.	Zapote	14		13	1
Passiflora foetida L.	Bedoca	1		1	
Phaseolus lunatus L.	Haba pallar	3		3	
Phytelephas aequatorialis Spruce	Mococha	2	2		
Pouteria caimito (Ruiz & Pav.) Radlk.	Cauge	5	1	4	
Psidium friedrichsthalianum (O. Berg) Nied.	Guayaba agria	2	1	1	
Cassia grandis L. f.	Caña fístula	1		1	
Sicana odorifera (Vell.) Naudin	Jirón	1		1	
Solanum quitoense Lam.	Naranjilla	1	1		
Vitex gigantea Kunth	Pechiche	4		4	
Unknown 1	Guaba de río	1		1	
Unknown 2	Guaba cubana	1		1	

N[1]= Number of farmers who have the species on their f

SCIENTIFIC NAME	COMMON NAME	ABUNDANCE OF THE SPECIES ON THE FARM ACCORDING TO THE INTERVIEWEES					
		NOW					
		N[1]	CUT TO MAKE FIREWOOD OR COAL	DISPLACED BY AGRICULTURAL CROPS OR BY GIVING EXCESS SHADE	MORE THAN 10 INDIVIDUALS DISTRIBUTED IN THE FARM	PLANTS AFFECTED BY PESTS	THEIR NUMBER HAS BEEN MAINTAINED OVER THE YEARS
Annona cherimola Mill.	Chirimoya	4		3	1		
Annona muricata L.	Guanábana	10		9	1		
Bixa orellana L.	Achiote	6		5	1		
Carica papaya L.	Papaya amarilla	16		13	2	1	
Chrysophyllum cainito L.	Caimito morado	1		1			
Cucurbita maxima Duchesne ex Lam.	Zapallo	1		1			
Cyclanthera pedata (L.) Schrad.	Achojcha	1			1		
Eryngium foetidum L.	Culantro hediondo	2		2			
Eugenia stipitata McVaugh	Arazá	5		3	2		
Inga spectabilis (Vahl) Willd.	Guaba machete	9		9			
Inga edulis Mart.	Guaba de bejuco	14		12	2		
Inga manabiensis T.D. Penn.	Guaba de mico	3		3			
Ipomoea batatas (L.) Lam.	Camote	2		2			
Malpighia emarginata Sessé & Moc. ex DC.	Cereza	8		6			2
Maranta arundinacea L.	Tapioca	2		2			
Matisia cordata Bonpl.	Zapote	14	3	10	1		
Passiflora foetida L.	Bedoca	1		1			
Phaseolus lunatus L.	Haba pallar	3		3			
Phytelephas aequatorialis Spruce	Mococha	2			2		
Pouteria caimito (Ruiz & Pav.) Radlk.	Cauge	5		5			
Psidium friedrichsthalianum (O. Berg) Nied.	Guayaba agria	2		2			
Cassia grandis L. f.	Caña fístula	1		1			
Sicana odorifera (Vell.) Naudin	Jirón	1		1			
Solanum quitoense Lam.	Naranjilla	1			1		
Vitex gigantea Kunth	Pechiche	4		4			
Unknown 1	Guaba de río	1		1			
Unknown 2	Guaba cubana	1		1			

DISCUSSION

It is important to know the native species of a region, for their contribution to the food of its inhabitants. In Mariscal Sucre, Fabaceae had more species than the other 14 registered families. This is consistent with Poth, Colgrave, Philip and Kerenga (2011), who report that this family has the largest number of species worldwide, with great economic impact. In addition, Martínez, Evangelista, Basurto, Mendoza and Cruz-Rivas (2007), say that Fabaceae is the predominant family in most of the American continent and that it is a source of genetic resources for the benefit of humanity. In addition to the Fabaceae, other outstanding botanical families were Caricaceae, Annonaceae and Malvaceae, all with species of arboreal, shrubby or herbaceous habits. These results are similar to those obtained by Rubí et al. (2014), whose research in the southwest of the State of Mexico showed that the largest number of species in that region were trees; secondly the herbs and thirdly the shrubs. While Jeeva (2009) and Lascurain, Avendaño, del Amo and Niembro (2010), when studying in Veracruz, Mexico, the potential of native plants with nutritional value, found that those of arboreal habit dominate over the other forms of growth.

In the species reported in this investigation, the fruit was the most used edible part. In general, the consumption of the edible parts of plants in study was fresh, without prior preparation and raw, as reported by Asturizaga, Ollgaard and Balslev (2006), in a study on the edible fruits of the Central Andes of Peru, Ecuador and Bolivia. They claim that in those regions are used edible native fruits as food and consumed in different ways, without preparation in vegetable salads or fruit but are also processed like juices, made with water or milk, or mainteined as preserves. Echeverria (2014) mentions that in Chimaltenango, Guatemala, the food species under study are consumed in these ways because the interviewees do not know any other form of preparation, although the mothers consulted wanted to learn new ways to prepare them for their children to eat without reject them.

Currently, local knowledge about native food plants that are transmitted

from parents to children, either orally or through practices and customs, are being lost. In the present investigation differences between knowledge and ages of the interviewees were observed. Women had an age range of between 38 and 74 years and men between 53 and 87 years. In general, at a younger age, less knowledge about the plants under study. In the case of women there was an exception, a 44-year-old interviewee had a broad knowledge of these species because she likes to cultivate the land, and her mother teaches her about the conservation and use of these species. In the case of men, only one of 74 years showed mastery of the subject because all his life has been devoted to agriculture and learned from these plants, by transmitting knowledge from his parents. However, this case is worrisome because nobody in your family wants to get involved with agriculture, much less the preservation of these species; similar reality can be seen in most of the interviewees.

The problem described above is consistent with Jivaja (2016) who reports that local and popular knowledge related to edible vernacular plants are being lost since they are not transmitted to future generations. In addition, Muiño (2012), mentions that there is a process of loss of knowledge that corresponds to changes in the way of life, and they are shown through the replacement of food harvested by products manufactured in the market. On the other hand, Polanco, Vernaza and Burbano (2018), argue that this type of knowledge is being lost as societies develop.

Regarding the conservation status of the species, the results obtained were worrying, plants that have a habit of trees or shrubs such as "guaba machete", "guava de bejuco" and "guaba de mico" are being cut to establish monocultures of cocoa, CCN-51 variety, and Cavendish banana or because they provide excess shade for those crops or, as in the case of "zapote" to make firewood and coal. These activities show the disinterest of farmers in preserving these species, which is related to the low economic importance they give them. In addition, the case of "yellow papaya" is unique since the ant has become a plague for her. Due to these problems, Gonzales (2008) argues that the policies promoted today are developmentalist, which allow

deforestation and monoculture planting, which prevents the spread and survival of native food species. In turn, population growth has caused sites destined for this type of vegetation to continue disappearing. Manco (2015) says that the impact caused by man on socio-environmental deterioration is irreversible, which has caused the displacement, decrease and even destruction of the diversity of these species.

Two qualities of underutilized species are that they are adapted to the environment and are potential source of food for the communities, especially those that are in a condition of poverty or marginalization. This is evidenced in the work of Cilia, Aradillas y Días (2015) who evaluated local edible plants classified as vulnerable in the indigenous Huasteca Potosina community in Mexico. 46 edible genera were identified, adapted to that environment and used in the diet of local residents. These qualities also applies to the farms of Mariscal Sucre, where native edible species can serve as a complement to diet of families, improving the family basket. Villaseñor and Espinoza (2004) mention that there is a need to create strategies that allow the preservation and use of these plants as a source of germplasm, food and economic resources, associated with the development of research in its production, propagation, phytosanitary management, industrialization and commercialization.

CONCLUSIONS

There are several ways to define ethnobotanical research; for this study, it could be the analysis of the relationship between the producer of an agricultural farm and its surroundings. In the case of farmers in the rural area Mariscal Sucre, this relationship is very complex. On the one hand there is the need to produce intensively, with the practice of a commercial agriculture of crops such as sugar cane, banana and cocoa, mainly. On the other hand, there is the maintenance of native underutilized edible species, which were formerly part of their family diet. In general, the displacement of these plants by the commercial ones was appreciated; however, in this investigation it was observed that the size of the farms is fundamental for the relationship balance of the commercial production-maintenance of the native edible underutilized species. In most small farms, less than 10 ha, family farming is practiced, whose diet is complemented with the products of the species reported in this work.

Given the intensivism of agriculture in the area, the report of 29 underutilized native species on farms shows great diversity in the area, despite being such a fragile one. Thus, the farms under study have become redoubts for the in situ maintenance of the native germplasm and the conservation of plant biodiversity. Despite its importance, another major threat to the survival of these plants is the displacement of the food preferences of the inhabitants, who have changed the quality and variety of their diet, induced by propaganda, industrialization and globalization. These factors have influenced the loss of local knowledge about the conservation and uses of these plants. The new generations do not appreciate them or simply ignore their qualities and the older farmers do not give it all the necessary importance to continue with the generational transfer of knowledge.

Due to the problems that agriculture must endure to climate change, the species reported in this research should be considered important as a food source. Their condition as natives guarantees their adaptation to the

environmental factors of the environment of the farms where they persist. It is necessary to study its nutritional value and its potential commercial production, as an economic and easily available food source for the producer, which allows him a sustainable and sustained income over time and that contributes to his food security.

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APPLIED IT

Telematics irrigation importance in optimal water Management and its contribution to Agricultural Production

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ABSTRACT

This research characterizes telematics irrigation, its importance in the optimal management of water and its contribution to agricultural production. For this, it begins with the description of the telematics irrigation system, the implementation method is detailed, its importance in the optimal management of water and the contribution to agricultural production. In this sense, the implementation of technology through telematics irrigation in agriculture aims to improve the yield on agricultural production and reduce the time in the process of irrigation and saving of the water resource. The implementation of telematics irrigation systems requires components and/or elements of hardware, software and internet service. A comparative analysis between telematics irrigation and traditional irrigation was performed, so far were defined as cost, water management, and production; to managing to identify that telematics irrigation allows less workload to human resources, control and monitoring of water requirements and savings of water; therefore obtaining quality and efficiency in productivity, also finding certain advantages such as saving time, ease in programming irrigation and among the disadvantages, cost of equipment, lack of knowledge about innovative systems for irrigation management.

Keywords: agricultural production, telematics irrigation, technology, agriculture

INTRODUCTION

The agricultural sector worldwide can be considered a fundamental area of a country, because it addresses several needs regardless of whether the countries are developed or underdeveloped, which is why it is of great importance since it meets the needs of people and ensures opportunities for jobs, thus demanding productivity essentially from small farmers, in this way leading to expanding access to markets. Therefore, extensions of agricultural land must be established under criteria that seek to meet the needs to which they are exposed today, motivating the inclusion of technologies for certain processes.

The importance given to agriculture, is given to the fact that it is fundamental in the economy of a country because it provides employment to several people of a population, being considered the agricultural area as the first source of employment in certain countries, therefore, agriculture must have a continuous development and thus the production will be increased and the marketable surplus expands (INFOAGRO, 2018).

Ecuador is an eminently agricultural country, with agriculture being a productive sector for the Ecuadorian economy, this country allows diversified production due to the characteristics of the soil, climate, watersheds and geographic location; being favorable for the country; considering that the Coast and Highland regions are parts where the greatest agricultural production is focused on. (Gortaire, 2017).

Agricultural production requires permanent control and an important element within it is the application of irrigation, this being a fundamental process for all crops because it allows the improvement of production, therefore it is important to opt for new strategies that include technology, such as the case of telematics irrigation that allows communication with technological elements and thus be able to carry out irrigation in crops

through the internet connection from anywhere, obtaining real data on the plantation.

Irrigation has been developed since ancient times in order to provide water in adequate quantities to the crops thus allowing the production of food in dry season, which is to say where there is no frequent rain (Guillermo, 2017).

Irrigation technification raises farmers a way out of problems with irrigation management, rationalizing the water resource, obtaining improvements in their crops with the appropriate use of water, minimizing the waste of the same, which results in obtaining better agricultural conditions, obtaining benefits such as greater efficiency of the use of water and fertilizers in addition to the availability of time to be able to devote to other activities (TECNIAGRO, 2014).

The purpose of this review is to characterize the telematics irrigation system, description of the implementation of a telematics irrigation system including the description of its components and / or elements of hardware, software and internet service, in addition to the comparison of telematics irrigation with traditional irrigation applied to agriculture, it is necessary to define comparison criteria such as cost, water resource management and production, in order to identify the contribution of telematics irrigation to agricultural production, besides to knowing its advantages and disadvantages.

METHODOLOGY

The study shows the results and discussion of the analysis on the importance of telematics irrigation in water management and its contribution to agricultural production. It began with the definition of the problem, then the approach to the topic and keywords; in accordance with the nature of the study, bibliographic analysis was carried out based on the collection, classification and selection of documents with information from relevant and verifiable sources, which were structured according to the norm of documentary analysis. (Nel Quezada, 2015).

Analysis allowed identifying the importance of the application of telematics irrigation for the optimal management of water and its contribution to agricultural production, developing a theoretical, analytical and detailed framework.

Results were generated from the review and documentary analysis in correspondence with the theoretical framework for the construction of the discussion and the development of the objectives of the study that begins first with the characterization of telematics irrigation system, then the description of the implementation process of telematics irrigation in agriculture and finally identifying the telematics irrigation importance in the optimal management of water and its contribution to agricultural production, for the fulfillment of this last objective it was necessary to define the following comparison criteria : costs, water management and production.

RESULTS

Telematics irrigation system characterization

Irrigation has been developed since ancient times in order to provide water in adequate quantities to crops, thus allowing food production in dry season, that is to say where there is no frequent rain (Guillermo, 2017).

Technologies have taken an important turn to the productive processes in agriculture, providing efficient solutions with the development of technological tools, among them the sensors for monitoring that facilitates farmers to collect data on the water needs of crops, automation that can be implemented in irrigation systems (AGROPINOS, 2019).

Telematics irrigation system is characterized by being a system that consists of providing water to the crops using the different irrigation systems that exist, responsible for optimizing the use of water in crops through sensors and programmable equipment that help irrigate the crop (Escobar y Farfán, 2018).

It is important to modernize traditional irrigation for water saving through various irrigation systems, whether drip, sprinkler, among others and that together with telematics irrigation systems brings benefits for the environment such as saving water resources and mainly water global warming footprint reduction.

For the growth and development of the plants irrigation is necessary and of great importance, that is why the optimization of the irrigation in the crops is born, telematics irrigation allows to control the moment of irrigation in the plants with the use of technologies showing the real-time crop status for decision making on their plots (Aguado, Quevedo, Castro, y Vázquez, 2014)

Telematics irrigation implementation in agriculture

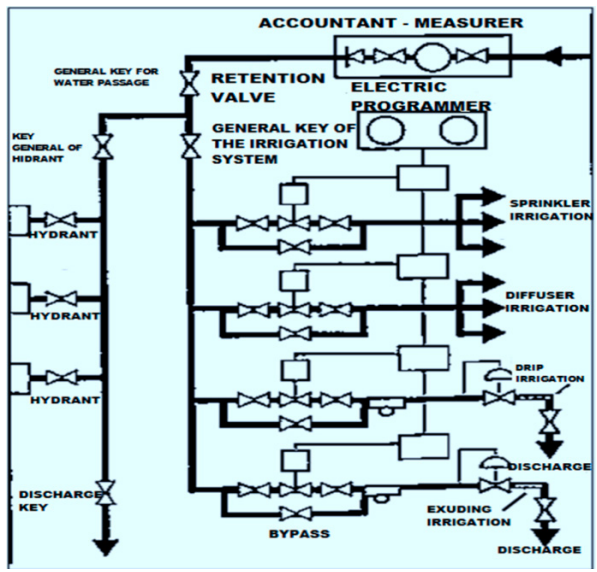
All types of irrigation system must be subjected to a prior study, this will identify if it is the most appropriate and covers the needs according to the type of crop to achieve better yield (Quispe, 2017).

Telematics irrigation system consists of programmable sensors and equipment that help the automation of irrigation in crops satisfying the plants, through orders such as time and time that are assigned by a computer (Laverde, 2016).

For telematics irrigation implementation it is necessary to take into account the general irrigation scheme, this being constituted by several sections of pipes such as the primary one that starts in the meter until the consumption

exits, it is composed of: irrigation mouths, valves, solenoid valves and station keys; the secondary that is between the valves, solenoid valves and water distribution systems such as sprinklers, diffusers, drippers and exudants; and water distribution, (AMBIENTUM, s.f.).

Figure 2. General irrigation network



Source: (Quispe, 2017)

Anaya and Peluffo, (2015) express that into telematics irrigation system implementation, different hardware and software components must be used, they basically recommend the use of open software and open hardware, with the purpose of reducing costs and thus being able to cover the needs according to the socio-economic characteristics of the agricultural producer, and access to the internet service must also be taken into account.

In the case of the hardware, automatic irrigation sensors are used, they transmit data on what is happening in the field, they are able to detect the state in which the soil is, that is, on the soil moisture; reducing risks, optimally managing crop irrigation, thus benefiting producers (Pizarro, 2017).

Another hardware element is the irrigation controller, it is installed in the

irrigation head and they handle the irrigation operations sequentially, this controller works with solenoid valves connected to the controller and to each field valve by means of hydraulic controls, so the valves work by the order that the controller issues by having each valve start and end the irrigation (Liotta, 2015).

According to Mullo, who cites Aguado, Quevedo, Castro and Vásquez, indicates another hardware element that is used in a telematic irrigation system and is the volumetric valves that control the desired water volume and automatically close after supply, these valves are can be programmed to work according to a certain sequence (Mullo, 2016).

In relation to software, there are technological platforms that help carry crop data in real time such as the case of Irrigation App, which is an application that allows us to manage irrigation easily, managing agricultural irrigation programmers of different brands, it is an App free that provides certain benefits to the farmer (García, 2017).

Another case in Spain is the SIAR App, which makes it possible to configure the irrigation system, visualize graphs of the state of the soil and activate a warning in the terminal when the crop varies its state of water risk. This app allows real-time access to the data supplied by the SIAR network of stations, consisting of 461 agrometeorological stations, of which 361 are owned by the Ministry and the remaining 100, from the collaborating Autonomous Communities, which allows a personalized calculation of the irrigation dose (INNOVAGRI, 2016).

Another of the important elements in a telematics irrigation system is the internet, this is used as a communication network which allows to determine the demands of water needed by the crop and thus be able to schedule real-time irrigation for crops (Servín, Tijerina, Medina, Palacios, y Flores, 2017).

Regarding telematics irrigation system implementation, as mentioned, it requires different elements of hardware, software and also the internet connection; for López Rubén, in his project, sensorization and domotization of the irrigation system with Arduino, he proposes the following components: Arduino programmable plate, Etherneth plate, temperature and air humidity sensors, earth humidity sensors, precision clock module, relay plate, micro-

SD cards, power supplies and solenoid valves; a web interface that provides automatic irrigation configuration, control and management (López, 2018).

Telematics irrigation importance in optimal water management

The introduction of technologies applied onto agricultural sector has allowed the evolution of production systems, demonstrating efficiently the profitability of the business, telematics irrigation system helps farmers to control irrigation from any place where they are saving money and time. displacement that takes to reach their crops (Peláez, 2017).

Telematics is a technology of great importance on agricultural sector since it allows teams to communicate with farmers. They may be able to indicate advanced diagnostic modules, alert about a problem or indicate if preventive maintenance is needed. (Ramírez, Ruilova, y Garzón, 2015).

Applied technology to agriculture through telematics irrigation allows to create development opportunities, better use of water, increase of agricultural production; in this regard, a telematics irrigation system must achieve automatic irrigation control and allow the crops to always remain hydrated, with the necessary amount of water and obtain a better quality in the final products (Guijarro, Cevallos, Preciado, y Zambrano, 2018).

Telematics irrigation system aims to optimize the use of water through technological resources that help facilitate irrigation in crops, using sensors that monitor soil moisture depending on whether the soil needs water, the system turns on otherwise, it is automatically switched off via solenoid valves (Gonzalez, 2017).

For the optimal operation of an irrigation system, an automated control system must be possessed to reduce time and avoid wasting water at the time of irrigation, the contributions that technology offers in this field is of great help to have good use of natural resources reducing environmental impact (Borja, 2018).

Telematics irrigation contribution to agricultural production

Farmer needs has led to innovate and automate agricultural processes in order to have a competitive agriculture in the market, thanks to modernized systems and automatic irrigation management, technologies help to carry

out optimal irrigation programming taking into account the characteristics of the crop giving the plant the amount of water necessary for its development (Ferruzola, Duchimaza, Bermeo, y Facuy, 2017).

To identify telematics irrigation contribution onto agricultural production, a comparative analysis has been carried out regarding the characterization of an irrigation system with telematics and a traditional technology, for which the following comparison criteria were defined: water management , production, costs.

CRITERIA	TELEMATICS	TRADITIONAL
COSTS	From the perspective of small farmers, telematics irrigation is not within their reach, but if it is applied it will bring great benefits.	Materials costs need continuous investment because maintenance must be performed from time to time.
	Less workload to the human resource	Workload to the human resource, therefore payment of values for the work performed.
WATER MANAGEMENT	Water the necessary amount that the crop needs saving water	It can produce waste of water and exceed the level of the liquid that the crop needs
	You can control and monitor water requirements from an App or website.	The control and monitoring of water requirements must be insitu.

PRODUCTION	It has better quality and efficiency in productivity making it higher in relation to traditional irrigation.	Production is not going to be totally satisfactory since the use of the resource would be limited either due to its availability, inaccuracy in the quantities required by the crop and mainly due to climatic factors.

Table 1.Comparison of Telematic Irrigation vs. Traditional Irrigation

Source: Personal collection

Telematics irrigation system advantages and disadvantages

Telematics irrigation advantages mostly are water saving, time saving, easy to program, can irrigate large areas of land with the proper use of elements (Camaltec, 2018).

Among telematics irrigation system disadvantages we have equipment costs are perceived as high by farmers, they may present compatibility problems with existing machinery, little knowledge about innovation in the sector, certain computer skills for systems implementation (Ferruzola, Duchimaza, Bermeo, y Facuy, 2017).

An automated irrigation system aims to satisfy the crops of their water needs with the necessary amount at the appropriate time in an efficient manner, guaranteeing optimal conditions for plants (Espinosa, Flores, Ascencio, y Carrillo, 2016).

It can be identified that telematics irrigation advantages are controlling and adjusting doses irrigation, achieving greater efficiency, saving water and among the disadvantages, its initial cost and the useful life of the irrigation system are considered as it will depend on durability and how the implementation per hectare of the network density is carried out.

Montalvo and Bajaña, (2017) identify in their study on the knowledge of intelligent irrigation systems in Ecuadorian agriculture that 93% of the population according to the study, has perceived the benefits such as: decrease in labor, optimal use of fertilizers, water saving, product quality improvement, irrigation frequency reduction, productivity increase, less damage to the system.

DISCUSSION

Within the study carried out by Avello Fernández Lianet in 2018, he expresses that the new technologies contribute with a set of solutions that allow automating, collecting information and obtaining results to manage and make better decisions in agricultural irrigation (Avellano, Izaguirre, and Vidal, 2018). Therefore, it presents agreement with the study because it can be identified from the review carried out that telematics irrigation implementation contributes to water management since with the inclusion of hardware, software and internet connection we can manage the irrigation, optimize the water use, obtain relevant information for decision making, maintain the humidity necessary for the crop and therefore increase productivity.

CONCLUSIONS

Country's agricultural field has a boost in economic development that is why so necessary to integrate technology into agricultural activities that will help increase productivity and profitability, one of these elements is telematics irrigation.

Telematics irrigation system consists of the implementation of technology for optimal water management, among the elements that must be used are hardware such as: sensors, programmable equipment, Arduino programmable board, power supplies and solenoid valves, among others; in the case of the software, a web interface that provides water to the crops in relation to the different irrigation systems that exist, in addition to the internet connection to be able to access remotely and allow the agricultural producer to make decisions in the management of the system of irrigation.

With the telematics irrigation system strategic implementation, large contributions are identified such as the control and monitoring of water requirements from an App or website, less workload to the human resource and better quality and efficiency in productivity due to optimal management of water and maintenance of the moisture required in crops.

Recommendations

We recommend that this review be a reference for the approach and development of research projects that propose technological alternatives in the control and management of irrigation for small agricultural producers in different types of crops such as cocoa, rice, short cycle, among others; with the aim of improving productivity and in view of its growth as agricultural producers.

Perform cost-benefit studies in relation to the implementation of technological resources for the management and management of irrigation in different types of crops to identify the feasibility and contribution of technology in the development of the agricultural sector of small and medium producers.

Propose strategic information technology projects that meet quality standards, innovation, control and management of the irrigation system in different crops; with telematics elements that provide timely information, allow the correct decision making in irrigation management and therefore obtain better production results.

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Evaluation of the level of agricultural modernization in Milagro canton using SPSS software

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ABSTRACT

Agricultural modernization plays an important role in agricultural socio-economic development. Three multivariate statistical methods, hierarchical clustering analysis, factor analysis, and discriminant analysis were applied to a subgroup of the dataset to assess its utility in classifying agricultural modernization in Milagro canton and to identify hidden patterns of agricultural modernization. The factor analysis revealed three factors that explain more than 91% of the total variance. The hierarchical grouping analysis and the discriminant analysis showed that the agricultural modernization regions studied can be grouped into three groups, that is, relatively less agricultural modernization level, medium agricultural modernization level and highly agricultural modernization level regions in Milagro canton. The recognition capacities of the two discriminant functions were 97.8% and 2.2%, respectively. The level of agricultural modernization in the eastern and northern regions in Milagro canton was higher, while that the western and southern regions was lower. This study demonstrated that SPSS software and multivariate statistical techniques are effective for classification of agricultural modernization and for rapid evaluation of agricultural modernization.

Key words: hierarchical cluster analysis, factor analysis, discriminant analysis, agricultural modernization, SPSS software, Cantón Milagro

INTRODUCTION

Agriculture is the important aspect of development that led to the rise of human civilization. Agricultural modernization has become a major concern, due to its values for socio-economic agricultural development. Hena, S., Jingdong, L., Rehman, A., & Zhang, O. (2019) analyzed the role of agricultural technology among countries in economic development, and proposed that agricultural modernization has a positive effect on both economic growth and human development. Janssen, W. and Delondono, N. R. (1994) analyzed the modernization of bean cultivation systems in southern Colombia. Therefore, evaluation of agricultural modernization is necessary for effective management of agriculture.

SPSS is a computer program used for statistical analysis that includes descriptive statistics, bivariate statistics, prediction of numerical results and identification of groups such as factor analysis, cluster analysis (CA) and discriminant analysis (DA), etc. Multivariate statistical techniques, such as factor analysis, CA and DA, are widely applied in facial recognition (Datta, 2015), atmospheric deposition (Hůnová, I., Maznová, J., & Kurfürst, P., 2014), geochemistry and mineralogy. (Trindade, J., Rocha, F., & Dias, I., 2010), quality control (Singh, K., Jha, K., Chaudhary, A., Yadava, S., & Rai, B., 2010), nuclear magnetic resonance (Marcone, F., Wang, S., Albabish, W., Nie, S., Somnarain, D., & Hill, A., 2013), water quality (Jung, Y., Lee, L., Im, H., Lee, J., Kim, S., Han, Y., & Ahn, M.., 2016) and heavy metals (Lu, 2010). However, very few studies have been carried out to assess the level of agricultural modernization using multivariate statistical techniques. The objective of the present study was to evaluate the relationships between the variables and the hidden patterns and levels of agricultural modernization, for a case of Milagro canton, using multivariate statistical techniques.

In a research carried out by Morejón, R., and Díaz, S. (2013), the combination of multivariate

statistical techniques and modified augmented design (DAM) were analyzed in the selection of test lines in the rice genetic improvement program (Oryza sativa L.). That study allowed by means of the use of DAM to overcome the limitations of a non-replicated experiment, allowing there to be an economic benefit for the reduction of area, the saving of experimental material and control of environmental heterogeneity, in combination with multivariate statistical techniques provide a more efficient methodology in the selection of promising lines in the rice genetic improvement program.

Righetto, J., Nakamura, R., Bautista, L., & Dias, S. (2014) analyzed the application of multivariate statistical techniques for the grouping of genetic cocoa materials (Theobroma cacao L.) allowing that with the help of the factor analysis, by the latent root criterion, three factors were retained, which explain 84.14% of the accumulated variance of the original variables. After factor analysis, the authors applied a grouping analysis, which result was to group the 20 genetic materials into 5 different groups.

METHODOLOGY

Multivariate statistical techniques

In this study, factor analysis was used by the main components extracted from the data and rotated using Varimax. For hierarchical clustering analysis, the dendrogram was constructed using the Euclidean squared distance between the normalized data to measure the similarity between the sample cities and the room method to establish different groups. Fisher's linear discriminant analysis was used to derive the discriminant functions of each classified group. In the discriminant analysis, a discriminant function was created for each group, given by where it denotes the number of the group gi; ki that represents the constant inherent in each group., n is the number of parameters used to classify a set of data into a given group; and wij is the weight coefficient assigned to a selected parameter given pij by the discriminant analysis (Sharma, 1996).

$$f(g_i) = k_i + \sum_{j=1}^{n} w_{ij} p_{ij}$$

Software SPSS

Multivariate statistical analysis was performed by SPSS 22.0 software packages for Windows.

Data treatment

In this study, the data sets included X1 (total power of agricultural machinery), X2 (electricity consumed in the rural area), X3 (consumption of chemical fertilizers), X4 (area plowed by tractors), X5 (irrigated area) and X6 (stable yields guaranteed despite disasters) of the 4 parishes in Milagro canton. Standardized skewness and kurtosis were determined to assess whether the samples came from a normal distribution. The agricultural modernization evaluation data used in the analysis were obtained from the statistical

yearbooks of the farmers' associations of Milagro canton.

RESULTS AND DISCUSSION

Factorial analysis

Spearman's rank correlation coefficients in raw data for agricultural modernization in Milagro canton are presented in Table I.

Variables	X_1	X_2	X_3	X_4	X_5	X_6
X_1	1.000	0.649	0.674	0.695	0.601	0.499
X_2	0.649	1.000	0.676	0.804	0.726	0.652
X_3	0.674	0.676	1.000	0.871	0.922	0.829
X_4	0.695	0.804	0.871	1.000	0.962	0.940
X_5	0.601	0.726	0.922	0.962	1.000	0.964
X_6	0.499	0.652	0.829	0.940	0.964	1.000

Table 1 List range correlation coefficients on raw data of the level of agricultural modernization in Milagro canton
Source: The Authors

Table 1 showed the high interdependence between particular parameters such as the high correlations between the electricity consumed in the rural area and the area plowed by tractors, the electricity consumed in the rural area and the irrigated area, the consumed of chemical fertilizers and the area plowed by tractors, and the consumed of chemical fertilizers and irrigated area and assured stable yields despite disasters.

The redundancy of the information in the correlation matrix suggests the application of factor analysis to reduce the dimensionality of the data set in agricultural modernization. The total variance explained is presented in

Table II.
Table 2 Total variance explained

FREQUENCY	INITIATIVE OWN VALUES			ROTATING SUMS OF SQUARE LOADS		
	Total	Difference (%)	Accumulative (%)	Total	Difference (%)	Accumulative (%)
1	4.858	80.965	80.965	3.444	57.400	57.400
2	0.614	10.225	91.191	2.027	33.790	91.191
3	0.346	5.763	96.954			
4	0.152	2.540	99.494			
5	0.018	0.297	99.791			
6	0.013	0.209	100.000			

Source: The authors

The number of components to maintain was based on the Kaiser criterion, for which only the main components with a total variance greater than 85% are considered important. Based on the cumulative variance> 85%, the factor analysis developed two factors that explain approximately 91.191% of the total variance.

The Kaiser-Meyer-Olkin (KMO) measure of sample adequacy was used to determine if factor analysis was adequate for the data studied. The result of the KMO test was 76.67%. As the value of 76.67% is greater than 50%, it was also concluded that the data set was appropriate for factor analysis.

Based on the results obtained from the factor analysis, 91.191% of the variability of the original data set is now collected in the first two new variables (components or factors).

The first factor, which is denoted as F1, quantifies the maximum possible variation between different sites. F1 explains the greater proportion (80,965 or 57.43%) of the total variance and has high positive charges in the consumption of chemical fertilizers, area plowed by tractors, irrigated area and assured stable yields despite disasters (Tables I).

Factor 2, which is denoted as F2, explains a significant proportion (10.2250 or 33,790%) of the total variance and has high positive charges on the total power of agricultural machinery, the electricity consumed in rural areas.

Table 3 The rotating load matrix of the main component

Variables	Factor 1	Factor 2
Total power of agricultural machinery	0.2636	0.9241
Electricity consumed in rural areas	0.5274	0.6933
Chemical fertilizer consumption	0.7953	0.4810
Area plowed by tractors	0.8429	0.5100
Irrigated area	0.9204	0.3767
Guaranteed stable yields despite disasters	0.9520	0.2438

Source: The authors

Table 3 shows that F1 includes X3, X4, X5, and X6, while F2 includes X1 and X2.

At the beginning, farmers thought modernization was just mechanization. Mechanization is essential for agricultural modernization in Milagro canton. Therefore, agricultural industrialization must be applied if we want to carry out agricultural modernization. But we believe that four indicators of chemical fertilizer consumption, area plowed by tractors, irrigated area and assured stable yields despite disasters are more important in agricultural modernization, in the specific case of Milagro canton. The factor scores of the level of agricultural modernization in Milagro canton are listed in ***Table 4***.

Table 4 Score of factors of the level of agricultural modernization in Milagro

canton

Parish	Factor 1	Factor 2	Total	Location
Mariscal Sucre	0.4687	1.0823	0.6348	3
Roberto Astudillo	0.6546	1.3038	0.8163	1
Chobo	1.8300	-1.0474	0.6965	2
Milagro	0.6097	-0.9073	0.0434	4

Source: The authors

In ***Table 4***, the high scores of the factor correspond to the high level of agricultural modernization in Milagro canton. The order of the general level of agricultural modernization in the Milagro canton according to the factor scores was as follows: Roberto Astudillo, Chobo, Mariscal Sucre and Milagro. The order of the F1 level of agricultural modernization in Milagro canton was as follows: Chobo, Roberto Astudillo, Milagro and Marcelino Maridueña. The order of the F2 level of agricultural modernization of Milagro canton was as follows: Roberto Astudillo, Marcelino Maridueña, Milagro and Chobo.

Hierarchical cluster analysis

Hierarchical grouping analysis is a data classification technique, classifying objects so that each object is similar to the others in the group with respect to a predetermined selection criterion (Iscen, 2008).

The results obtained determine that the level of agricultural modernization in Milagro canton can be grouped into three groups. Group I formed by Roberto Astudillo corresponds to the highly agricultural modernization level. Group II formed by Chobo and Mariscal Sucre corresponds to the medium level of agricultural modernization. Group III formed by Milagro corresponds to the lowest level of agricultural modernization. Hierarchical clustering analysis results are in good agreement with factor analysis results. The level of agricultural modernization in the eastern and northern regions of Milagro canton was higher, while that the western and southern regions was lower.

Discriminant analysis

Discriminant analysis was used to confirm the agricultural modernization level groups using hierarchical grouping analysis. The diagram of the discriminant functions is presented in ***Figure 1***.

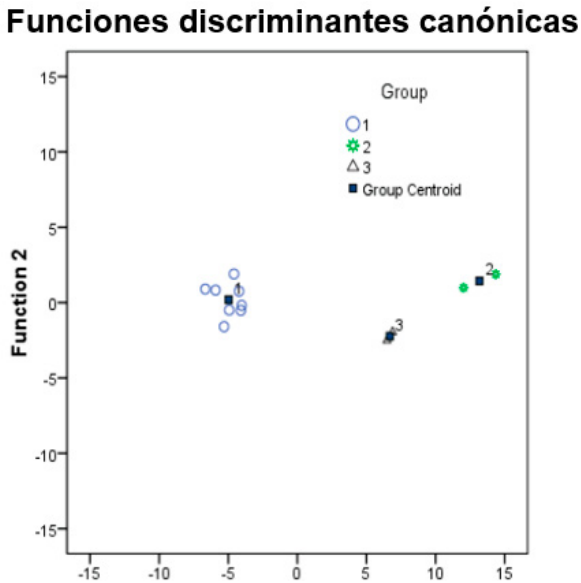

Figure 1. Discriminant Functions

Source: The authors

Figure 1 showed that the level of agricultural modernization in Milagro canton can be grouped into three groups by discriminant analysis based on the similarity of the characteristics of agricultural modernization.

Fisher's discriminant functions are as follows:

$$Group1 = -209.2353 + 0.0038 \times X_1 - 0.0001 \times X_2 - 0.0022 \times X_3 + 4.6817 \times X_4 + 4.8697 \times X_5 - 4.6510 \times X_6$$

$$Group2 = -4.9048 + 0.0304 \times X_1 - 0.0003 \times X_3 + 0.3868 \times X_4 + 0.5701 \times X_5 - 0.4450 \times X_6$$

$$Group3 = -45.3349 + 0.0060 \times X_1 - 0.0001 \times X_2 - 0.0008 \times X_3 + 1.7826 \times X_4 + 2.1356 \times X_5 - 1.9526 \times X_6$$

The discriminant analysis was grouped within the groups of correlations between the discriminatory variables and the standardized canonical discriminant functions. Variables ordered by absolute correlation size within the function. The results of the discriminant analysis showed that the level of agricultural modernization studied in Milagro canton can be divided into three groups and 100% of the original grouped cases are correctly classified. This means that the derived discriminant functions can be used to properly classify the groups. Therefore, the results of the discriminant analysis are in agreement with the results obtained from hierarchical grouping analyzes that confirmed that the level of agricultural modernization in Milagro canton can be divided into three groups. At least one missing discriminant variable and missing or out of range group codes are both zero, indicating that there are no missing variables. The first 2 canonical discriminant functions were used in the analysis. The recognition capacities of the two discriminant functions were 97.8% and 2.2%, respectively.

Therefore, this study illustrates the utility of factor analysis and discriminant analysis for the analysis and interpretation of complex data sets and in the evaluation of agricultural modernization, the identification of factors, and the understanding of spatial variations in the level of modernization. for effective management of agricultural modernization.

DISCUSSION

This study presents the utility of multivariate statistical techniques by SPSS software for the evaluation and interpretation of the level of agricultural modernization to obtain better information. The factor analysis revealed three factors that explain more than 91% of the total variance. The hierarchical grouping analysis and the discriminant analysis showed that the agricultural modernization studied can be grouped into three groups, that is, relatively less level of agricultural modernization, medium level of agricultural modernization and regions of highly agricultural modernization level in Milagro canton. The level of agricultural modernization in the eastern and northern regions of Milagro canton was higher, while that in the western and southern regions was lower. This study demonstrated that SPSS software and multivariate statistical techniques are effective tools for classifying agricultural modernization and for rapid evaluation of agricultural modernization.

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Prototype of an embedded system for irrigation and fertilization in greenhouses

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ABSTRACT

In this literature review article, three questions were performed which guided the research work regarding the subject. A strategy for the search of information was established considering as exclusion criteria embedded systems that are applied in other areas than agriculture. Articles published in virtual libraries and electronic books in English based on embedded systems for irrigation and fertilization in greenhouses were selected. The IEEE Xplore virtual library was in this literature research the library that contributed most to articles published in recent years related to systems embedded for greenhouses. In succession, the ResearchGate virtual library and electronic books also provided relevant information on the subject. The main objective of this literature review is to specify what it is an embedded system or integrated system, its structure and its contribution to the agricultural sector in greenhouses, resulting after the data search that an embedded system works with hardware elements and a software. An embedded system helps farmers perform work in greenhouses automatically without the use of much manual inspection. It is detailed that embedded systems are alternatives for the agricultural sector since it lowers costs and automates processes.

Keywords: Embedded system, fertigation, greenhouses.

INTRODUCTION

The present study search through a review of specific literature of what it is an embedded system or integrated system, its structure and its contribution to the agricultural sector in greenhouses.

The strategy used for the present investigation consisted in the compilation of the necessary bibliography associated with the subject of study, which contributed with relevant information for it.

According to the research, it is known that a greenhouse is a closed structure that protects plants from extreme weather conditions, in this case: wind, ultraviolet radiation and attacks of pests and insects. Irrigation of the agricultural field is carried out by automatic drip irrigation, which operates according to the soil moisture threshold which is established for having an optimum amount of water applied to the plants[1][2].

The concept of agricultural IoT uses networking technology in agricultural production, the hardware of this agricultural IoT includes temperature, humidity and light sensors that are connected to a data processing center which helps the monitoring and care of crops; these hardware devices are connected by various types of wireless communication technology for short distance, such as Bluetooth, WiFi or Zigbee. In fact, according to research ZigBee technology due to its convenient network and low power consumption, it is widely used in agricultural IoT. The network is combined to remotely control and monitor sensor data[3].

The Internet of Things (IoT) and data analysis (DA) are used in agriculture to improve mainly operational efficiency and productivity. The IoT integrates several existing technologies such as WSN, radio frequency identification (RFID), cloud computing, middleware systems, and end-user applications[2].

Inventions in the robotics domain exist and can be applied directly to the agricultural sector, especially for vehicles used in this activity. The application of new popular robotic technologies will increase the manufacture of agricultural vehicles in the future such as mobile robots, flying

robots, and forest robots, which are used exclusively for improving the accuracy and precision in the different activities [4]. Research [5], prop proposed a mechanism for automatic control and fertilization and irrigation management to improve the porosity and soil nutrients through timely application of fertilizers and the necessary water level for the growth and development of crops. The operation is controlled by the interface of several components and intelligence units such as ISE sensors, DHT11 sensor, actuator, AT89C52 microcontroller and other components to automatically apply soluble agrochemical fertilizer and water according to the needs of the plant. In India, an automatic watering system was developed for detecting the moisture content of the soil through PV (photovoltaic cell progression) and GSM [6] , it is a system that automatically activates a water pump via SMS in response to a real-time alert system and after reaching the proper humidity level the farmer can disconnect the water pump by sending an SMS or by a manual task. The components are fed through photovoltaic cells. Chung-Liang Chang and Kuan-Ming Lin [7], proposed a scheme that combines computer vision and multitasking processes to develop a small-scale intelligent machine that can automatically remove the weeds and perform irrigation with a variable rate within a cultivated field using fuzzy logic. The experimental results show that the system can classify plants and weeds in real-time with an average rate of 90% classification. Xue et al. [8], designed a novel method of artificial vision with variable field of view that allows a robot to navigate between rows of maize fields, the artificial vision hardware consisted of a camera with motion control for pitch and yaw. Image processing algorithm was also used for the morphological characteristics and the robot was guided along these lines using fuzzy logic control, showing a maximum error of 15.8 mm and stable navigation behaviour. At work proposed by Shama and Borse [9] they designed and built an autonomous mobile robot for sensing plant diseases, for growth monitoring and spraying mechanism of pesticides, fertilizers, and water with application in agriculture or greenhouses; it has a compact platform that allows spraying pesticides, fertilizers and water directly to the plant. This approach will help farmers make the right decision by providing real-time information about the plant and its environment using basic principles of the Internet, sensors technology

and image processing. Researchers Walter Schmidt and Yucel Toprak [10], they patented a mobile device with the process to adequately irrigation of the soil, in which the movable carriage has a control unit for irrigation of the soil and a mobile unit for measuring by microwaves determine the water content of the soil along a measuring path; furthermore it has a water tank to irrigate the land autonomously.

In the machine design procedure, it is fundamental the experimentation on proto-types that are the product of the application of both: a design methodology and simulation models at an experimental level are established in order to contribute developing low-cost systems that can be useful for the automation of various tasks. Theories of similarity and likeness are used to achieve these small-scale models [11].

In this research, it will be explained the general considerations and physical sustenance that must be taken into account for the design and construction of scale models of embedded systems for automation of irrigation and fertilization in greenhouses.

MATERIALS AND METHODS

The main objective of this literature review is to specify what it is an embedded system or integrated system, its structure and its contribution to the agricultural sector in greenhouses. Therefore, the necessary information was collected through three research questions.

Research questions

The research questions (RQ) were formulated as follows:

RQ I: How do you define an embedded system?

RQ II: How is an embedded system structured?

RQ III: What would be the ideal methodology for the development of an embedded system?

Search strategies

To answer the research questions, a search strategy or the criteria for the search were applied in the relevant research papers. The following is the search string that was used:

(Embedded systems) AND (for irrigation and fertilization) OR (embedded systems methodology) AND / OR (embedded systems architecture).

This search strategy is related to Table 1 where research papers were selected in the periods from 2011 to 2019. Period less than this was not considered for systematic review.

Exclusion criteria

The exclusion criteria were those articles that, despite having the phrase

embedded systems in their content, did not contribute mainly to the subject of the review, as was the case of embedded systems used for homes, medicine, education. Therefore, the studies that were excluded were embedded systems in the field, in remote locations. These studies helped the introduction, but for the development of research questions we only rely on embedded systems for irrigation and fertilization in greenhouses.

Table 1. Search Sources

Paper	Publication Year	Virtual Library	Citation Index	Language
[1]	2011	Science Direct	26	English
[9]	2012	Science Direct	80	English
[18]	2012	Google Scholar	42	English
[5]	2013	ResearchGate	23	English
[14]	2014	ResearchGate	4	English
[22]	2014	Sciendo	2	English
[11]	2015	Google Scholar	13	English
[16]	2015	ACM Digital Library	15	English
[19]	2015	ResearchGate	11	English
[22]	2015	Springer	22	English
[10]	2016	Springer	4	English
[15]	2016	IEEE Xplore	2	English
[17]	2016	Google Scholar	3	English
[20]	2016	IEEE Xplore	3	English
[4]	2017	IEEE Xplore	17	English
[6]	2017	ResearchGate	2	English
[2]	2018	IEEE Xplore	1	English
[3]	2018	IEEE Xplore	52	English
[7]	2018	IJSRET	1	English
[8]	2018	MDPI	4	English
[13]	2018	Libro Electrónico	62	English
[12]	2019	Libro Electrónico	46	English

Search sources

Table 1 shows the search sources from where the systematic review of literature was performed. Search sources include virtual libraries and e-books listed below. The researched article, the year of publication, the name of the scientific journal, the number of times the article has been cited and the language in which it was published are specified. It should be noted that the review was carried out in the search sources in articles containing the key words according to the search strategies.

RQ I: How do you define an embedded system?

In software engineering, embedded systems [12] refer to every digital electronic circuit that is able to perform computing operations, usually in real-time, which serves to fulfil a particular or specific task.

Embedded systems consist of limited resources and own applications that make them productive and useful in multiple environments that are commonly used nowadays, for example, modern cars, mobile phones, medical and agricultural equipment.

RQ II: How is an embedded system structured?

The most important characteristics of an embedded system lie in the low production cost and low power consumption. These should automatically respond to stimuli from the environment where they are. Embedded systems design [13] faces hardware limitations since they usually have no hard drives, keyboards or monitors; a flash memory replaces the disks and some buttons, and an LCD screen normally replaces the interface device. Programming these devices is done in assembly language or C language.

Figure 1 shows the architectural specification of an embedded system [14] which consists of the following elements: a microprocessor and software running on it. But this software needs a place to be stored before being executed by the processor, this is called RAM or ROM memory. Every embedded system needs a certain amount of memory that even can be located within the same processor chip and additionally, a number of inputs and outputs necessary to communicate with external devices. The work performed by embedded systems is relatively easy, processors commonly use records of 8 or 16 bits. In its memory, it only remains the program to master a particular application. Its

input/output (I/O) lines support the connection of the sensors and actuators of the device to control and all additional available resources are intended to meet its requirements. This is the common architecture of embedded systems, everything else will be totally different for each of them in particular due to the variety of available applications.

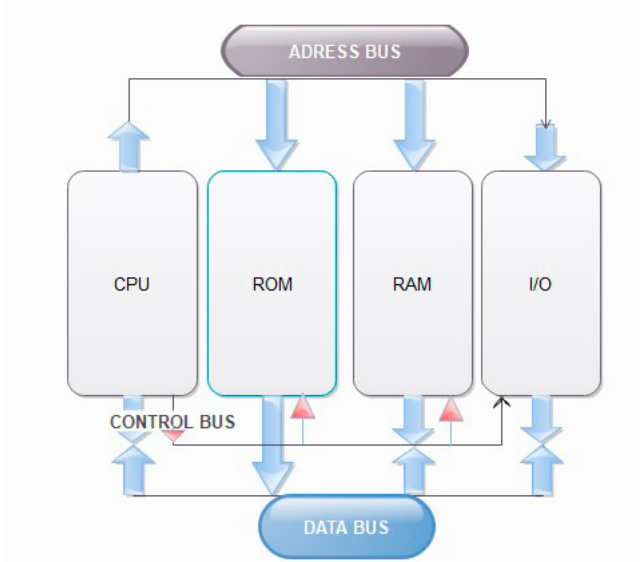

Fig 1. The architecture of an embedded system

RQ III: What would be the ideal methodology for the development of an embedded system?

The hardware/software co-design methodology is the ideal methodology for embedded systems [15] [16], it is a design process to break a problem into a hardware component (usually designed and optimized for special purposes) and software component (usually by controlling the hardware part). The main objective of the HW/SW design methodology is to get most of the benefits from the microcontroller's features so that the software controls the highest percentage of functionalities of the device. [17].

RESULTS AND DISCUSSION

The three questions raised in the literature review focused on research work for the collection and analysis of data on embedded systems. The search chain strategy used allowed to obtain relevant information on the subject.

It was very important to consider the exclusion criteria since only the research was based on embedded systems for irrigation and fertilization in greenhouses, so there are also various systems embedded for other areas.

The ***Table 2*** details that articles were specifically selected from virtual libraries in English, the IEEE Xplore virtual library has been the most contributor to information from the last years of embedded systems followed by the ResearchGate virtual library. It is important to consider that electronic books in English also provided updated information on the subject.

Table 2. Number of Articles by Search Sources

Number of Paper	Year	Virtual Library	Language
2	2011,2012	Science Direct	English
3	2012, 2015, 2016	Google Scholar	English
4	2013-2015,2017	ResearchGate	English
1	2013	Sciendo	English
1	2014	ACM Digital Library	English
2	2015,2016	Springer	English
5	2016-2018	IEEE Xplore	English
1	2018	IJSRET	English
1	2018	MDPI	English
2	2018,2019	Libro Electrónico	English

The ***Table 3*** details that the article published in the Science Direct virtual library titled "Automatic Agriculture Spraying Robot with Smart" [3] has in recent years been the most cited concerning the subject of the review, followed by the electronic book titled " Embedded Systems Design and Verification "[13]. It can be verified that the book provides relevant information regarding the structure of embedded systems; while the article describes a

system embedded in the area of agriculture specifically for irrigation, which is complemented by article [9] where an intelligent system in greenhouses is explained.

Table 3. Article with the most citations

Paper	Year	Virtual Library	Citation Index
[9]	2012	Science Direct	80
[13]	2018	Libro Electrónico	62
[3]	2018	IEEE Xplore	52

Through the selected articles of the different virtual libraries detailed above, it is clarified that the embedded systems are a significant contribution [18] to the different sectors where they intensify their use.

Embedded systems are electronic circuits and consist of limited resources of their own hardware and software that make them productive.

Every embedded or integrated system has a microprocessor, software and additionally they have series of outputs and inputs necessary to communicate with external devices.

Consequently, hardware materials and software tools are combined for the design of an embedded system.

CONCLUSIONS AND FUTURE WORK

Modern agricultural industries based on greenhouses are the recent requirement in every part of agriculture worldwide. With this technology, the humidity and temperature of the plants are precisely controlled [19].

With the information obtained in this research work, it is known that if you want to design an embedded system as an automated alternative for fertigation in the agricultural sector, you should work together with a software tool contributing positively in some aspects such as economic and in the service it would provide to the farmer, since he will have access in real time to the data that would be transmitted by the sensors or other devices to be used through wireless technology.

As part of this study is important to mention that the water is very valuable for all humans and for plants or trees. The agricultural industry uses the largest amount of freshwater for irrigation. By using nebulizers, the water will remain at a constant level, it means that the water will reach the roots of the plants without damaging them. This is very important because it can guarantee the survival of plants.

Future work is taken as reference, therefore the recognition of the person who will use the prototype can be improved with the use of fingerprints [20], also a specialized pattern recognition software would be configured for this purpose.

One might also consider not only capture but also images processing [21].

Recent developments in the field of communications for embedded systems are focused on the acquisition and control of high-speed data[22] using optical fiber because they have shown that longer transmission distances for data acquisition can cause errors.

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SOFTWARE DESIGN FOR THE CALCULATION OF THE PROPER LEVEL OF FERTILIZERS IN RICE CROPS

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ABSTRACT

In order to improve crop yields and promote sustainable management of rice cultivation, it is necessary to control the doses of fertilizer which must be applied accurately, efficiently and in a reliable way. In this context, both agronomic and environmental requirements of sustainable agriculture need to be satisfied, giving, as a result, an optimization of the usage of chemical resources with minimum waste. These chemical compounds offer a variety of nutrients and must be used properly for avoiding the damage of the soil. This research introduces a methodological framework and technological architecture for the design development of mobile software which allows making an appropriate decision on the usage of fertilizers for cultivation. The development process is iterative and incremental, and embedded environments were used in the programming language. Finally, emulator testing is done on the different devices and operating systems on which the prototype was deployed. This includes the processes of collecting, storing and presenting information related to the recommended dose of fertilizer, with the aim of streamlining and facilitating decision-making for farmers.

Keywords: Fertilization, system, software, 4R model, crop, rice

INTRODUCTION

According to the National Institute of Statistics and Census[1], in 2018, rice which is one of the most used products in the Ecuadorian diet had the highest harvest in its category: 1'350.093 tm. And the acreage nationwide was 301.853 ha, concentrating 72.7% of the production in Guayas.

Considering that the economic development of Ecuador is largely dependent on the agricultural sector and that one of the main products is rice (Poveda Burgos & Andrade Garofalo, 2018) The author mentions "that rice production in Ecuador as in many countries of the region depends heavily on the weather station. The main growing areas are located in Guayas, Los Ríos, Manabí, Esmeraldas, Bolivar, among other provinces" because of their climatic features.

There are several factors that determine the rice yield, and these can be defining, limiting or reducing factors.

Defining factors consider the structure of the crop (genotype, date, and density of the atmosphere) and also the quality of the environment (site, soil and water). Limiting factors involve two main elements, the usage of fertilizers and the application of irrigation. And finally, reducing factors refer to pests control, weeds and crop disease. (Quintero, 2018)

Plants often grow in soils that contain very low concentrations of significant macronutrients like nitrogen, phosphorus, potassium, and sulfur. In order to get adapted and grow in nutrient-deprived environments, plants tend to analyze the changes in the internal and external mineral nutrients concentrations and they adjust their growth to the availability of resources. (Schachtman & Shin, 2007).

There is multiple software in the agricultural subject including Sofhyare which employs a novel technique that provides precise fertilizer recommendations. It employs a method based on artificial neural networks with an approximation of the profit function, which allows providing a system for decision support. The ex-

perimental results suggest that this proposed technique is applicable to some specific crops. (Pokrajac & Obradovic, 2001).

SimCorn is a software designed to support the management of nutrients and it is available in specific places for small farmers in the tropics. Among its functionalities, we have the automatic calculation of fertilizer dose, soil analysis and information management of specific nutrients available in the place. The software allows to estimate the amounts of nutrients N, P and K and how to supply these nutrients using existing fertilizer materials, which rarely come in the desired proportions of N, P and K. It employs an algorithm that is based on a Decision Support Model for obtaining the exact quantities of fertilizers needed. This software was implemented first on a portable platform using a Palm operating system and then deployed on a desktop computer with Windows XP operating system by extension agents and others who are interested in this type of process. (Attanandana, Phonphoem, Pinchongskuldit, & Yost, 2006) .

The 4R Nutrient Stewardship provides a framework for horticulture, improves nutrients management and it is important because of its social, environmental and economic aspects. The adoption of the 4R Nutrient Stewardship (right source, right rate, right time and right place) provides a basis for examining the underlying scientific principles behind the use of fertilizers. 4R concepts are based on global principles related to chemistry, biology, physics, and economics, but the selection of specific practices fits the individual field conditions, depending on experience and local data. Interested parties should develop performance indicators to measure progress made by adopting 4R management techniques. (Mikkelsen, 2011).

Nutrient management for horticultural crops is complex and requires the integration of biological, chemical and economic factors (Mundial, 1993). Global food demand continues to grow, and it is currently estimated that fertilizers are responsible for at least half of the current food supply (Marohn et al., 2013). The responsible nutrient management and sustainable horticultural production should include the consideration of environmental, economic and social components. While successful production systems address these three components, the focus and attention given to each individual component depends on the expectations of

stakeholders and may change with knowledge improvement and practice.

This project will identify the benefits of applying fertilizers on crops by following the 4R methodology, which allows farmers to provide a suitable dose at the right time, as mentioned before. The contribution of this research will be informative and applied, due to the use of verifiable and sustainable information from admissible research sources. Recognition is given to these research sources, because of their contribution towards this specific study. There are plans of changing the way of applying fertilizer, outlining the design of a program where basic data of the cultivation is entered, and the user immediately gets an accurate response about the quantity to be applied. This solves the problem of poor application of fertilizers, helping to lower costs and maximize the efficiency of the process.

MATERIALS AND METHODS

For the development process, it is recommended to follow an iterative and incremental model, which is an approach where the lifecycle consists of a sequence of iterations. Each iteration might be defined as a small project that includes activities such as analysis, design, implementation, and testing in several devices as emulators, with the goal that each iteration results in an increase that will ultimately give a product or better result than the previous one (Sommerville, 2011).

Considering that fertilizers play an important role in crop cultivation, a mobile application was designed and it allows to establish the correct dose of nutrients like N, P, K. It is a design that presents a friendly interface for any type of user who does not have access to information or facilities needed to run sophisticated models. In also allows using the 4R Nutrient Stewardship model (Mikkelsen, 2011), which was developed by the fertilizer industry as a process to guide the Best Management Practices (BMP) in all regions of the world.

In order to choose the language to start programming this kind of project, there are many aspects that might be considered such as software requirements, technology costs, quality, ease of use of the devices, support, experience, among others. A wide variety of environments for the development of mobile applications can also be found, some of the best known for programming in personal computers, have incorporated plugins or framework that extend the mobile development for the user.

General Structure of the Program

The structure of the program consists mainly of the database, user interface, and query history. The user interface allows the input of needed parameters for the calculation of the exact amount of nitrogen, phosphorus, potassium and other fertilizers for the specific number of hectares of the crop. The

program also contains a log or history of queries and the corresponding support of the use of the application as shown. In ***Fig 1***. the prototype's three main sections are shown:

Fig.1. The main menu of the software

Section A: Recommended doses of fertilizers

In Figure 2, a form is presented to the user to collect the following information: type of organic matter, phosphorus level, potassium level and the number of hectares that are intended to fertilize. Concentration levels of phosphorus or potassium in the soil can be low or high. These are considered primary macronutrients and due to the extraction, that has taken place over the years, their levels may become deficient. Another reason for the phosphorus or potassium level to be deficient is the cultivation of high yield varieties, which demand more nutrients than local varieties.

Fig 2. Software interface to calculate rice crop fertilizers

For the dose calculation, it is recommended to use a formula based on the industry-standard (Payne & Webber, 1960) which calculates the amount of fertilizer in pounds per square foot of cultivation. Ie. For 1000 square feet, we take one pound and divide it by the percentage of N needed.

$$\frac{1\ Pound\ (N)\ /\ 1000\ feet^2}{N(\%)}$$

After the software has calculated the amount of each nutrient ($N, P_2O_5\ and\ K_2O$) suitable for the particular field, it should also provide general information as shown in ***Figure 3***.

Fig 3. User interface – Recommended dose

Section B: Help section for the program operation

This section provides help for using the program. It also contains information about the researchers and the team who developed the program.

Phyton was the programming language selected for the implementation of the design, along with the Tkinter library (Gui & Tk, 2016) which is the basis of the program design and allows users to view the required information. Finally, the system works together with RDBMS (Relational database management system), which is a database motor that stores all data of the process. In addition to the architecture is referred to as the prototype model view controller (MVC), as illustrated in ***Figure 4***.

An MVVM (Molina Ríos, Loja Mora, Zea Ordóñez, & Loaiza Sojos, 2016) divides an interactive application into three areas: model, view, and controller, for which it uses the following abstractions levels:

-Model: Clumps data and its functionalities. It is the business logic of the

system where the structure of the database is created. One of the restrictions to consider is that mobile devices have limited resources so it is necessary to condition the creation of files.

-View: Allows to display information to the user and obtains data from the model or database. Multiple views of the model can be visualized, and they are associated with the components of the controller.

-Controller: It receives the input data, usually as events that encode the movements, presses of buttons keys or inputs of touch screens, etc…, which are translated into user service requests for the model or the view.

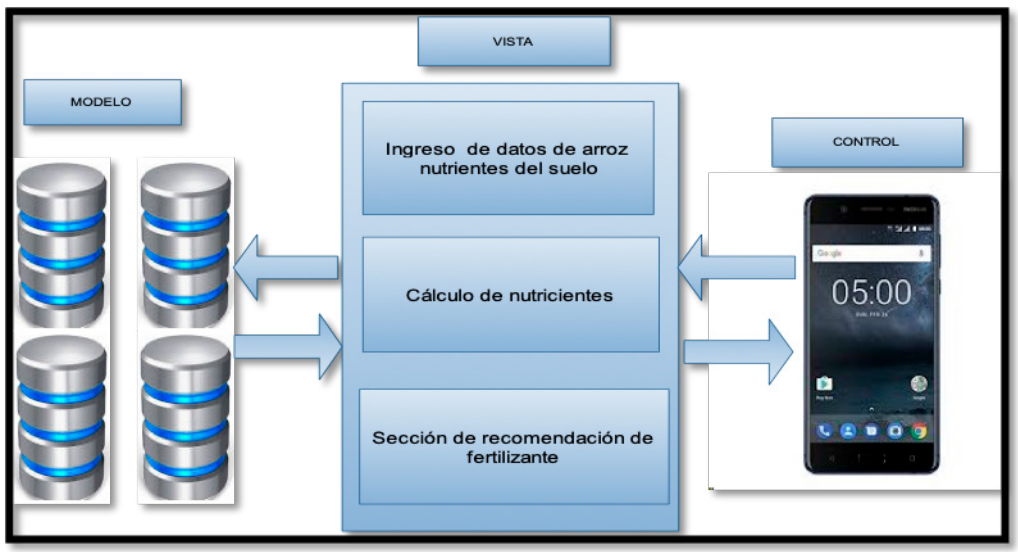

Fig.4. Mobile application architecture

RESULTS AND DISCUSSION

It is important to research in deep about the appropriate fertilizers that each crop needs, in this specific case for rice crops, it is necessary to obtain valid information for the development of agriculture and production improvement.

This project allowed the research group to address project development in mobile devices, by defining the methodology and tools needed to develop applications specifically for mobile devices. Results were presented by designing the prototype for the rice sector and it was possible to encourage research regarding these platforms.

During this research, it was preferred a formula that fosters the 4R method for establishing the appropriate dose of fertilizer for the crop. It would be also convenient to identify and set in the mobile application, the different brands that market fertilizers and their composition in order to obtain a good mixture and better result.

CONCLUSIONS

Fertilizers, organic and inorganic, are a very important tool for the development of agriculture, they also help to promote better applicability for the crops. Nowadays, inorganic fertilizers are the most used in different parts of Ecuador for the development of the rice industry, even though organic ones are getting more acceptance, inorganic fertilizers result to be more cost-effective.

Interfaces design, which are structures part of the program developed, lets the user visualize the basic data to enter, for this purpose it is important to use a software that allows defining size, color, among other features desirable in the interface.

The application design allows the development of the apps to be performed in a mobile tool that facilitates to meet the needed requirements. Furthermore, in the future, it would be possible to add more information about other main nutrients, like calcium. With the new information, it would improve the decision-making process by simulating the growth of the rice crop with realistic data.

In addition, simple questions can be answered with existing information or domain knowledge of the expert and decision rules can be created with the application of fuzzy logic methodologies. The above-stated advantages optimize the interface with a structure that is inbuilt the program and facilitates the visualization of input data and results to the user.

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ENVIRONMENT

TREATMENT OF POST-ELECTROCOAGULACING LEACHATES OF LANDFILL YURAK KASHA DEL CANTÓN CAÑAR.

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ABSTRACT

This work was carried out with the aim of determining the most efficient technology for treating the post- electrocoagulation leachates of the "Yurak Kasha" Sanitary Filling From Canton Cañar, by comparing the results obtained by applying advanced oxidation – Fenton (activated carbon plus hydrogen peroxide at 50% in 3 different doses) and phytorremediation with three plant species: Water Jacinto (Eichhornia crassipe), water lentil (Lemna minor) and Alfalfa (Medicago sativa); Preliminary characterization determined the following parameters for electrocoagulated leachates: suspended solids 2.928 mg/L, dissolved solids 9.12 mg/L, total solids 7.691 mg/L, turbidity 320 NTU, pH 8.8 and Aluminium 48. 598 mg/L. After the analysis of the data collected and application of the statistical process it was determined that the most efficient technology was advanced oxidation-Fenton, with the use of 1 gram of activated carbon plus 20 ml of Hydrogen Peroxide at 50%, results were obtained that were within the permissible limits in the Ecuadorian legislation in force, for suspended solids with 1.32mg/L, dissolved solids 6.85 mg/L, total solids 3.94 mg/L, turbidity 89.1 NTU and pH 8.5 however Aluminium exceeded the permissible limit as it obtained a result equal to 7.0961 mg/L.

Keywords: Advanced Oxidation - Fenton, phytoremediation, water hyacinth (Eichhornia crassipe), water lentil (Lemna minor).

INTRODUCTION

Among the different processes applied for the treatment of leachate from sanitary landfills is advanced oxidation, where a combination of Hydrogen Hydroxide H_2O_2 (Hydrogen Hydroxide) and $FeSO_4$ (Iron Sulfate) in acidic conditions is applied to the contaminant sample, to optimize the process and at the same time enhance the purification capacity of the applied solution (Méndez, García, Castillo, & Sauri, 2010).

In the Republic of Ecuador, the management of urban solid waste has deficiencies due to low technology available and a reduced interest from the authorities; therefore, the commonwealth formed by the administrations of Cañar, Biblián, El Tambo and Suscal´s cantons, part of the Cañari indigenous group, in Ecuador, undertook a program through which a sanitary landfill called "Yurak Kasha" was implemented in order to eradicate poorly managed dumps (EMMAIPC-EP, 2012), and as a case to show the importance of creating alternatives to reduce pollutant loads in leachates of landfills.

The exponential increase in population density, poor management of natural resources, lack of territorial planning, insufficient treatment of urban wastewater and other problems are considered as the main causes that increase problems of unhealthiness for developing countries, which leads to inadequate environmental management, at the same time generating other problems in the environment such as the generation of leachates in sanitary landfills, gases, soil contamination and water bodies close to the communities, degrading the necessary conditions for life; however, the technification of the processes to manage urban waste has become a growing concern, involving the use of technologies that allows the treatment and final disposal of waste generated by the population (Manrique, Martínez, & Ospina, 2007).

Among the difficulties for the treatment of leachates generated in the sanitary landfills, there is the complexity that is within its composition since it is defined by physical, chemical and biological factors of

the environment, which make it impossible to use a specific methodology to treat them (Najera, 2003), in the search for affordable treatments, the present research has as a general objective to determine the most appropriate treatment for post electrocoagual leaching by making a comparison between phytoremediation and advanced oxidation-Fenton, in addition the hypothesis was affirmed stating that "Phytoremediation and the advanced oxidation-Fenton are efficient for the treatment of leachate, from the Yurak Kasha Landfill, submitted to electrocoagulation.

The presence of landfill with insufficient technology for the treatment of leachates that do not fulfill the regulatory parameters of the legislation, so it is pertinent to try to solve this problem to avoid negative impacts on water sources, mainly.

For the solution of this problem, an alternative for the subsequent treatment of leachates was proposed, after being submitted to an electrocoagulation process, benefiting the communities of Cañar, Biblián, El Tambo and Suscal who are direct beneficiaries of the "Yurak Kasha" Landfill , belonging to the Cañar region of Ecuador.

Literature Review

Through the investigation carried out in the sanitary landfill of the city of Mérida, the optimal conditions and doses for the advanced oxidation-Fenton process were determined: contact time of 20 minutes, pH equal to 4, concentrations of H_2O_2 600 mg / L and Fe^{+2} of 1,000 mg / L; with which percentages of removal of organic matter were obtained in leachates of 77% based on the COD (Méndez N., García, Castillo, & Sauri, 2010).

According to Olguín and Hernández (1998), cited by Arroyave (2014), the characteristics that the aquatic plants that will be used for the treatment of wastewater must have should be the following: high productivity, high efficiency of removal of nutrients and pollutants, high predominance in adverse natural conditions and easy harvest; affirming that the species Lemna minor meets all these characteristics and can be used in water decontamination systems.

In the city of Xochimilco - Mexico, Eichhornia crassipes species was used to perform the phytoremediation process where it was established that the bioaccumulation coefficients shown are enough to accumulate metals, but, it shows little transloca-

tion power, a desirable characteristic in accumulator plants, so it is necessary to remove the lily constantly (Carrión, et al 2012).

The capacity of nickel removal by the species L. minor and E. crassipes was evaluated in solution. Concluding that the elimination capacity is greater during the first 24 hours of exposure to the contaminant, although the species L. minor was more efficient than E. crassipes when exposed to low concentrations. Demonstrating that they can be used for phytoremediation of water contaminated with metals (Bres, Crespo, Rizzo, & La Rossa, 2012).

METHODOLOGY

The following materials were used: masks, gloves, photographic camera, sphericals, precipitation vessels, test tubes, potentiometer, turbidimeter, buffer reagents, analytical balance, plant placement vessels, mask, gloves and protective glasses.

For the phytoremediation process were considered as dependent variables to the following plant species: Eichhornia crassipe, Lemna minor and Medicago sativa, while for advanced oxidation- Fenton were Activated Carbon and 50% Hydrogen Peroxide, The following independent variables are used for the two treatments: suspended solids, total dissolved solids, total solids, turbidity, pH and Aluminium.

The samples were taken from the landfill Yurak Kasha belonging to Canton Cañar, for the transport and maintenance of the samples taken after the electrocoagulation process was carried out according to the norm INEN 2169 for Water. Water Quality. Sampling. Sample Management and Conservation.

The investigation lasted three months from 10 February to 10 May 2019.

Determination of the physico-chemical parameters of post-electrocoagulation leachates before treatment.

The preliminary analysis of the measurement parameters in the leachate was carried out in the laboratory of the Agricultural University of Ecuador, using the following established techniques : method 2540 D. Total Suspended Sólids Dried at 103 – 105 °C, method 2540 C. Total Dissolved Sólids Dried at 180 °C, method 2540 B. Total Sólids Dried at 103 – 105 °C ,method SM/3120/ICP (Aluminium), measurement by multiparameter potentiometer (pH) and turbidimeter (turbidity) (Standard Methods For the Examination of

Water and Wastewater, 2017).

METHODOLOGICAL DESIGN

Application of phytoremediation and advanced oxidation treatments.		
METHODOLOGY	PYTOREMEDIATION	ADVANCED OXIDATION
	1. The plant species (Eichhornia crassipe, Lemna minor and Medicago sativa) were placed in 5-litre containers of electro-coagulated leachate, with two replicates. 2. Visible changes in plant species are monitored over the days. 3. Was allowed to act for 15 days. 4. The respective samples were taken. 5. Multiparametric analyses were carried out in the laboratory of the Universidad Agraria del Ecuador in the samples previously taken.	1. 100 ml of leachate was placed in beakers. 2. One gram of activated carbon plus 50% hydrogen peroxide was placed in 3 different dosages (10 ml, 15 ml and 20 ml respectively), with two repetitions of each. 3. The immediate reaction was recorded. 4. Was allowed to act for 24 hours. 5. Multiparametric analyses were carried out in the laboratory of the Universidad Agraria del Ecuador in the samples previously taken.

Determination of the physical-chemical parameters of leachate after treatment

After sampling, we analyzed the results obtained through the experimental processes carried out at the Agrarian University of Ecuador, except for the measurement of Aluminium, which was sent to the Laboratory of Sanitation Stage in Cuenca-Ecuador (SM/3120/ICP method was used), taking a sample of the best applied treatment of phytoremediation and advanced oxidation-

Fenton.

Statistical design

For the statistical process the software INFOESTA was used, where ANOVA test of hypothesis F and analysis of average (Tukey at 5%) was applied. In the determination of the best treatment, a comparison was made between the means and percentages of removal obtained from the results and their repetitions in the following parameters: suspended solids, dissolved solids, total solids, turbidity, pH and Aluminium.

R E S U L T S

Prior to the application of the treatments, an analysis of the parameters was carried out in the post-electrocoagulation leaching of the landfill, Yurak Kasha, from the canton of Cañar, obtaining the following results:

Table 1. Results of physico-chemical analyses of post-electrocoagulation leachates.

PARAMETERS	UNITS	POST-ELECTROCOAGULATION
Solids Suspended	mg/L	2.9280
Solids Total dissolved	mg/L	9.12
Solids Total	mg/L	7.6910
Turbidity	NTU	320.67
pH		8.8
Aluminium	mg/L	48.598

Source: Arguello (2019)

As shown in the table above, the parameters of turbidity (320.67 NTU) and Aluminium (48,598 mg/L) have higher values compared to the others, in the preliminary characterization of post-coagulation leachates.

For the phytoremediation process the following species were placed: Eichhornia crassipe, Lemna minor and Medicago sativa. The results obtained are shown in ***Table 2***.

Table 2. Means resulting from analysis in post-electrocoagulation leachates submitted to phytoremediation.

TREATMENT PHYTOREMEDIAT				
Parameters	Units	Ec	Lm	Ms
Solids Suspended	mg/L	1.49	1.41	2.9
Solids Total dissolved	mg/L	9.45	7.54	8.44
Solids Total	mg/L	348.17	71.96	8.31
Turbidity	NTU	5.3	5.93	85.59
pH		8.47	8.42	8.55

Source: Arguello (2019)* Ec : Eichhornia crassipe Lm: Lemna minor Ms: Medicago sativa.

As shown in ***Table 2***, the underlined values represent the lowest averages, Lm in the parameters of suspended solids, dissolved solids and pH, unlike Ec which shows a low average turbidity and Ms with its minimum mean in total solids. Therefore, it is considered how the best treatment in which the plant species Lemna minor was used for the improvement of the quality of the post-electro coagulation leachates, also presented a higher survival rate, As of day 15 it still had live specimens, while the other treatments did not survive the estimated time.

With the application of the advanced oxidation technique, an immediate reaction was observed, with the release of gases and foam. After 24 hours, samples were taken for further analysis, obtaining the following results:

Table 3. Means resulting from analysis in post-electrocoagulation leachates subjected to advanced oxidation.

TREATMENT ADVANCED OXIDATION- FENTON				
Parameters	Units	10 ml	15 ml	20 ml
Solids Suspended	mg/L	1.88	1.34	1.32
Solids Total dissolved	mg/L	7.76	7.57	6.85
Solids Total	mg/L	4.16	4.32	3.94
Turbidity	NTU	82.95	95.71	89.1
pH		8.38	8.28	8.5

Source: Arguello (2019). *10 ml. , 15ml. and 20 ml. correspond to the ml. of Hydrogen Peroxide for each sample of leachate.

Table 3 shows the lowest averages for advanced oxidation treatments- Fenton post-electrocoagulation underlined, treatment 20 ml has the lowest mean values for suspended solids, dissolved solids and total solids, while the lowest value for turbidity was 10ml and the lowest pH value was 15 ml, so it is considered at 20 ml as the best advanced oxidation treatment- Fenton.

After determining the most efficient treatments, an Aluminium analysis was carried out in the Sanitation Laboratory Stage in which the following results were obtained:

Table 4. Aluminium measurement results.

		FITORREMEDIACIÓN	OXIDACIÓN AVANZADA-FENTON
Parameters	Units	Lm	20 ml
Aluminium	mg/L	38.5990	7.0961

Source: Laboratorio de Saneamiento Etapa. Cuenca-Ecuador.

Made by Arguello 2019.

Table 4 shows the difference between the results obtained from the analysis, in which it is evidenced that the treatment 20 ml of advanced oxidation-Fenton decreased to 7.0961 mg/L the presence of Aluminum so it is considered the most efficient, as opposed to phytoremediation (Lm) in which 38,5990 mg/L was obtained.

Table 5 shows the percentages of removal generated after the application of Advanced Oxidation-Fenton treatments and post-electrocoagulation phytoremediation for the determination of the best treatment.

Tabla 5. Percentages of removal .

	PERCENTAGE OF REMOVAL FROM	
Parameters	Phytoremediatio (Lm)	Advanced Oxidation-Fenton(20 ml)
Solids Suspended	51.84%	54.98%
Solids Total dissolved	17.32%	24.90%
Solids Total	0.00%	48.78%
Turbidity	98.15%	72.21%
pH	4.32%	3.40%
Aluminium	20.57%	85.40%

Source: Arguello (2019)

DISCUSSION

By characterization of post-electrocoagulation leachates it was determined that the parameters of turbidity with a result of 320.67 mg/L and Aluminium 48.598 mg/L; were above the maximum permissible limits in the Unified Text of Secondary Legislation of the Ministry of the Environment (TULSMA) in its Book VI Annex: 1, unlike suspended solids, dissolved solids, total solids and pH that were well below permitted.

Martelo & Lara (2012) mention that the use of floating species for the reduction of suspended solids records decreases with values that are in ranges from 21% to 9%, which are lower values than the results obtained with the species Eichhornia crassipe, Lemna minor that were 51.84%, the main difference between these results is associated with the characteristics of their roots and resistance.

As for the survival of aquatic species, in the study carried out by Jaramillo & Flores (2012), chlorosis and/or rot were presented on the 5th day, unlike this study where this phenomenon was presented in the first 24 hours for the two species, limiting in this way the expected time of action from 15 days to only 7 for Eichhornia crassipe and 15 for Lemna minor (although there was a decrease of around 90% in the living specimens for this plant species), which can be attributed to factors such as the pollutant load of leachate, in addition to climatic conditions.

Méndez, García, Castillo & Sauri (2010) state that the optimal pH value is 4 for the application of advanced oxidation- Fenton with the use of Hydrogen Peroxide and iron sulfate, In contrast to the present study where Hydrogen Peroxide plus Activated Carbon was used at pH of 8, both treatments removed contaminants, although different parameters were measured.

Medina, Mortero del Aguila & Cruz (2017) applied Advanced Oxidation-Fenton where sampling was performed after 20 min because they neutralized the pH of the sample to optimize the process, in the present study let it act for 24 hours, because it was worked with an alkaline pH.

After the application of activated sludge Rosales (2014) used Fe^{+3} and H_2O_2

for the advanced oxidation process, by which removal percentages of 69.5% were obtained for turbidity, being less than that obtained for this study by the application of electrocoagulation and later advanced oxidation [Fenton, which was 72.21%, attributing this difference to the substitution of Fe^{+3} by activated carbon.

CONCLUSIONS

The physical-chemical parameters of the post-electrocoagulation leachates of the Sanitary Landfill were determined by means of a preliminary characterization where the present values of suspended solids, dissolved solids, total solids were measured, color, pH, turbidity, and Al.

It was determined that the most efficient treatment was advanced oxidation-Fenton 20 ml (1 gram of Activated Carbon plus 20 ml of 50% Hydrogen Peroxide in 100 ml of leachate).

According to TULSMA Book VI in Discharge Limits to a Freshwater Body, Annex 1, suspended solids, total solids and pH in Fenton advanced oxidation treated leachates (20ml) are below permissible limits.

TULSMA Book VI Annex 1, the turbidity parameter is below the permitted limits.

According to the limits of discharge to a body of fresh water, from the TULSMA Book VI Annex 1 the Aluminium in the most efficient treatment are outside the permitted ranges in the current Ecuadorian legislation

ACKNOWLEDGEMENTS

Determine the presence of heavy metals such as: Boron, Cadmium, Arsenic, Iron, among others, which increase the toxicity of leachates, in addition to biological parameters as they pose a risk to workers who work daily in the vicinity of the Sanitary Landfill Yurak Kasha.

Investigate and apply techniques to reduce the values of heavy metals in leachates, after application of advanced oxidation for final disposal.

Constantly monitor the values of the parameters present in the leachates to establish if they are under the permissible limits stipulated in the current Ecuadorian TULSMA regulations.

It is recommended to acidify the leachate sample, which could lead to higher removal rates, and to investigate optimal removal times.

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MYCORRHIZAL ACTIVITY IN ROOTS OF CLIMBING PLANTS OF THE RAMSAR

Wetland of Santay Island, Guayas, Ecuador.

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ABSTRACT

Mycorrhizae play a fundamental role in the functioning of natural systems, so it is very important to contribute with information about this issue in disturbed environments, in process of restoration, as in the case of the wetland RAMSAR Island Santay. To do this, it was evaluated the mycorrhizal activity in the most important species from the synusiae of climbing plant, such as pioneers in the recovery - succession, under two levels of disturbance, represented by the high and low density of the exotic palm R. oleracea, biological interaction that could facilitate the establishment in this group of plants. The percentage of mycorrhizal colonization (%CM) was determined in four climbing species (Entada polystachya (L.) DC., Ipomoea carnea Jacq., Paullinia pinnata L., Funastrum clausum (Jacq.) Schltr.), ten replications for each species, at two ages (juvenile and adults). The %CM for each species were different, with higher levels of mycorrhizal activity being found in the low-density area with an average of 42.98% and at juvenile ages. In addition, significant differences were determined by age, species and level of disturbance with the aid of the Kruskal Wallis statistical test, obtaining a critical value "p" <0.0001, below the established significance level of 0.05, which indicated that there are significant differences when comparing interactions of all the factors involved in the% CM. This work represents a contribution about mycorrhizae associated with climbing plants in wetlands, under the disturbance of exotic species.

Keywords: Disturbed environments, Wetlands, Mycorrhizae, Climbers plants, *R. oleracea*.

INTRODUCTION

Mycorrhizal are nature's oldest mutualistic symbiosis, particularly endomycorrhiza or arbuscular mycorrhizae. It is now known that this association is present in approximately 90% of vascular plants and their effects are manifested not only individually, in the host plant and the fungus in question, but also at the ecosystem level (Alvarez y Naranjo, 2003; Allen, 1991).

In ecological systems, arbuscular mycorrhizals are playing a very important role in maintaining biodiversity and developing the succession process of plant communities, which, in recent decades, have played the role of arbuscular mycorrhizal fungi particularly in ecological wetland systems, have been the role of arbuscular mycorrhizal fungi particularly in ecological wetland systems, have received increasing attention (Aguilera, Olalde, Arízaga y Contreras, 2007).

The National Recreation Area Santay and el Gallo Island is one of the most important RAMSAR wetlands on the Ecuadorian coast, located between the cities of Guayaquil and Durán in the province of Guayas, in the estuarine system of the Guayas River, which, after a long process of disturbance and from its international recognition as a RAMSAR site in 2000, it is going through a natural recovery process, backed by its inclusion as a Protected Area of Ecuador in 2010 (Ministerio del Ambiente, 2011). During the process of disturbance to which the island was subjected, through anthropic activities, the introduction of exotic species occurred, contributing to important changes in biodiversity. Among these species is the imperial palm (Roystonea oleracea), a species listed as invasive and naturalized in wetlands of Central and South America (Henderson, Galeano y Bernal, 1995; Svenning, 2002, Nascimiento, de Araujo, Dan, Netto y Braga, 2013, Herrera, et al., 2017). In Brazil, Zucaratto and Pires (2014), determined that the presence of this exotic palm could have an impact on the decline of plant richness and repopulation by native plant species.

According to Aguilera, et al. (2007),

Seguel, Rubio, Carrillo, Espinosa and Borie, (2008) and Vargas (2015), mycorrhizae play an important role in the succession process for the restoration of environments, favoring the rapid establishment of the group of climbing plants, known as pioneers in the early stages of said process, and provide other additional benefits such as: greater survival and resistance to diseases and environmental stress conditions, increased nutrient uptake surface, etc., of infested plants.

Although climbers are competitive by nature, recent research emphasizes their benefits in maintaining biodiversity and ecosystem productivity, since they are structural and dynamic components of the forest (Pincheira, 2011, Schnitzer, Bongers, Burnham, and Putz, 2014). However, its population density can be reduced in areas where there is a greater disturbance due to the presence of exotic species such as the imperial palm.

Although in the literature reviewed, there are not many contributions in relation to mycorrhizae associated with climber plants in wetlands in the process of natural recovery, some works can be highlighted that indicate how this symbiosis can colonize an unusual environment and contribute to the repopulation process faster than other biological bioremediation mechanisms (Fester, 2013).

Rodríguez, Torres and Furrazola (2014), report arbuscular mycorrhizal fungi associated with Júcaro de ciénaga (Bucida palustris) and Soplillo (Lysiloma latisiliquum), characteristic species of Ciénaga and Semi-deciduous forests, respectively, in the Ciénaga Biosphere Reserve of Zapata, Cuba; providing information on the diversity and functioning of mycorrhizal symbiosis in these natural systems, opening new strategies for conservation and sustainability of ecosystems that involve mycorrhizae.

Xu, Ban, Jiang, Zhang and Liu (2016) provide information on the roles of arbuscular mycorrhizal fungi in ecological wetland systems, in terms of the composition, succession and diversity of the plant community, as well as in the growth and nutrition of these; where the effects of this symbiosis will be different according to the characteristics of each infested species and the conditions of each particular wetland.

Studies carried out on Santay Island by the Ministry of the Environment, in 2011, determined the presence of 65 species of plants, of which only

two are vines, that is, climbers (Mansoa sp. and Entada polystachya). However, Méndez and Hernández Rosas (2017), report 9 species in the same area of our study.

In this work the mycorrhizal activity in the most important climbing plant species in the RAMSAR wetland Santay Island is evaluated, by determining the degree of symbiotic association between mycorrhizae and the roots of the most important climbing plants.

MATERIALS AND METHODS

Two sampling sites were selected for the implementation of the experimental work, depending on the density and the Roystonea oleracea imperial palm (***Figure 1***). Its geographical coordinates are:

HIGH DENSITY OF THE IMPERIAL PALM	LOW DENSITY OF THE IMPERIAL PALM
2°13'31'' S 79°52'2'' O	02°13'26'' S 079°52'2'' O

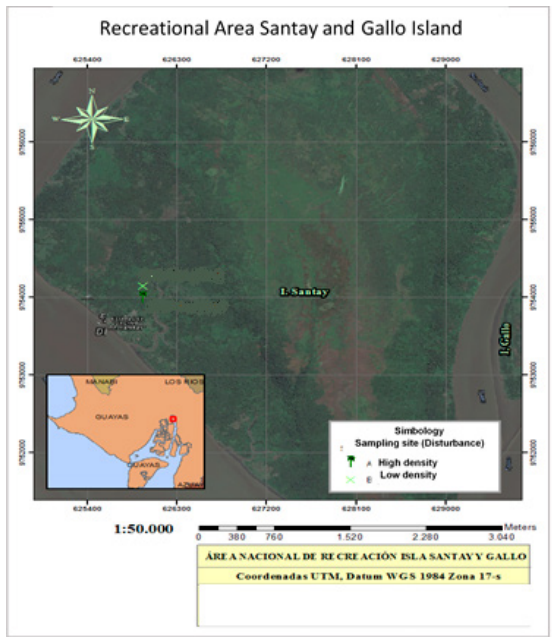

Figure 1. Geographical location of Santay Island and sampling sites

At each level of disturbance, was collected 10 samples of complete plants, 5 juvenile individuals and 5 adult individuals, from four species of climbing plants: Entada polystachya (L.) DC. (Fabaceae), Ipomoea carnea Jacq.

(Convolvulaceae), Paullinia pinnata L. (Sapindaceae) and Funastrum clausum (Jacq.) Schltr. (Apocynaceae), identified as the most important in the area of study by Mendez and Hernández Rosas (2017).

Then, in the laboratory, the roots were separated, cleaned and tested for the evaluation of the presence of arbuscular mycorrhizal fungi and determination of the percentage of mycorrhizal colonization (% CM).

The finest roots of each sample were selected, which were measured, with 20 segments 1 cm long parallel on slide plates.

These segments were subjected to staining and clearing using the method proposed by Phillips and Hayman (1970). Then to evaluate the presence of fungal structures (arbusculos-vesiculars), the stained roots were observed under a microscope, following the method of Giovanetti and Mosee (1980), which allows obtaining the percentage of mycorrhizal colonization (% CM) in each individual (cited by Moreira, 2012) using the following formula:

$$\%CM = \frac{NIM}{NTI} x100$$

Where:

NIM: Number of intersections with mycorrited roots

NTI: Total number of rooted intersections

Statistical analysis

The results obtained from mycorrhizal activity were statistically analyzed in a descriptive and inferential manner, observing their behavior and determining the significant differences between the% CM of each species, for the two age classes and the two levels of disturbance established; as well as the interaction of all variables: species, age class and level of disturbance, using the non-parametric Kruskal Wallis test, for two or more independent

variables, with the help of Infostat software (2017).

RESULTS

Evaluation of mycorrhizal activity

The descriptive analysis of the results reflected different characteristics for each of the individuals analyzed, depending on the species, disturbance levels (high and low palm density); the two age classes (young and adults) (***Table 1***).

If each of the species is considered, in the case of the species F. clausum, there is a greater mycorrhizal activity in the high density area in relation to the other species, with a range of % CM between 22.37 - 45%, as well as a length of mycorrhized root between 17 - 28 cm. By age class, in the high density area there was slightly greater mycorrhizal activity at adult ages, while in the low density area, it was at young ages.

The species E. polystachya has the highest % CM in the area of low density, in relation to the other species, with a range between 36.73 - 87.78%, as well as at adult ages, with a range between 51.58 - 87.78% and mycorrhized root length between 30 - 79 cm.

In addition, the presence of radical nodules was found in all collected individuals, indicating that this species possibly establishes a symbiotic association with atmospheric nitrogen-fixing bacteria (***Figure 2***).

Figure 2. Presence of radical nodules in the species E. polystachya (young individual)

In the species I. carnea, the %CM were similar by disturbance level and age class. In the high density area (high disturbance) total root lengths between 59 - 85 cm, mycorrhizal root lengths between 49-143 cm, and micorrhizal colonization percentages between 23.72 – 33.77% were obtained.

In the area of low density, for I. carnea, a greater mycorrhizal activity was obtained with a range between 28.41 - 72.07%; thus also a range of total root length between 77-145 cm and lengths of mycorrhized root between 25 - 80 cm.

And finally, the species P. pinnata has higher% CM, in the area of low palm density with an interval between 26.36% - 70.80% and a length of mycorrhizal root between 29 - 80 cm, being slightly higher in adults with a range between 58 - 80 cm and percentages of mycorrhizal colonization between 37.50 - 61.73%.

Table 1. Mycorrhized root length and percentage of mycorrhizal colonization by species, age and disturbance level

DISTURBANCE LEVEL	AGE CLASS	SAMPLE NUMBE	E. POLYSTACHYA		P. PINNATA		I. CARNEA		F. CLAUSUM	
			MYCORRHIZED ROOT LENGTH	% MYCORRHIZAL COLONIZATION	MYCORRHIZED ROOT LENGTH	% MYCORRHIZAL COLONIZATION	MYCORRHIZED ROOT LENGTH	% MYCORRHIZAL COLONIZATION	MYCORRHIZED ROOT LENGTH	% MYCORRHIZAL COLONIZATION
HIGH DENSITY	YOUNG	1	33	22,30	15	7,69	49	32,45	23	27,38
		2	46	25,70	11	5,61	78	33,77	27	45,00
		3	38	34,86	20	12,50	64	27,35	25	29,41
		4	24	22,22	18	8,37	54	26,47	25	32,05
		5	28	21,37	18	19,35	91	32,85	17	22,37
	ADULT	6	16	13,33	20	15,50	137	26,50	24	40,68
		7	9	5,88	23	7,77	143	27,50	23	33,33
		8	14	9,15	19	9,55	105	33,02	28	35,00
		9	12	8,28	30	15,31	60	23,72	18	28,57
		10	14	7,33	15	7,21	82	30,60	22	30,56
LOW DENSITY	YOUNG	1	30	37,97	80	70,80	25	32,47	24	31,58
		2	30	37,97	59	60,20	25	28,41	25	30,12
		3	60	82,19	63	60,58	48	42,48	48	44,04
		4	36	36,73	60	56,60	72	49,66	25	27,47
		5	34	44,16	58	50,43	70	59,83	27	28,42
	ADULT	6	74	67,89	39	37,50	80	72,07	14	13,21
		7	53	60,23	45	47,37	40	40,82	36	40,00
		8	79	87,78	35	38,04	40	41,67	25	31,25
		9	42	51,85	29	26,36	36	33,03	23	28,05
		10	70	74,47	50	61,73	50	41,32	27	33,75

During the field collection in the low density area it was also observed that the rootlets of this species presented nodules in young and adult individuals.

The percentages of average mycorrhizal colonization, by age, species and level of disturbance, reflect a higher CM% in the area of low palm density with 42.98%, where the species F. clausum had the highest percentage of mycorrhizal colonization with 31.86%, followed by I. carnea with 29.23%, E. polystachya with 14.51% and P. pinnata with 10.10%; with respect to the high density area where 19.22% was obtained, E. polystachya, the species with the highest mycorrhizal activity of 55.28%, followed by P. pinnata with 49.08%, I. carnea with 42 , 55% and F. clausum with 29.57%. While, by age, the% CM were higher in both areas at youth ages (30.69%), in relation to adults (26.92%).

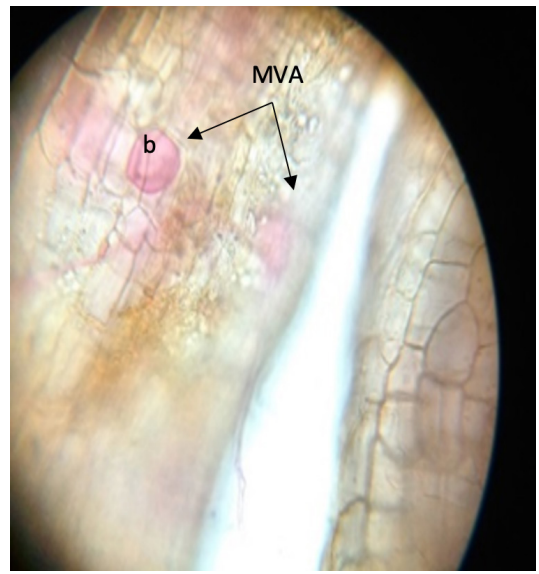

Figure 3. Visualization in 10x lenses of vesicle-arbuscular mycorrhizal structures (AVM) in juvenile (a) and adult (b) individuals of P. pinnata.

In the analysis of the root samples, by means of optical microscopy, it was possible to observe, in addition to vesicle-arbuscular mycorrhizal structures (MVA), other possibly pathogenic fungal structures that were not identified (***Figure 3***).

And finally, the inferential analysis of the results allowed to determine different responses for each species (depending on the age of the plant and the level of disturbance). When comparing the factors evaluated and involved with the% CM (species, age and level of perturbation), highly significant differences were obtained, with a probability (p value) <0.0001 (significance level of 0.05 and 95% reliability) (***Table 2***).

DISCUSSION

The laboratory analyzes allowed to determine the presence of endotrophic structures, in the roots of all the collected individuals, being this, the most common type of mycorrhiza found in more than 80% of the vascular plants (Smith and Read, 2008).

Table 2. Average percentages of mycorritic colonization (by species, age, and level of disturbance)

Global Averages (% CM)					
DISTURBANCE LEVEL	Species	% CM by age		% CM by species	% CM by level of disturbance
HIGH DENSITY	E. polystachya	Young	24,86*	14,51*	19,22*
		Adult	8,47*		
	P. pinnata	Young	9,73	10,10*	
		Adult	10,49		
	I. carnea	Young	30,42	29,23*	
		Adult	28,08		
	F. clausum	Young	30,40	31,86	
		Adult	33,38		

LOW DENSITY	E. polystachya	Young	45,37	55,28*	42,98*
		Adult	67,35		
	P. pinnata	Young	59,36	49,08*	
		Adult	40,57		
	I. carnea	Young	41,04	42,55*	
		Adult	44,13		
	F. clausum	Young	31,84	29,57	
		Adult	27,47		

(*) Significant differences according to Kruskal Wallis analysis.

Given the nature of this type of mycorrhizae and the high degree of variability in the benefits that are shared in the mutualistic relationship, this symbiotic association could influence the ecosystem level, optimizing the uptake of nutrients from the soil by native plants, including climbers, and jointly significantly improve the success of the restoration of degraded environments by boosting the succession, as well as other additional benefits of the RAMSAR wetland Santay Island (Cooke and Lefor, 1998; Asmelash, Bekele and Birhane, 2016).

Depending of the plants species and the system characteristics, the response of the communities and their spatial distribution will be different, since the effects of this symbiosis on individual plants may vary over time (Hart and Reader, 2002; Martínez and Pugnaire, 2009).

The plant age is one of the exogenous factors, which influenced the% CM, because the host plant species, presented different responses to the infection depending on the age, as indicated by research conducted by Jones and Smith (2004) and Viera et al. (2017).

Disturbance intensity, which in our case was established based on the density of the exotic palm R. oleracea, allowed to show greater percentages of radical colonization by Arbuscular Mycorrhizal Fungi (AMF) in areas with less disturbance.

Considering that all the species evaluated, are reported as native plants, in

the Tropics database (Missouri Botanical Garden, 2017), it can be deduced that in areas where the density of the exotic palm is lower or non-existent, a higher percentage is found of mycorrhization, depending on the presence of climbing plants, as reference (Ayala et al., 2016), where the palm occupies approximately 25% (554 ha) of the total area of the island.

On the other hand, mycorrhizal fungal communities may be affected by the introduction of exotic - invasive plant species, causing repercussions on the richness of local, native and / or threatened plant species (Wilcove and Master, 2005, Gurevitch and Padilla, 2004), and influence ecosystem properties by providing positive or negative feedback (Raizada, Raghubanshi, and Singh, 2008). However, the directions of the changes and their magnitude may differ between habitats.

Some studies indicate that invasive plants can alter the spore composition of Arbuscular Mycorrhizal Fungi (AMF) at ground level, reducing the population of fungi that have a greater specificity with native plants in the environment. That is, there is a positive feedback, which favors the invasive species and decreases the associations with AMF of the native species, making them less dominant (Zhang, et al., 2010; Pringle, et al., 2009).

Invasive plants that do not form associations with mycorrhizae or have low symbiotic dependence can inhibit the effects of AMF, which reduces the competitiveness of native plants that depend on AMF. In contrast, invasive plants that are more dependent on mycorrhizal association can modify the abundance of AMF and species richness and, as a consequence, receive greater benefits from it than native plant species (Shah, Reshi, and Khasa, 2009).

This is possible, due to certain characteristics that invasive plants develop, such as the production of secondary metabolites, compounds derived from secondary metabolism such as alkaloids and glucosinolates and even exudates in their roots, which are not found in native plants (Callaway and Aschehoug, 2000; Callaway and Ridenour, 2004), which allows them to increase their competitive capacity compared to other species in a particular environment (Yuan, et al., 2014).

Secondary metabolites can directly and indirectly mediate the competition of invasive plants through strong effects on the nutrient cycle (Hättenschwiler and Vitousek, 2000), native plants (Thorpe, et al., 2009) and soil microorganisms as the fungi community (Yu, 2005).

In transition ecosystems such as wetlands, the introduction of exotic species can have a negative impact on the effects of mycorrhization of the species, in this case the most important and dominant, as well as the process of natural recovery and plant diversity. However, this presumption could be confirmed by further deepening this study, to clarify and understand the effects of arbuscular mycorrhizal fungi in areas with greater and lesser disturbance, in this case by exotic species, such as the imperial palm R. oleracea.

CONCLUSIONS

All species subjected to experimentation showed a typical colonization of arbuscular mycorrhizal fungi, where the highest % CM were obtained in individuals located in areas where the disturbance is lower (Low density of R. oleracea), in contrast to individuals located in areas of increased disturbance (high density of R. oleracea).

Juvenile individuals showed higher% CM in both areas, high and low disturbance, in relation to adult individuals, being the age of the plant another factor to consider that could influence the degree of mycorrhizal infection.

In Santay Island, up to 75% of its surface, it can have plant species with a significant percentage of mycorrhizal colonization, not showing the presence of a significant number of individuals of R. oleracea.

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