# *Ananas comosus*

**Carolina Rosas Gil**

**Colegio Bolivar**

**Agricultural Science**

**2016-2017**

# TABLE OF CONTENTS

## Contents

## 1.0 INTRODUCTION

*Ananas comosus* (L.) Merr is the accepted name for the commonly known pineapple fruit. It was first described by the father of taxonomy Carl Linnaeus and later by Elmer Drew Merrill. The pineapple is one of the top produced agricultural products in Colombia with the major producer being Costa Rica. The fruit is native of South America and its harvest importance relies on its contribution to the world production of tropical fruits. Important producers are Costa Rica, Brazil, Thailand, Philippines, Indonesia, Nigeria, China, India, Mexico, and Colombia. It best grows in subtropical and tropical areas were the weather is warm, but cool at night. The pineapple has a world production of 25.4 million metric tonnes.

The consumption of the pineapple is wide due to its sweet and acidic flavor and varies as it is consumed fresh, cooked, juiced, or preserved. The tropical fruit is an excellent source of vitamins, minerals, and nutrients and is rich in antioxidants. Surprisingly, pineapples are made up of a cluster of multiple berries that grow within the second year of cultivation and is harvested one year later.

In this monograph the topics will describe the different aspects of *Ananas comosus* distributed in 5 chapters. The information expanded will be: in the first chapter the importance will be discussed and in the second chapter, the Ecology and biology of the pineapple will be focusing on its taxonomy, distributional context, and life cycle. On chapter 3, the vegetation components will be assessed including the interaction with its environment. Then, in chapter 4, the propagation and management of the crop's cultivation will be expanded and in chapter 5, the emerging products and potential markets will be the main topic. Finally, the last chapter is devoted to the medicinal uses of the fruit residues which focuses on a protein found in the fruit called Bromelain.

# 2.0 ECOLOGY AND BIOLOGY

## 2.1 ECOLOGY

### 2.1.1 Affinities

The pineapple (*Ananas comosus*) is a member of the Bromeliaceae family. It is from the domain Eukarya because it has a center nucleus and bound organelles which makes it similar to species like the avocado, ostrich, and others. Through photosynthesis it creates its own food making it an autotrophic plant member of the Plantae. It is part of the Magnioliophyta because its seed develop in the plant's ovary and grows there to become a fruit. They have one cotyledon; their petals grow in multiples of three and have fibrous roots which place them in the class Liliopsida. Pineapples grow in sunny and dry regions so that's why they are form the order Poales. The family is Bromeliaceae and subfamily Bromelioideae (Engebos, 2012). Therefore, their genus is *Ananas* and specie *Ananas comosus*. Their process of photosynthesis is different from most of the other type of plants. It undergoes a pathway called Crassulacean Acid Metabolism (CAM) which allows the plant to conserve moisture in periods of drought. It works on the plant at night when the stomata [pores in the leaves that can open and close to the atmosphere] ("The Pineapple," 2009). opens and carbon dioxide is fixed to be stored and produce sugar and starch. A quality of the CAM plants is that the carbon dioxide stored within the plant, serves as malic acid which allows them to close the stomata during the day using the malic acid to go through photosynthesis (Engebos, 2012).

### 2.1.2 Origin

The English word pineapples originated in 1398 when it was used to describe the reproductive organs of what we know now as pine cones (words first recorded in 1664) which replaced the words pineapple in 1694 ("Oxford," n.d.). Pineapples were first found in South America between the Amazonia and Orinoquia regions in Colombia, Brazil, and northern Paraguay (Federacion Nacional de Cafeteros de Colombia, n.d.). After their discoveries, pineapples plantations started spreading around all South America reaching the Caribbean region, Central America and Mexico. When Christopher Columbus arrived to the New World he learned about this fruit in the island of Guadeloupe in 1493. The natives of the Caribbean placed the crown of the fruit outside their establishments as a symbol of hospitality. He named it *piña de indes* and brought it to Spain. The time it was spread to Europe, it was the first time a bromeliad species [family of monocot flowering plant native mainly to the tropical region of America] was introduced outside of South America. It was later introduced to the Philippines, Hawaii, India, Zimbabwe and Guam (Morton, 1987).

In South America a Dutch colony in Surinam, brought the pineapple to northern Europe. Pieter de la Court was the first person to successfully grow the fruit in Europe in 1658 after it was presented there in 1650. Later the pineapple was grown in great amount all over the European countries, China, Australia, East Indies, and in South Africa. In Oahu, Hawaii the first sizeable plantation of the fruit was 5 acres big in 1880 (Morton, 1987).

## 2.13 Present Distribution

Over the past 100 years, pineapples have become one of the greatest leading commercial fruit crop. The top pineapple producing countries (Figure 1) are Costa Rica, Indonesia, Thailand, Brazil, Philippines, and Nigeria, but they are also commonly found in Malaysia, Taiwan, Australia, South Africa, Singapore, Java, India, and Sumatra.

The commercial cultivation of pineapples started about 40 years ago in the western coastal areas. It has become the world's third most important cultivated tropical fruit after bananas and citrus (Morton, 1987). About 30 cultivars are grown commercially and these are put into eight groups to make trading easier. The groups are Smooth Cayenne, Red Spanish, Queen, Pernambuco, Honey Gold, Hawaiian King, Porteanus, and Variegatus. About 70% percent of the pineapples produced are consumed as fresh fruit in the country while other major pineapples distributors produce canned pineapples.

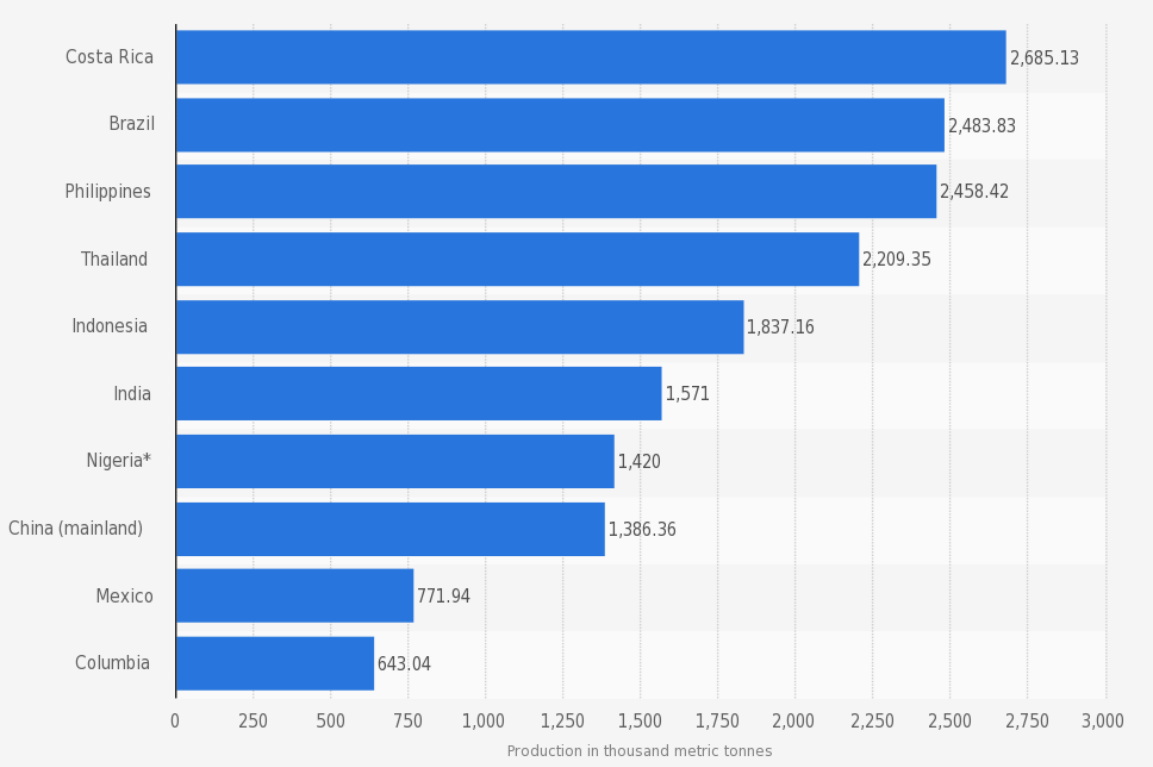


**Figure 1: Leading countries in pineapple production worldwide in 2013 (in 1,000 metric tonnes) *http://www.fao.org/faostat/en/#data/QC/visualize*.**

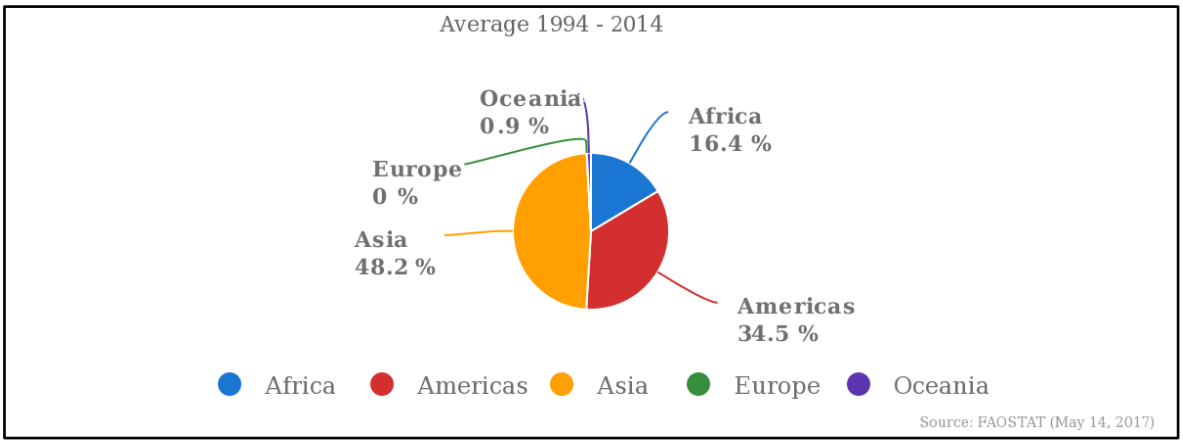


**Figure 2: Production share of Pineapple by region**

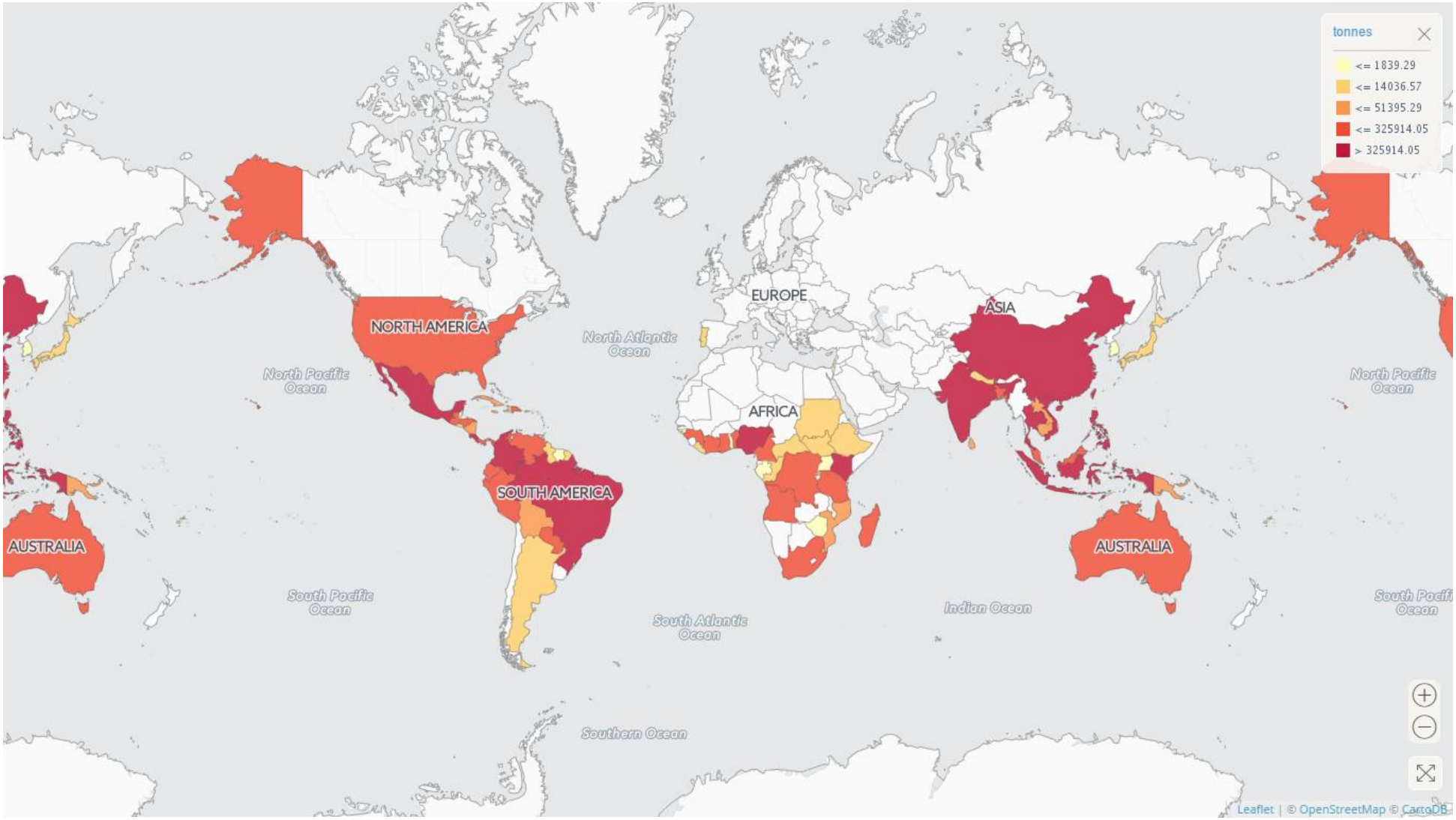


**Figure 3: Production quantities of pineapple by country.**

## 2.2 ENVIRONMENTAL FACTORS IN DISTRIBUTION

### 2.2.1 Elevation

The Dole Pineapple Plantation in Hawaii ("Pineapples in Hawaii," n.d.) confirms that pineapples thrive at elevations between sea level and the mountains of Hawaii. Sometimes they can be at 1,200ft and 3,500ft of elevation. Basically pineapples are very easy to grow because they can grow in a variety of places with different elevation. Hawaii is a tropical region so that's why the pineapples grow in different altitudes. In Colombia for example pineapples grow between 500 and 1,300 meters above sea level, but the average elevation for growing the fruit is between 0-1600 meters. Their flavor can change depending on the altitude, if they are growing above 1800 meters, they will be very acid and sour, while under 1350 meters they will be sweet and tasty (Hellen Omondi Kaudo, 2014).

### 2.2.2 Climate

The pineapple is a tropical fruit, therefore it best grows in warm climates. Even though the *Ananas comosus* are native to tropics they can also grow subtropical regions where the humidity is relatively high. In locations like Colombia the best temperatures can be 18 and 27 °C. On average the temperatures required for growing *Ananas comosus* range within 18-30°C (Hellen Omondi Kaudo, 2014). But 25°C is the best temperature for a good harvest. It is considered that sunlight is a very important factor for the cultivation of the pineapple due that the amount of sunlight they receive determine their weight (Engebos, 2012). This fruit can resist cold nights but for short periods of time, otherwise it will slow down the growth, delay maturity, and it lowers the quality of the fruit by making it more acid or even freezing it. It's ideal for the location of pineapples plantations to have a range

of cold nights and sunny days so it doesn't freeze nor get sunburned. Temperatures below 20°C can cause chlorotic discoloration.

### 2.2.3 Rainfall, Potential Evapotranspiration and Water Deficits

Pineapples have the ability to resist a wide range of rainfall conditions depending on the location and humidity (best between 70-80%) because of their CAM photosynthesis. The best precipitation would be 1,100mm, even though it can range from 650-3,800mm. It can resist long periods of drought due to their ability to store water on its leaves (Engebos, 2012). The maximum evapotranspiration is very low compared to other fruit crops because there is a suspension of transpiration during the day. Its photosynthesis process allows the plant to close the stomata during the day and opens it during the night, so most evaporation is from the soil. Therefore the evapotranspiration ranges between 700 and 1000 mm per year ("Crop Water Information: Pineapple," 2015). The plant's fragile root system is sparse and goes about 1 meter deep, but only the first 0.3 to 0.5 meters of the root extracts the retained water from the soil. According to FAO Water ("Crop Water Information: Pineapple," 2015) this fruit crop is very sensitive to water deficits because it retards grow, fruiting, and flowering specially in the vegetative phase of the plant's growing process.

### 2.2.4 Geology and Soils

The best soil for the pineapples planting should be well-drained, sandy with great amount of organic matter, and low in lime content. The soils required for growing this fruit should be low in magnesium and calcium in order for the pH to stay constantly low. Therefore acid soils are good for the crop to let chlorosis occur in the plant's leaves (Kotalawala, 1968). The best soil pH varies between 4.5-5.6 ("Land Requirements for Growing Pineapple," 2013). The soil should also have a texture that won't let the water stagnate, like non-compacted, well-aerated and free-draining loams without heavy rocks.

The good drainage is fundamental for the root system to be strong and to avoid heart rot diseases. The plant cannot resist waterlogging or subsoils.

## 2.3 BIOLOGY

### 2.3.1 Chromosome Complement

The number of chromosomes for *Ananas comosus* is traced as n=25. Usually it is identified as a diploid [two similar sets of chromosome], but other species of *Ananas* being triploids or tetraploids have been all also found (Moore, DeWald, & Evans, n.d.). Pineapples have in total 50 chromosomes in each cell (Bird, 2014).

### 2.3.2 Life Cycle and Phenology

#### *2.3.2.1 Life Cycle*

*Ananas comosus* don't reproduce by seed dispersal. They usually grow from the crown of the fruit or offsets that were produced around the base of an adult plant (Harrington, n.d.). When growing a pineapple, the crown and lower foliage should be cut off to let it grow the roots and therefore let another plant grow. It can take six to eight weeks for it to start growing the roots and for the foliage to start forming. The growing foliage will absorb the nutrients from the soil. It's best to use fertilizer to provide enough nutrients for the plant to grow healthy, preferably a monthly application (Harrington, n.d.).

Only at full maturity the plant will start flowering and fruiting. This will take up to three years and is ready to be harvested once the scales of the fruit start turning from green to yellow. The pineapple can only fruit once, but as said before, when the plant reaches maturity it produces offsets which can grow to full maturity to flower and fruit. The composition of a pineapple consists of the central stem and the off-shoots. There are three off-shoots; slips that are side shoots, the crown that is at the top of the plant, and suckers that are also side shoots but they develop lower on the stalk. Suckers can grow below and above ground, the suckers that grow below grown are ratoons while suckers growing above

ground are hapas. These shoots can be taken and planted to develop a new pineapple fruit (T., 2014).

The life cycle is divided into 3 phases (Pinto da Cunha, 2004). The first stage of the growing plant is the vegetative phase which involves the time from planting to flowering. Secondly, there's the reproductive phase or flowering and fruiting phase, which involves the period when the plant goes from flowering to maturing. And lastly, there's the propagative phase which is the productive phase that continues after the fruit is ready for harvest and after that, when the suckers and slips are planted again for future planting (Pinto da Cunha, 2004).

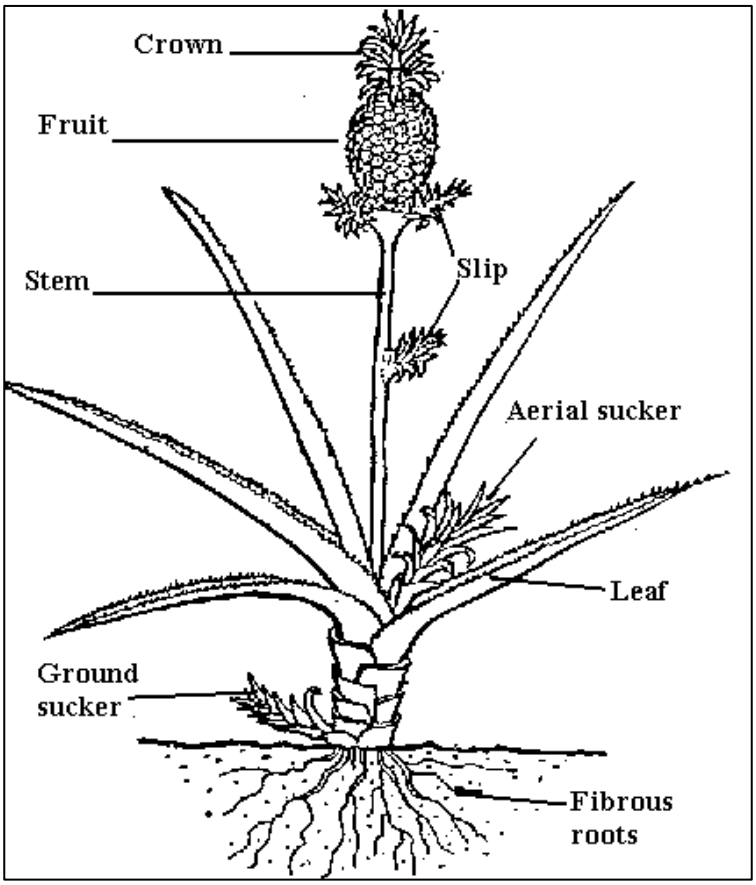


**Figure 4: Pineapple plant with fruit.**

#### *2.3.2.2 Phenology*

2.3.2.2.1 Flowering and Fruiting

The pineapple fruit is a multiple of seedless berries fused together that grow from the flower ovaries as they mature. The core is the center from where the berries grow, the outside layer of the overall fruit is made up of eyes that defines the position of the individual fruits. Environmental conditions and crop management determine the time it takes a pineapple to fruit. Depending on the location, for example in Hawaii, if the pineapple is grown from crowns it will take up to 28 months, from the slip 24 months, and from the suckers about 16 months for the plant to flower, and it will last about two weeks. From there on, the fruit will require another 6 months to begin growing (Sauls, 1998).

In a pineapple's life cycle, it takes from 12 to 30 months, for the first frutescence to start growing. But the flowering phase can be manipulated with the use of chemicals products to regulate the plant growth. The developing flowers are about 50-200 individual hermaphrodite flowers, meaning that it consists of three petals, three sepals, six stamens with an inferior trilocular [divided into three compartments] and tricarpellate ovary. This stage is the transition from the vegetative structures to forming an inflorescence (Pinto da Cunha, 2004).

### 2.3.3 Reproductive Biology

#### *2.3.3.1 Pollen*

*Ananas comosus'* anthers are divided into two lobes that turn inward and contain a great amount of spherical and symmetrical pollen grains that have two apertures ("The Biology of *Ananas comosus* var. comosus (Pineapple)," 2008). Pollen grains size vary on the pineapple variations. The Queen and Smooth Cayenne reported having 35 to 81 microns

[micro] and 36 to 68 [micro]. Theres also a difference in the pollen size between cultivars and clone (44.62 [micro] to 62.49[micro]). Triploids produce sterile pollen grains due to irregular sex cells production. Tetraploids produce the largest sized pollen grains, bigger than diploids and tetraploids ("The Biology of *Ananas comosus* var. comosus (Pineapple)," 2008).

#### *2.3.3.2 Sexuality*

Pineapple plants have very slow germination, so sexual reproduction is very rare to occur (Engebos, 2012). That's why the reproductive process of the *Aanans comosus* is vegetative propagation. This means using one part of an already grown plant to cultivate another one. As mentioned before, a pineapple plant have crowns, slips, suckers, and shoots that are the specific parts used to grow another plant.

#### *2.3.3.3 Anthesis*

When the reproductive stage starts, new leaves stop developing and the ones that were in their growing process, fail to grow to a full size. The first structure to appear is the bract followed by the sepal, petal, stamen primordia, and lastly, the carpels ("The Biology of *Ananas comosus* var. comosus (Pineapple)," 2008). When the very first flower starts growing, the peduncle increases its length. About 5-10 flowers open in the sequence of their origin, at night for a period of 10-30 days.

The fruit onset from the inflorescence at the terminus of the plant. The fruit can be translucent or opaque when it's reaching maturation depending on the presence or absence of liquid in the intercellular spaces (Schaffer & Andersen, 1994).

#### *2.3.3.4 Pollination and potential pollinators*

Due to the high self-incompatibility, the pollen in a pineapple plant germinates on the stigma, but it doesn't grow how it should and it effects fertilization (Rieger, n.d.). They are self-sterile meaning that they can't produce seeds if they self-pollinate. When they are cross-pollinated by the natural pollinator which is the Hummingbird, small amount of tiny brown seeds will appear beneath the peel of the plant. There is no wind pollination because it is very sticky. In Australia, hummingbirds aren't present to participate in the pollination, but native bees, honey eaters, pineapples beetles, and ants are the visitors that feed on the nectar and take part on cross-pollination and pollen dispersal ("The Biology of *Ananas comosus* var. comosus (Pineapple)," 2008).

#### *2.3.3.5 Fruit development and seed set*

2.3.3.5.1 Ovule Development

Most of ovules in *Ananas comosus* are anatropous [an inverted ovule at an early stage of growth. Micropyle turns towards the funicle, and the embryonic root is at the opposite end] a very few being orthotropous [the ovule is straight, at the base it's the chalaza and the micropyle at the end]. The ovules are also crassinucellate (thick nucellus) and bitegmic [has two outer cell layers that enclose the nucellus of the ovule] (Rao & Wee, 1979). The embro sac develops as a Polygonum (four well-defined megaspores) type and the endosperm as a helobial type (between nuclear and cellular types). The embryo development is an Asterad type [embryo generates from both terminal and basal cells] and as it matures, it becomes a monocotyledonous. The seed coat forms from the outer and inner integuments and the seed takes 120 to 130 days to mature after fertilization.

2.3.3.5.2 Ovary wall development

Pineapples have an anther wall that consists of an epidermis, endothecium, and two middle layers (Rao & Wee, 1979). From the middle layers, one degenerates at maturity while the other, along with the endothecium, develops fibrous thickenings. The tapetal cells are binucleate, having two nuclei, and are the glandular type. The cell plate formation create a reduction division where the microspores are separated.

### 2.3.4 Ecophysiology

The temperature averages determine a pineapples leaf's photosynthetic rate. The highest of these rates happen during temperatures from 20 to 25°C. There's few data available to show how irradiance influence on these rates because the effects are very difficult to measure on leaves that take up the carbon through the CAM pathway ("Pineapple News," 2010).

*Ananas comosus* can grow under full exposure in dry environments because its CAM photosynthesis allows the plants to convert drought-sensitive plants into drought-resistant (Mulkey, Chazdon, & Smith, 2012).

# 3.0 VEGETATION COMPONENTS

## 3.1 Associated Species

The *Ananas comosus* related species are characterized by having a short stem, narrow sharp leaves arranged in a circular cluster, and having a terminal inflorescence [group of flowers arranged on the stem composed of a single branch]. That's because they are in the family *Bromeliaceae*, but the genus of the pineapple, makes it recognizable from other plants in the family because of their inflorescence in a single "dense rosette" of wide leaves and their large size. They differ from other monocots due to their "star-shaped, scale-like multicellular hairs" ("The Biology of *Ananas comosus* var. comosus (Pineapple)," 2008).

The *Ananas nanus* is a wild pineapple characterized by its tiny size and pink color. In English language it is often called Dwarf or Pink Pineapple ("Ananas nanus," 2005). Different from the *Ananas comosus*, this particular pineapple specie grow in cooler and arid locations. Its leaves are long and stiff similar to the ones of a pineapple, but these ones grow sharp spines and they doesn't store water in the middle of the cluster. This fruit is more ornamental than edible because it has a more acid flavor. When it reaches maturity, its pink color changes to be pale yellow.

Relative to the genus *Ananas*, the *Ananas Ananassoides* is a small to medium size pineapple. It has a very short stem at the end of the rosette. The leaves also grow in a spreading rosette and are short and rigid with sharp, red, and longer spines. This specie grows well in savannah or in low-shaded forest [in rain forest along river beds] where soils are sandy and can hold water ("Ananas ananassoides," 2005).

Lastly, the *Ananas Bracteatus* or Red Pineapple, is also a very small with violet to red colors pineapple that grow mostly in tropical forests. It flowers between pink and spiny inflorescences that are followed by the miniature fruit. The leaves are linear and long with sharp spines at the end (Kinsey, n.d.).

## 3.2 Soil Interactions

Pineapples cause soil deterioration, deforestation, erosion, and it can contaminate the water supplies in not proper cultivations (Engebos, 2012). There was an experiment conducted in Costa Rica that investigated the effects of different agricultural systems on soil quality. It studied mainly cacao plantations vs. forests, but a part of the experiment used a pineapple monoculture with similar soil types. It analyzed the soil bulk density [indication of soil physical structure] (Cornwell, 2014) earthworm abundance, exchangeable nutrient cations or cation exchange capacity (CEC) [indicates the nutrient retention capability of a soil by measuring the quantity of available negative charges to which nutrient cations] (Cornwell, 2014) physicochemical soil characteristics, and percentage on organic carbon.

The soil bulk density for the pineapple monoculture was the greatest meaning that the soil in this plantation was less favorable for plant growth. There was a low number and mass of earthworm's abundance in the soil within the pineapple monoculture. This means that the pineapples monoculture didn't get the benefits that an earthworm give like their aid in decomposing organic matter, nutrient cycling, microbial activity, soil porosity, and bulk density. The only good thing about the small amount of earthworms is that the plants don't need to compete for water and nutrients. The pineapples monoculture decreased the soil

pH. As for the cation exchange capacity, the pineapples monocultures registered fewer $Ca^{2+}$ indicating that the nutrients taken up by rainwater or the plants weren't replaced, so the soil's nutrients decreased (Cornwell, 2014). Finally the percentage of organic carbon was the lowest in the pineapple monoculture meaning there was less organic matter in the soil.

As concluded in the study, the pineapple monocultures require an addition of pesticides and chemical fertilizers in order to maintain a high level of productivity in the soil (Cornwell, 2014). Therefore pineapple plantations interactions with soil will reduce its nutrients and overall quality for future uses of it.

### 3.3 Relationship with animals and insects

*Dysmicococcus Neobrevipes* and *Dysmicoccus Brevipes* are both miniature white insects that transmit *Pineapple mealybug wilt-associated virus* to pineapples plants. The virus transmitted will cause leaf symptoms and discoloration [pink coloration] due to root damage and will make the plant lose rigidity. In some cases when the plant has reached recovery from the disease, it will keep growing but its root length, weight, and leaf size might be reduced (Egelie & Gillett-Kaufman, 2015). They can also cause rotted bottoms, mealybug stripe [discoloration with tissue damage], and chlorotic areas [parts of the plant that cannot produce the right amount of chlorophyll] which can weaken the plant increasing its vulnerability to other diseases and pests. Molds and black spots grow within the plant when they are exposed to a buildup of honeydew by the mealybugs (Egelie & Gillett-Kaufman, 2015). These are found on the tropics and subtropics regions mostly in pineapples cultivations. The mealybug built its colonies on the stem and roots of the plant so they don't feed on the fruit and leaves of pineapples (Egelie & Gillett-Kaufman, 2015).

The *Strymon megarus* or Pineapple Fruit Borer is a pest found in pineapples plantations that affects the plants by causing yield losses. It attacks mainly during the flowering and growing of the fruit. When the insect is at a larvae phase, it's feeding produce visible damage in the fruit in the form of frass production and sticky exudate. It later penetrates the inflorescence, to become a pupa, as it destroys the tissue and leaves a resin colored gummy liquid that when it solidifies, it turns dark brown. Then the adult phase is a greyish moth that flies around the fruits laying eggs (Joy P. P., Anjana R., & Soumya K. K., n.d.).

The Pineapple Weevil includes many species like the *Diastethus bromeliarum Champion, Cholus spinipes, Cactophagus lojanus,* etc. They cause great damage to the fruit since the whole life cycle occurs within the plant. Females lay the eggs in the leaves where then the larvae moves to the stem leaving tunnels destroying the inner tissue. In the adult stage, the insect causes exudation of a gelatinous material and leaves feeding marks on the leaves. The damages in the plant include the decomposition of central leaves and the browning of them, and they affect the crown, flower stalk, and fruit (Joy P. P., Anjana R., & Soumya K. K., n.d.).

# 4 PROPAGATION AND MANAGEMENT

*Ananas comosus* occurs in relatively humid regions, could be near the sea or inland as long as the temperatures are not as extreme; it does not resist long periods of either very cold or hot temperatures. In addition the best soils for its cultivation should be well drained and with a light sandy texture because the plant is sensitive to waterlogging ("Pineapple," n.d.).

## 4.1 Natural Regeneration

*Ananas comosus* is a seedless cultigen and can only be propagated vegetatively. Sexual reproduction is rare due that the pineapple is self-sterile which means that seeds when they are produced by self-fertilization, germinate slowly with low vigour and weak seedlings ("The Biology of *Ananas comosus* var. *comosus* (Pineapple)," 2008). Therefore pineapples grow from vegetative propagules like suckers, slips, hapas, or crowns (see Figure 4, section 3. 2.3.2.1) that are cut from an already full mature plant which is ready to harvest. Natural regeneration in pineapples is not common.

## 4.2 Nursery Propagation

### 4.2.1 Vegetative Propagation

#### *4.2.1.2 Cuttings*

Cuttings are specific parts from the structure of a pineapple plant that are commonly used for growing an *Ananas comosus*. There are four types of materials from the plant for the vegetative process: the side shoots, ground suckers, slips, and crowns or tops.

Ground suckers or ratoons are also shoots that arise from buds on the stem in the rooting zone. The side shoots or stem shoots are produced from the portion of the stem

above the ground. The slips are small axillary shoots produce from buds immediately below fruits. And the crown or tops is the short stem and leaves growing from the top of the fruit, it terminates the plant. This last portion of the plant is not recommended its usage for planting due that it takes them the most time for the fruit to mature. It takes 22-24 months when grown from the crowns and 20 months when grown from the slips in order to harvest a mature fruit, so both of them aren't the best for the pineapple planting ("The Biology of *Ananas comosus* var. comosus (Pineapple)," 2008). Therefore the ratoons and shoots are stated to be the best parts for cultivating *Ananas comosus*. They have shown earlier fruiting for the plant and it takes about 15-18 months to harvest the plant using these materials. A reason why this might occur is because the ratoons and shoots are in closer contact to the ground and they develop from the subterranean buds while the parent plant is still vegetative, so they are potentially capable of maturing more quickly than slips and crowns (Ddungu, 1973).

### 4.3 Planting

In Santander, Colombia pineapples are cultivated at low densities, about 22.000 plants per hectare. This will result in less production but the fruit will have a bigger size, so if they are grown for commercial viability, then they should be best cultivated at high densities for more productivity (Federacion Nacional de Cafeteros de Colombia, n.d.).

*Ananas comosus* are planted at the start of the rainy season or anytime of the year in the irrigated areas ("Pineapple Production," n.d.). Usually any day in November to the 15th of February and the 15th of July to the 1st of September (Federacion Nacional de Cafeteros de Colombia, n.d.). The pineapple is a perennial fruit and a tropical to subtropical plant, so it is best grown in the warmest regions. When growing them in very cool locations, they

need to receive proper care and they can even be grown indoors (Allman, n.d.). Mature plants typically reach 1-3 feet in height and 3-4 feet in width. The long-pointed leaves are 20-72 inches in length and the fruit can be up to 12 inches long and might weight 1-10 pounds ("Pineapple," n.d.).

It is necessary to have prepared the land very well to have excellent development of the crop. The plow must be 20-25cm deep and about 15cm in circumference (Federacion Nacional de Cafeteros de Colombia, n.d.).

In sub-tropical and mild humid conditions, the cultivation's density is better at 63,400 plants per hectare. With 22.5cm of spacing between plants, 60cm from each crop row and 75cm from trench to trench. In high humidity and hot regions a plant density of 53,300 plants per hectare is mostly recommended. These must be spaced 25cm between plants, 60cm within crop rows, and 90cm from trench to trench. And in rained hilly locations a low density of 31,000 plants per hectare is recommended ("Pineapple Farming Info Guide for Beginners," 2017).

The advantages of a high density planting would be a harvest of 70-105 tons per hectare as well as less weed infestation, protection of fruits from sun burn, and a major production of slips and suckers ("Pineapple Farming Info Guide for Beginners," 2017). Essential intercultural operations in pineapples cultivation include moving soil from the ridge into the trench. The roots are very shallow so the plants are lodged under heavy rainfall conditions and flat-bed lands. This result in a lopsided growth of the plant when the fruit is growing and possible ripening of it as well as an uneven development. In a high density cultivation, this operation wouldn't be as necessary because the plants prop each other preventing lodging ("Pineapple Farming Info Guide for Beginners," 2017).

## 4.4 Management

Pineapples plants require nitrogen and potassium application due that these nutrients are prone to heavy losses in the soil, this plant is a shallow feeder of them. About 12g of each nutrient per plant, the fertilizer will determine its efficient usage. Nitrogen is applied in 6 split doses, the first one 2 months after planting and the last dose after 12 months. Potassium should be applied in 2 split doses, the first dose the same time of planting it and the second 6 months later ("Pineapple Farming Info Guide for Beginners," 2017).

### 4.4.1 Tending

*Ananas comosus* require a frost-free environment. They resist short periods of cold temperatures but its best if grown in warm conditions. The pineapple is small enough to be covered completely when frost threatens ("Pineapple," n.d.).

Well drained and light in texture sol is best for the growing of pineapples because they don't resist waterlogging. It must have a high organic content within a pH of 4.5 to 6.5.

During the dry season irrigation should be done so the fruit doesn't produce low yields. 4-6 irrigations in the summer with 20-25 days intervals ("Management Practices: pineapple," n.d.).

# 5. EMERGING PRODUCTS, POTENTIAL MARKETS

*Ananas comosus* is one of the most popular tropical fruits in the world. It is the only member from the Bromeliaceous family that is cultivated for human consumption (García Suárez & Serrano, 2005). The economic and commercial importance of the pineapple has promoted further investigation in the field of biotechnology to develop techniques that will improve pineapple growth and production (García Suárez & Serrano, 2005). Since it's a tradable crop it generates reasonable income and provides over 24.8 million tones according to 2013 data (Dawson, 2016). The main uses of this fresh fruit are for human consumption such as a fruit and its juice, for making jam, in tenderizing various types of meat, it has medicinal uses, and its different parts like the leaves make ropes and coarse cloth. In general the production of pineapple has one extended and varied market.

## 5.1 World Trade

### 5.1.1 Exports

From the humongous amount of produced pineapple, only 3 million tons of it are traded and about 9.5 tons of fruit are processed proportionally (Dawson, 2016). Costa Rica, being the first producer of fresh pineapple in the world, is the country that exports the majority of its products while leaving little of them for local consumption. In general the African pineapple producing countries, Ghana, and Cote d'Ivoire, as of 2013, are the ones that have a highest exporting data than the other producing countries (Dawson, 2016). Costa Rica sends 150,000 tonnes per month of fresh pineapples mainly to the European Union, United States, and China according to 2014 data.

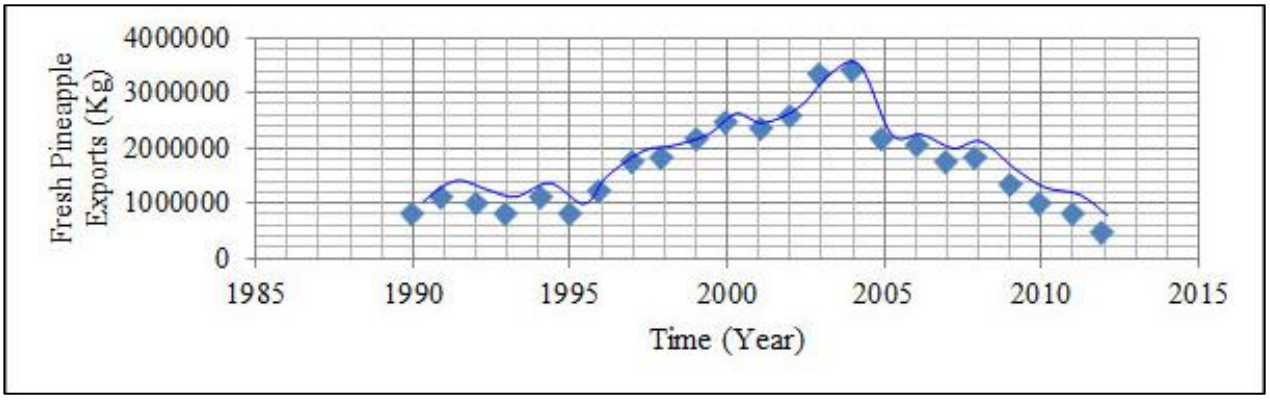


**Figure 5: Export performance of fresh pineapple since 1990 to 2012**

Data from Trademap states that during 2011 there were between 200 and 250 thousand tonnes of pineapple juice exports and in that same year between 1200 and 1250 thousand tonnes of canned pineapple exports in a world average (Dawson, 2016).

### 5.1.2 Imports

Table 6--U.S. imports of fresh and frozen pineapples, by country, 2007-12

| Country | 2007 | 2008 | 2009 | 2010 | 2011 | Jan.-Apr. 2011 | Jan.-Apr. 2012 |
|---|---|---|---|---|---|---|---|
| | | | | *1,000 pounds* | | | |
| Costa Rica | 1,280,268 | 1,302,686 | 1,312,971 | 1,508,093 | 1,555,291 | 656,536 | 566,123 |
| Mexico | 64,815 | 86,185 | 101,933 | 111,574 | 80,939 | 60,331 | 49,370 |
| Honduras | 44,445 | 49,869 | 48,648 | 48,188 | 60,056 | 27,917 | 25,932 |
| Ecuador | 74,935 | 63,728 | 63,499 | 54,846 | 47,813 | 16,026 | 12,214 |
| Guatemala | 60,562 | 56,875 | 40,031 | 28,075 | 32,302 | 12,095 | 11,906 |
| Panama | 17,094 | 20,448 | 25,479 | 35,721 | 31,113 | 19,027 | 12,695 |
| Philippines | 7,238 | 7,468 | 11,216 | 12,465 | 21,121 | 7,946 | 9,043 |
| Thailand | 7,410 | 9,151 | 8,594 | 9,627 | 8,187 | 3,214 | 3,410 |
| Other countries | 2,035 | 2,301 | 2,546 | 4,226 | 4,735 | 1,259 | 2,818 |
| World | 1,558,803 | 1,598,711 | 1,614,917 | 1,812,814 | 1,841,557 | 804,352 | 693,512 |

Source: U.S. Department of Commerce, U.S. Census Bureau.

**Table 1: U.S. imports of fresh and frozen pineapples, by country, 2007-12 ("Pineapple Market Growth 2007-2012," 2012).**

## 5.2 Flavor in *Ananas comosus*

Pineapple has a very attractive sweet flavor, which is why it is consumed around the world in many different formats: fresh, canned, processed in juices, and used as an ingredient in many types of food. Through extended studies in the volatile components* of the pineapple, more than 280 compounds have been found to be involved in generating the unique flavor of this fresh fruit (Zheng et al., 2012). These volatile compounds (Table 3, below), that produce the pineapple's flavor, are dependent on many factors including: the different areas of the crop's cultivation; pineapple varieties; stage of ripening; different seasons; fruit development; flesh position, and storage conditions. These factors have helped find out that the compounds include diverse esters, acids, lactones, hydrocarbons, and carbonyl and sulfur-containing compounds (Zheng et al., 2012).

| Categories | Component name | Molecular formula | Relative contents (%) | | |
|---|---|---|---|---|---|
| | | | T1 | T2 | T0 |
| Esters | Hexanoic acid, methyl ester | $C_7H_{14}O_2$ | 55.14 | 25.71 | 62.61 |
| | Hexanoic acid, ethyl ester | $C_8H_{16}O_2$ | — | 26.11 | 2.20 |
| | Propanoic acid, 3-(methylthio)-, methyl ester | $C_5H_{10}O_2S$ | 5.79 | 5.59 | 4.36 |
| | Heptanoic acid, methyl ester | $C_8H_{16}O_2$ | — | — | 1.42 |
| | Hexanoic acid, 5-methyl-, methyl ester | $C_8H_{16}O_2$ | 0.86 | — | — |
| | Pentanoic acid, 2-methyl-, methyl ester | $C_7H_{14}O_2$ | 0.30 | — | — |
| | 4-octenoic acid, methyl ester, (Z) | $C_9H_{16}O_2$ | 1.42 | 1.27 | 1.60 |
| | Octanoic acid, methyl ester | $C_9H_{18}O_2$ | 25.85 | 15.43 | 15.08 |
| | Octanoic acid, ethyl ester | $C_{10}H_{20}O_2$ | — | — | 0.69 |
| | Hexanoic acid, 5-(acetyloxy)-, methyl ester | $C_9H_{16}O_4$ | 0.61 | 0.49 | 0.48 |
| | Decanoic acid, methyl ester | $C_{11}H_{22}O_2$ | 0.45 | — | — |
| | Ethyl 3-acetoxy hexanoate | $C_{10}H_{18}O_4$ | — | 0.82 | — |
| | Methyl decadienoate | $C_{11}H_{18}O_2$ | — | 0.69 | 0.68 |
| | Pentane-1,1-diol diethanoate | $C_9H_{16}O_4$ | 0.29 | — | — |
| | Methyl 4-acetylhydroxypalmitate | $C_{19}H_{36}O_4$ | 0.32 | — | — |
| | Methyl 5-acetylhydroxypalmitate | $C_{19}H_{36}O_4$ | 0.23 | — | — |
| | Methyl 3-acetoxyhexanoate | $C_9H_{16}O_4$ | 3.19 | 11.90 | 2.19 |
| Alcohol | Farnesol | $C_{15}H_{26}O$ | 0.09 | — | — |

| Categories | Component name | Molecular formula | Relative contents (%) | | |
|---|---|---|---|---|---|
| | | | T1 | T2 | T0 |
| Alkenes | Cyclohexene, 3-ethenyl-4-(1-methylethenyl) | $C_{11}H_{16}$ | 1.16 | 1.25 | 1.74 |
| | 1,3,6-octatriene, 3,7-dimethyl-, (E) | $C_{10}H_{16}$ | — | — | 1.07 |
| | Aristolen | $C_{15}H_{24}$ | 2.29 | 2.68 | 2.87 |
| | à-gurjunene | $C_{15}H_{24}$ | — | 0.35 | 0.37 |
| | Sativen, (+) | $C_{15}H_{24}$ | 0.29 | 0.31 | 0.52 |
| | à-copaene | $C_{15}H_{24}$ | — | 2.71 | — |
| | â elemene | $C_{15}H_{24}$ | — | 0.55 | 0.43 |
| | Germacrene-D | $C_{15}H_{24}$ | — | 0.63 | — |
| | (-)-Isoledene | $C_{15}H_{24}$ | — | 0.31 | — |
| | Valencene | $C_{15}H_{24}$ | — | 0.98 | — |
| | Calarene | $C_{15}H_{24}$ | 0.48 | — | 0.53 |
| | à-muurolene-(-) | $C_{15}H2_4$ | 1.04 | 2.21 | 0.98 |
| | Delta.-cadinene | $C_{15}H2_4$ | 0.19 | — | 0.17 |

**Table 2: Aroma components and relative contents in pineapple fruits of the treatment and control.**

There were several studies conducted with techniques such as hydrodistillation and hydrodistillation by passing nitrogen gas, to find the aroma volatile compounds in the

pineapple processing residues. The compounds were then captured and identified with high resolution gas chromatography.

| Peak | | Compound | Area (%) | |
|---|---|---|---|---|
| SIMP | $N_2$ | | SIMP | $N_2$ |
| 1 | 2 | 2-methyl-3-buten-2-ol | 8.69[a] | 9.33[a] |
| 2 | 3 | methyl pentanoate | 1.62[a] | 1.06[a] |
| 3 | 4 | 2-pentanol | 0.94[a] | 0.62[a] |
| 4 | 6 | 2-heptanone | 0.76[a] | 0.39[b] |
| 7 | 7 | z-ocimene | 0.05[a] | 0.23[b] |
| 10 | 8 | 1-hexanol | 3.84[a] | 60.19[b] |
| 11 | 9 | (Z)-3-hexen-1-ol | 33.58[a] | 0.18[b] |
| 15 | 10 | acetic acid | 0.08[a] | 0.13[a] |
| 16 | 11 | ethyl octanoate | 0.48[a] | 1.19[b] |
| 17 | 12 | furfural | 0.04[a] | 0.02[a] |
| 18 | 14 | benzaldehyde | 0.04[a] | 0.07[a] |
| 19 | 15 | 2,3-butandiol | 0.06[a] | 0.09[a] |
| 21 | 16 | linalool | 1.07[a] | 1.08[a] |
| 22 | 17 | methyl-3-(methylthio)-propanoate | 0.04[a] | 0.06[a] |
| 14 | 18 | dimethyl succinate | 0.05[a] | 0.44[b] |
| 25 | 19 | methyl decanoate | 0.16[a] | 0.04[b] |
| 26 | 21 | methyl benzoate | 0.04[a] | 0.12[b] |
| 27 | 22 | ethyl decanoate | 0.11[a] | 0.08[a] |
| 28 | 23 | α-terpineol | 0.03[a] | 0.04[a] |
| 30 | 24 | γ-hexalactone | 0.96[a] | 1.09[a] |
| 31 | 25 | 2-phenyl-ethyl-acetate | 0.19[a] | 1.72[b] |
| 33 | 26 | ethyl-phenyl-acetate | 0.11[a] | 14.54[b] |
| 34 | 27 | 2-phenyl ethanol | 13.51[a] | 0.69[b] |
| 35 | 28 | γ-octalactone | 0.18[a] | 0.77[b] |

SIMP – Simple hydrodistillation; $N_2$ – Hydrodistillation by passing nitrogen gas. Values with different superscript letters (a, b) are significantly different ($P < 0.05$).

**Table 3: Comparison between hydrodistillation methods- Common volatile compounds identified in the distillate of pineapple processing residue.**

## 5.3 Food Item Based on Pulp, Skin, and Juice

### 5.3.1 Fresh

Pineapple is mostly consumed worldwide as fresh fruit due to its rich flavor, taste, and size. Consumed this way, it can be an excellent source of vitamin C, vitamin B1, vitamin B6, manganese, magnesium, copper, and dietary fiber ("Fresh Pineapples," 2008). Consumers only need to peel, core, and slice the pineapple for consumption.

### 5.3.2 Canned

Canned pineapples has a wide market as processed fruit. There are a great variety of the canned presentations such as whole, slices, or rings, fingers or spears, cubes, chunks, wedges, and tidbits. Plain cans are used to pack the fruit because they doesn't contain tin plate which dissolves due to the fruit acid. (Lobo & Paull, 2017). The manufacturers use three-piece cans with welded sides and easy-open lids in small canned products. Canned pineapple come in different sizes/weight, from 227g to 3kg.

Sometimes the fruit is packed in syrup to hold its color, shape, and flavor or it can be canned with water or fruit juice to reduce the sugar content ("Canned Pineapples Slices, Tidbits, Pieces," 2008).

### 5.3.3 Dried fruit

The drying method is one of the oldest processes to preserve food, such as fruit. Dried fruits are very popular products. When drying a fruit, the water is removed so that micro-organisms won't be able to grow ("Dried Fruit," n.d.). Also, the bulk and weight is reduced cutting down storage and transport costs when marketing the product. This type of pineapple presentation is very high in sugar content in order to keep the fruit safe from spoilage (Robinson, 2010). The dried pineapple usually come in free-shell slightly thin

rings that have been spread on drying pans and have a water and sugar solution poured over them. Sometimes instead of coating them in this solution, pineapple juice concentrate is used (Roehl, 1996).

### 5.3.4 Frozen pineapple

Slices, concentrates, and juices are included in frozen pineapple production. To protect these from weight loss and freeze burn, the materials for packaging should be deep freeze grades of polyethylene (PE) [common plastic]. In distributing these, the temperature should be controlled completely for the quality and safety of the product (Lobo & Paull, 2017). The frozen pineapple juice concentrate can be used in baby food items, fruit cream, juices, puddings, etc. ("Frozen Pineapple Juice Concentrate," 2008).

### 5.3.5 Pineapple juice

'Smooth Cayenne', 'Perola', 'Queen', and 'Red Spanish' are the most widely cultivated pineapple varieties to be processed as fruit juice (Lobo & Paull, 2017).

#### *5.3.5.1 "Not from concentrates" pineapple juice*

This type of product is the normal unfermented liquid obtained from the fresh fruit. The highest quality pineapple juice is obtained from the mature fruit right after harvesting. The juice is produced from slices that look defective and from the residual flesh that is stuck to the shells after they are removed (Lobo & Paull, 2017). For the conservation of the juice, it must undergo a thermal treatment (Lobo & Paull, 2017). Due that its pH is lower than 4.2, molds and yeast are the only microorganisms that should be removed through processes such as aseptic packaging or hot filling (Lobo & Paull, 2017). Aseptic packaging consists on sterilizing the juice in permanent flows at high temperatures (110°-115°) over short periods of time (15s-20s) and then cooled at room temperature (25°-30°). After they are completely sterilized, the juice is poured into previously sterilized containers. This

method maintains the quality of the juice and permits its storage at room temperature (Lobo & Paull, 2017). The hot filling process consists on heating the juice at 95°-97°C and then filling a container with the already heated juice which is finally hermetically closed for 3-5 min before it's cooled.

#### *5.3.5.2 Concentrated juice*

The concentrated juice is the fruit liquid from which enough water has been removed in order to increase the Brix level value* at least 50% (Semin & Sesup, 2005). The overall reason for producing concentrated juice is to facilitate juice storage and transportation. This juice can be prepared also from the flesh stuck to the shells, defective slices, and cores or from the whole fruit. Usually, when gathering the concentrated juice from the flesh, it is shredded and then the juice is extracted and placed in a device where the enzymes are inactive. To eliminate suspended solids, the filtration method is mostly used (Lobo & Paull, 2017). To conserve the concentrated juice, a bag-in-drum system is utilized. This method consists of multilayered plastic and aluminum sterile bags in a steel drum that can hold from 1-1000kg. Other packaging technique could be in a single or double-headed compact aseptic filler bags that can hold 3-20 liters. These concentrates can be used for making soft or alcoholic drinks, squashes, jellies, etc. (Lobo & Paull, 2017). Lastly, concentrated juice can be frozen at 0°C, packed in plastic bags, and then stored at 18°C to complete the freezing process (Lobo & Paull, 2017).

### 5.3.6 Pineapple Jam

Pineapple jam's preparation consists in boiling the fruit pulp with sugar until it has a thick consistency. It should contain more than 68.5% of the total soluble solids. Acid, pectin, sugar, and water are the essential elements of a jam (Basu & Raghavan, 2007).

### 5.3.7 Meat tenderizer

The pineapple fruit flavor pairs well with pork, beef, chicken, and some fishes, but it is also a great tenderizer for tough cuts of meat. This fruit contains an enzyme, bromelain, which digests protein as it softens the meat tissues (Johnson, n.d.).

## 5.4 Items Based on Other Parts of the Fruit

### 5.4.1 Pineapple leaf fibre

Pineapple leaf fiber is a hair-like material in elongated pieces similar to thread. The leaf fiber is a comprised mainly of cellulose (Bongarde & Shinde, 2014). It has a light color and is much softer than other natural fibers for which it is glossy and smooth like silk. Tonnes of this fiber is produced every year promoting in the agricultural industry, non-food based products. It has a high specific, rigidity, strength, and flexibility making it an outstanding alternative raw material for markets, even though its application isn't too common due to lack of knowledge for its utilization (Asim et al., 2015).

### 5.4.2 Pineapple peel

The pineapple peel, similar to the leaf, is rich in carbohydrates like cellulose. When stored and fermented in a silo*, the pineapple peel produces methane which is anaerobically digested* to be used as a biogas and to create slurry feed for animals ("Pineapple," n.d.).

# 6. MEDICINAL USES FROM THE FRUIT RESIDUES

The pineapple fruit residues are produced from the peeling of the fruit which gathers the shells that still contain a big amount of pulp. Processing the residue can be used for feeding animals and other products derived from the pineapple processing. It is important to find methods in which these residues, that cause environmental pollution, can be utilized and for that several studies have been made.

## 6.1 Bromelain

Bromelain is a well-known component from the pineapple's stem. It is a protein-digesting enzyme that has medicinal properties that help reduce inflammation and treat other conditions. In vitro and in vivo studies show that this enzyme exhibits several antiedematous, fibrinolytic, anti-inflammatory, and antithrombotic activities (Upadhyay, Lama, & Tawata, 2010). It is easily absorbed by the body without losing its proteolytic activity and it doesn't produce major side effects (Pavan, Jain, Shraddha, & Kumar, 2012). Bromelain accounts for may medicinal properties as its used for the treatment of sinusitis, bronchitis, wounds, surgical trauma, and enhances the absorption of drugs specially antibiotics. It possesses anticancerous properties due to its stimulation for death cells (Pavan, Jain, Shraddha, & Kumar, 2012).

# REFERENCES


Basu, S., & Raghavan, V. S. (2007). Time Dependent Rheological Characteristics of Pineapple Jam (Scientific). Retrieved from https://www.researchgate.net/publication/240793657_Time_Dependent_Rheological_Characteristics_of_Pineapple_Jam

Bird, C. (2014). The Fundamentals of Horticulture: Theory and Practice (ilustrada). Cambridge University Press.

Bongarde, U. S., & Shinde, V. D. (2014). Review on natural fiber reinforcement polymer composties, 3. Retrieved from http://www.ijesit.com/Volume%203/Issue%202/IJESIT201402_54.pdf

Ddungu, J. C. M. (1973). Rooting-Behaviour of Different Types of Pineapple Propagating Material. In ISHS Acta Horticulturae 33.

Egelie, A. A., & Gillett-Kaufman, J. L. (2015). Pineapple Mealybug. Florida: University of Florida. Retrieved from http://entnemdept.ufl.edu/creatures/FRUIT/MEALYBUGS/pineapple_mealybug.htm

Engebos, M. (2012a, de Abril). Pineapple Adaptation. Retrieved November 10, 2016, from http://zotero.org/support/quick_start_guide

Engebos, M. (2012b, de Abril). Pineapple Classification. Retrieved October 8, 2016, from http://bioweb.uwlax.edu/bio203/s2012/engebos_meag/classification.htm

Engebos, M. (2012c, de Abril). Pineapples Habitat [Blog]. Retrieved October 10, 2016, from http://bioweb.uwlax.edu/bio203/s2012/engebos_meag/habitat.htm

Engebos, M. (2012d, de Abril). Pineapples Interactions. Retrieved November 27, 2016, from https://bioweb.uwlax.edu/bio203/s2012/engebos_meag/interactions.htm

Engebos, M. (2012e, April 22). Reproduction [Blog]. Retrieved December 14, 2016, from https://bioweb.uwlax.edu/bio203/s2012/engebos_meag/reproduction.htm

Fresh Pineapples. (2008). Retrieved April 1, 2017, from http://www.pineappleindia.com/Fresh-Pineapples.html

Frozen Pineapple Juice Concentrate. (2008). Retrieved April 1, 2017, from http://www.pineappleindia.com/Fresh-Pineapples.html

García Suárez, M. D., & Serrano, H. (2005). La piña, *Ananas comosus*(L.) Merr. (Bromeliaceae), algo mas que un fruto dulce y jugoso (Scientific) (pp. 55–61). Retrieved from PDF.

Harrington, J. (n.d.). What is the Life Cycle of a Pineapple Plant? Retrieved December 12, 2016, from http://homeguides.sfgate.com/life-cycle-pineapple-plant-58192.html

Hellen Omondi Kaudo. (2014, de Diciembre). Pineapple Production [Blog]. Retrieved November 10, 2016, from http://hellenomondikaudo.blogspot.com.co/2014/12/pineapple-production.html

Johnson, J. (n.d.). How to Tenderize with Pineapple Juice. Retrieved April 6, 2017, from https://www.leaf.tv/articles/how-to-tenderize-with-pineapple-juice/

Joy P. P., Anjana R., & Soumya K. K. (n.d.). Pests of Pineapple and their Management. Retrieved from

http://prsvkm.kau.in/sites/default/files/documents/pests_of_pineapple_and_thier_management.pdf

Land Requirements for Growing Pineapple. (2013, October 31). Retrieved November 10, 2016, from https://www.daf.qld.gov.au/plants/fruit-and-vegetables/fruit-and-nuts/pineapples/land-requirements-pineapple

Lobo, M. G., & Paull, R. E. (2017). Handbook of Pineapple Technology: Production, Postharvest Science, Processing and Nutrition. Wiley. Retrieved from https://books.google.com.co/books?id=Jq6GDQAAQBAJ

Management Practices: pineapple. (n.d.). Retrieved February 15, 2017, from http://cms.cnr.edu.bt/cms/fruitproductionDIP/?Management_Practices:_pineapple

Moore, G. A., DeWald, M. G., & Evans, M. H. (n.d.). Micropropagation of Pineapple. In High-Tech and Micropropagation II (Vol. 18, pp. 460–470). Retrieved from http://link.springer.com/chapter/10.1007%2F978-3-642-76422-6_24

Morton, J. F. (1987a). Fruit of Warm Climates. Miami, FL. Retrieved from https://www.hort.purdue.edu/newcrop/morton/pineapple.html#Origin and Distribution

Morton, J. F. (1987b). Fruits of Warm Climates. Miami, FL. Retrieved from https://www.hort.purdue.edu/newcrop/morton/index.html

Ms Carolina Dawson. (2016). Pineapple (p. 22). Presented at the UNITED NATIONS CONFERENCE ON TRADE AND DEVELOPMENT, New York and Geneva. Retrieved from http://unctad.org/en/PublicationsLibrary/INFOCOMM_cp09_Pineapple_en.pdf

Mulkey, S. S., Chazdon, R. L., & Smith, A. P. (2012). Tropical Forest Plant Ecophysiology (ilustrada). Springer Science & Business Media. Retrieved from https://books.google.com.co/books?id=9m_gBwAAQBAJ&pg=PA68&lpg=PA68&dq=ecophysiology+of+ananas+comosus&source=bl&ots=Ldbxp7mXXe&sig=xhf2n0ZuA4mPYjAUTlcWJBY5Od8&hl=es&sa=X&ved=0ahUKEwjjlJvw58fRAhXBiJAKHXXGBQMQ6AEIJDAB#v=onepage&q=ecophysiology%20of%20ananas%20comosus&f=false

Pavan, R., Jain, S., Shraddha, & Kumar, A. (2012). Properties and Therapeutic Application of Bromelain: A Review. Biotechnology Research International, 2012, 976203. https://doi.org/10.1155/2012/976203

Pineapple. (n.d.-a). Retrieved April 6, 2017, from http://foodscience.wikispaces.com/Pineapple

Pineapple. (n.d.-b). [Educational organization]. Retrieved November 5, 2016, from https://www.crfg.org/pubs/ff/pineapple.html

Pineapple Farming Info Guide for Beginners. (2017, March 6). Retrieved February 4, 2017, from http://www.agrifarming.in/pineapple-farming/

Pineapple Market Growth 2007-2012. (2012, October 22). [Blog]. Retrieved May 5, 2017, from http://www.chfusa.com/blog/?p=536

Pineapple News. (2010, July). Presented at the 7th International Pineapple Symposium, Johor Baru, Malaysia. Retrieved from http://www.ishs-horticulture.org/workinggroups/pineapple/PineNews17_addendum.pdf

Pineapple Origin. (n.d.). [Dictionary]. Retrieved November 10, 2016, from https://en.oxforddictionaries.com/definition/us/pineapple

Pineapple Production. (n.d.). Retrieved from http://www.naads.or.ug/files/downloads/PINEAPPLE%20PRODUCTION.pdf

Pineapples in Hawaii. (n.d.). [Online Business]. Retrieved October 9, 2016, from http://www.themodernhonolulu.com/pineapples-in-hawaii

Rao, A. N., & Wee, Y. C. (1979). Embryology of the Pineapple, *Ananas comosus* (L.) Merr. In The New Phytologist (Vol. 83, pp. 485–497). Retrieved from https://www.jstor.org/stable/2434149?seq=1#page_scan_tab_contents

Rieger, M. (n.d.). Pineapple-*Ananas comosus* [Blog]. Retrieved December 9, 2016, from http://www.fruit-crops.com/pineapple-ananas-comosus/

Roehl, E. (1996). Whole Food Facts: The Complete Reference Guide. Inner Traditions/Bear. Retrieved from https://books.google.com.co/books?id=H8lwmA52ltIC

Sauls, J. W. (1998, December). Home Fruit Production-Pineapple. Retrieved December 12, 2016, from http://aggie-horticulture.tamu.edu/citrus/pineapple.htm

Schaffer, B., & Andersen, P. C. (1994). Handbook of Environmental Physiology of Fruit Crops (ilustrada, Vol. 2). CRC Press. Retrieved from https://books.google.com.co/books?id=wynac3NvzLsC&pg=PA245&lpg=PA245&dq=ananas+comosus+anthesis&source=bl&ots=PiL3w22G4i&sig=I24kd8-dIR0G6jSZ432lBNL3nms&hl=es&sa=X&ved=0ahUKEwiytdTf4_TQAhVKOZAKHVpCD9sQ6AEIMDAC#v=onepage&q=ananas%20comosus%20anthesis&f=false

Semin, & Sesup. (2005). General standard for fruit juices and nectars (p. 19). Retrieved from PDF.

T., J. (2014, December 27). Pineapple, Bananas, and Coffee [Blog]. Retrieved December 12, 2016, from https://cr2014studyabroad.wordpress.com/daily-topic-updates/pineapplecoffee-jackie/

The Biology of *Ananas comosus* var. comosus (Pineapple). (2008, February). Retrieved from http://www.ogtr.gov.au/internet/ogtr/publishing.nsf/content/pineapple-3/$FILE/biologypineapple08_2.pdf

The Pineapple. (2009, de Agosto). Retrieved from file:///C:/Users/Carolina/Downloads/Ch1-The-Pineapple%20(1).pdf

Upadhyay, A., Lama, J. P., & Tawata, S. (2010). Utilization of Pineapple Waste: A Review. https://doi.org/10.3126