



Aloe Barbadensis Miller

Aloe Vera

Agricultural Science
2016-2017

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INTRODUCTION

As part of 12th grade's Agriculture class formalities students were asked to write a research about a specific plant. In this specific monograph, the plant of Aloe Vera is explored from different focus points, such as its ecology as chapter one, biology as chapter two, propagation and management as chapter three and finally, marketing economy as chapter four. Within the first chapter, the plant is analyzed from its origin; the genus, species and group they belong to; the environmental factors that affect it, more specifically like geology and soils in which it grows, the best climate, rainfall and its relationship with other animals and plants. Subsequently, chapter two consists in its molecular composition, its life cycle, pollination, sexuality, phenology, anthesis, flowering and fruiting. Furthermore, in chapter three the analysis focuses on propagation and management, exploring more the sowing and germination process, ovule development, vegetative propagation, planting and storage. Finally, in chapter four, marketing and economy, the analysis is based on emerging products and potential market and cosmetic and medical products.

ECOLOGY

Aloe barbadensis Miller, also known as Sabila or Aloe Vera, has over 300 species all around the world and it is one of the most grown crops since it is used in the cosmetic, pharmaceutical and food industries. The name Aloe comes from the Greek word referring to the bitter juice from the plant's leaves, though it is said to be derived from the word alloeh in Arabic or allal in Hebrew, both meaning shining bitter substance (Sung, 2006) .



Figure 1: Figure 1: Aloe Vera Crop

2.1 DISTRIBUTIONAL CONTEXT

2.1.1 Affinities

Aloe Barbadensis was categorized for a long time between the *Liliaceae* family but botanists corrected the label and it belongs to the *Aloaceae* family, a subdivision of the *Liliaceae* family although it is not widely accepted. The taxonomy consists in being categorized under the class of Equisetopsida, and Magnoliidae as the subclass. Based on the characteristics of the leaves and stems, three different categories can be identified: *Aloe acauleas*, *Aloe subcauleas* and *Aloe cauleas*. The first one consists in plants that have no stem or a very short one, including *Aloe barbadensis*, *A. saponaria* and *A. aristata*. Furthermore, Aloe Subcauleas consists in plants that have visible stem but is still short, Aloe Succutrina and Aloe Chinensis are included in this category. Finally, Aloe Cauleas is based on plants that have a very long stem, even meters, like Aloe Ferox and Aloe Alborescences.

Group: Monocot
Duration: Perennial
Class: Liliopsida
Subclass: Liliidae
Family: Aloaceae
Genus: Aloe
Species: Barbados aloe

2.1.2 Fossil record

Aloe Barbadensis fossil record to be part of the Lily family but it is no longer consider part of; however, it is related to many other plants including *Allium Ceba*, *Allium Sativum* and *Asparagus Officinalis*.

2.1.3 Origin

Aloe Barbadensis originated in Africa (Figure 1, below) and spread around the world through natural sources and human activities. The use of it dates to 1500 B.C and it is supported by the fact that there are ancient tablets from the Mesopotamians, expressing how Aloe was being used for medical means. The Egyptians expressed how their' people were cured through the use of Aloe around 550 B.C.E and in 74 C.E, the Greek physician and botanist published a book called "De materia medica" after traveling through the Roman Empire as the army's surgeon and wrote about how Aloe could heal and recuperate the floral intestine, the skin from infections and burns, and cure diseases like hemorrhoids.

2.1.4 Present distribution

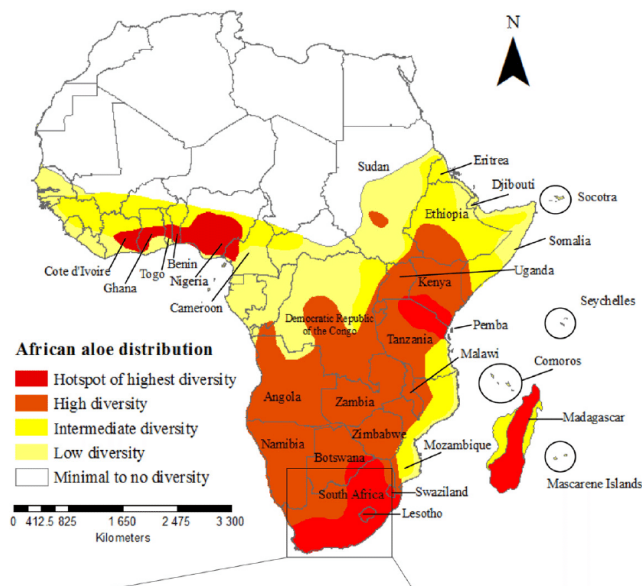


Figure 2: Figure 2: Distribution of Aloe sp. in Africa.

https://www.researchgate.net/profile/Stephen_Cousins3/publication/256941630/viewer/AS:301499579158528@1448894511390/background/2.png

Due to the healing characteristics of this medicinal plant, it is now cultivated all around the world, found in the warm climatic areas of Asia, Europe and America, to be more precise South America is a great producer of Aloe Vera.

2.2 ENVIRONMENTAL FACTORS IN DISTRIBUTION

2.2.1 Elevation

Since it survives strong conditions and different environments, *Aloe Vera* is found in various elevations/altitudes, in regions like America, Mediterranean, Africa and India.

2.2.2 Climate

Aloe Barbadensis in relation to climate is considered as a plant that survives in extreme conditions and has adapted to heat, since it needs temperatures over 40 degrees to grow properly. Nevertheless, maturity will depend on the climate conditions and the resources that are available. As an example, it can be taken into consideration the physical changes the leaves go through when left at exposure; when they are exposed to room temperature they tend to scar turning brown, rather than when it is exposed to extreme cold or even frozen, in which the leave scars turning red.

2.2.2.1 Rainfall, potential evapotranspiration and water deficits

As stated before, Aloe Vera is a plant that has adapted to survive high temperatures and poor conditions; however, after an experiment carried out in Aruba (tropical area) concluded those plants irrigated “compared to non-irrigated treatments irrigation shows a positive influence on growth, number of developed leaves, raw gel figure and gel production per plant” (Genet, W.B.M. & van Schooten, 1991). According to (Das & Chattopadhyay, 2004), it requires about 150 mL of water per month to harvest good quality leaves

2.2.3 Geology and soils

Considering how important the quality of soil is for other plants proper growth, *A.barbadensis* is a plant that does not require great quality soil: this plant is known for its capacity to grow in arid and dry soils, which lack minerals, nutrients and conditions that do not suit many other plants. However, the ideal soil for this plant is sandy loam with a pH up to 8,5 which is slightly alkaline, providing the perfect combination of minerals and nutrients (Das & Chattopadhyay, 2004).

2.3 AS A VEGETATION COMPONENT

2.3.1 Associated Species

According to Royal Botanic Garden Kew, some related species of *Aloe Vera* are: *Aloe welmelensis*, *Aloe plicatilis*, *Hemerocallis fulva*, *Aloe ciliaris*, and *Xanthorrhoea preissii*. (Royal Botanic Gardens KEW, n.d.)

2.3.2 Interactions and Effects on soil

Aloe vera is known for being gifted with a nutritious gel which is 99% water (Balasubramanian & Narayanan, 2013) and the rest is distributed in minerals, vitamins, amino acids, glucomannans and lipids. Since it is such a nutritious plant, its relationship with soil could be called reciprocal; being the ideal soil for it to grow with a pH up to 8,5, slightly alkaline. (Das & Chattopadhyay, 2004).

2.3.3 Relationships with animals and insects

Aloe vera has no several plagues but some common ones as: *Tetranychus urticae*, *Aphis gossypii* and *Spodoptera frugiperda*. (Universidad Nacional Abierta y a Distancia, n.d.)

3.1 CHROMOSOME COMPLEMENT

The studies in Aloe Vera's chromosomes are not too wide; however, in 2010 a study was made tracing its karyotype, meaning "the chromosomes of a cell, usually displayed as a systematized arrangement of chromosome pairs in descending order of size." (Oxford English Dictionary, n.d.) The studied finally proved all Aloe's species contain equal number of diploid chromosomes ($n=7$), (Velásquez-Arenas & Buiza, 2008) diploid meaning two haploid sets of homologous chromosomes. According to (Gunjan & Krishna Roy, 2010) the morphological features consisted in 8 large chromosomes and 6 small in size with "submedian, median and subterminal centromere" (Chaudhari & Chaudhary 2012)

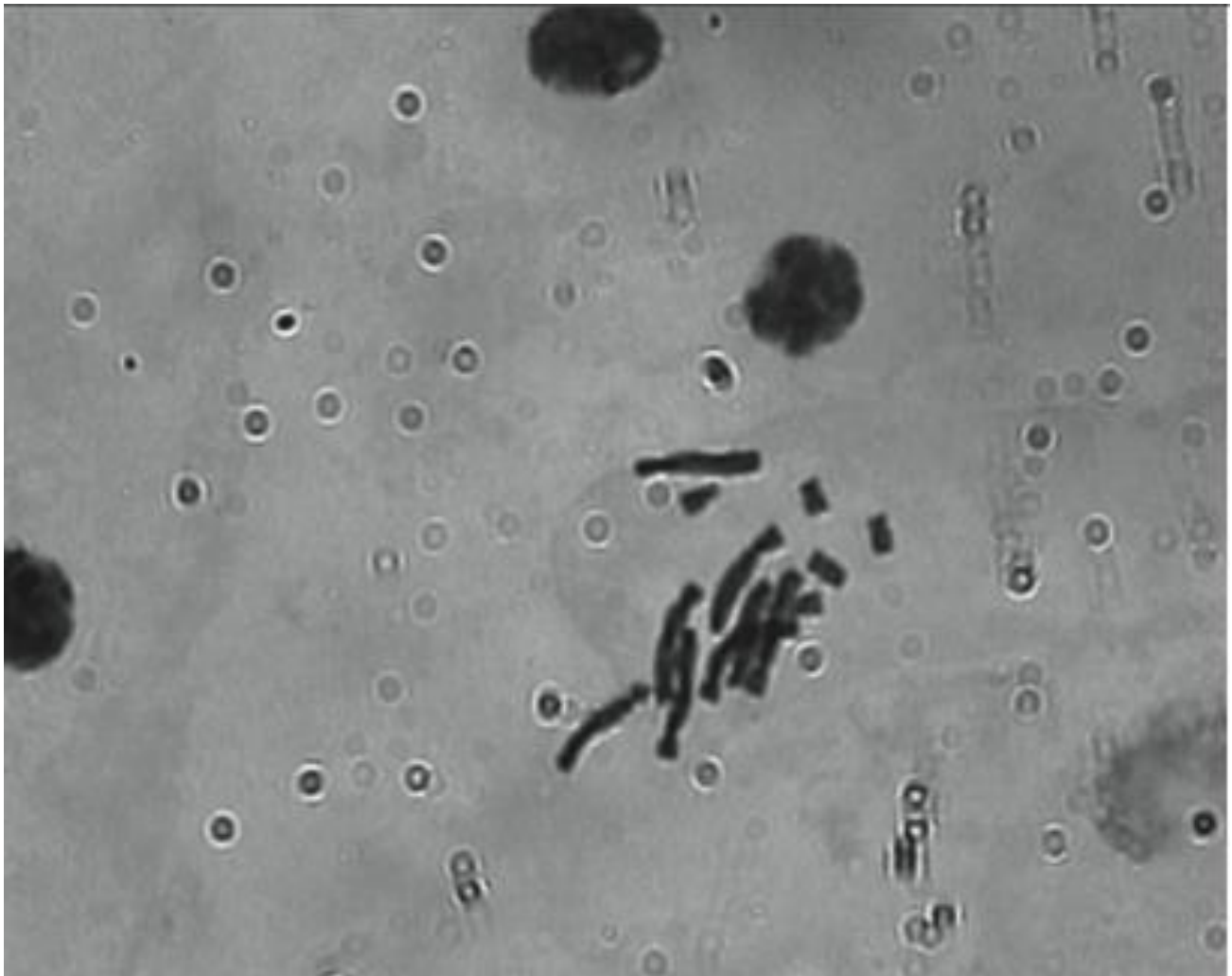


Figure 3: Chromosomes 7

3.2 LIFE CYCLE AND PHENOLOGY

3.2.1 Life cycle

Aloe Vera is an extremely strong plant (**Figure 2**): when the seed is in contact with warm soil it germinates, starting with a root that grows downwards meanwhile the first leaves start growing. As long as temperatures don't get too extreme, the plant will keep producing gel and leaves will remain hydrated. The plant is structured in a rosette form in which leaves have thorny ridges, and yellow flowers (Peteler, 2007). It has been analyzed that the plant has reached maturity when it has 2-4 feet long and a base of 3 or more inches in diameter (Talhouk, Fabian & Dagher, 2015)



Figure 4: Aloe Plant

3.2.2 Phenology

3.2.2.2.1 Flowering and fruiting

Aloe is known for nourishing a flower between winter and midsummer; (Talhouk, Fabian & Dagher, 2015) the flower erupts from the center of the rosette of leaves growing into a group of small, yellow, tubular flowers. These flowers are then pollinated, resulting into a small green pod that with time will dry and brown, leaving the new seeds ready to germinate when the climate and the external factors are precisely what they need to.

3.2.3 Year-to-year variation in flowering and fruiting

For Aloe Vera, there are no extreme or huge changes between year-to-year; it is recognized because of the capacity to survive high and low temperatures, lasting up to 25 years or more. However, strong droughts, floods or extreme low temperatures will decrease its moisture or cause fungi to grow. (Talhouk, Fabian & Dagher, 2015)

3.3 REPRODUCTIVE BIOLOGY

3.3.1 Pollen

In regards to Africa, there are certain hummingbirds that pollinate the yellow flowers, yet pollination is not effective at 100%. After the process has been successfully completed, green pods are born that with time turn brown and dry out, leaving new seeds ready for germination.



Figure 5: Aloe Vera's Yellow Flower

3.3.2 Sexuality

Aloe Vera besides growing by propagation and pollination is known for being a Monoecious plant, in other words, bisexual (Talhok, Fabian & Dagher, 2015). Being a monoecious plant consists in having the stamens and the pistils in separate flowers but in the same plant; the stamens are the pollen-bearing organ of a flower, consisting of the filament and the anther- and the pistils are the ovule-bearing or seed-bearing female organ of a flower, consisting, when complete, of ovary, style and stigma. (Dictionary, n.d.;Keijzer & Cresti, 1986)

3.3.3 Anthesis

Although it is a bisexual plant, it is normally self-incompatible, avoiding self-pollination because of the way the stamens disperse the pollen before the stigma while the part of the pistil is receptive. On the other hand, since pollination through species of birds is common, pollinating different plants result in hybridization. In conclusion, the plant usually grows by pollination, propagation, offset, rhizomes and division. (Peteler, 2007;Keijzer & Cresti, 1986)

3.3.4 Pollination and potential pollinators

Being Africa the place of origin, (Rathod, Parmar, & Vaghela, n.d.) there are certain hummingbirds recognized for pollinating *Aloe Vera* when the flower explodes. Plus, other organisms including other species of birds and bees, although it is not quite frequent. (Peteler, 2007)

3.3.5 Fruit development and seed set

For Aloe Vera, there is no certain fruit, the same leaves are the ones producing all the moisture and gel used for medical, esthetic and industrial reasons. When the flower is fully grown, it is pollinated by organisms, resulting in green pods that once dry out release an amount of seeds ready for propagation when the time is correct (Peteler, 2007).

3.3.5.1 *Ovule development*

Aloe Vera is a bisexual plant, yet the most common way of propagation is through pollination of the yellow flowers turning into green pods (Peteler, 2007). It is very common to find most of the aloes being originated from hybrids.

3.3.5.2 *Ovary wall development*

The ovary wall consists in the wall of the green pods that cover the seeds; these are born after pollinating the yellow flowers. Once they dry out and turn brown, they leave the seeds fall into the soil, then when the seeds find the perfect combination of external factors they germinate (Peteler, 2007).

3.4 ECOPHYSIOLOGY

Taking into consideration photosynthesis, plants are categorized in three different groups: C3, C4 and CAM (Crassulacean acid metabolism). Aloe vera fits in the last description, which is a not so common type of photosynthesis. CAM is defined as “An elaborate carbon fixation pathway in which the stomata are open in cooler and more humid night-time hours, permitting the uptake of CO₂ to be fixed and stored as a four-carbon acid (i.e. malate) so that during the hotter and drier day-time hours the CO₂ is released providing the enzyme rubisco with high concentration of CO₂ while the stomata are closed to reduce water loss through evapotranspiration.” (“Biology online,” n.d.). (Difference Between.net, n.d.) (Khan Academy, n.d.)

PROPAGATION AND MANAGEMENT

4.1 NATURAL REGENERATION



Figure 6: Aloe Vera crops flowering Retrieved from <https://s-media-cache-ak0.pinimg.com/originals/83/ca/71/83ca71e8ed21fc0ab966589d4e00d93d.jpg>

4.2 NURSERY PROPAGATION

Aloe Vera is, as said before, a succulent plant related to the cactus family which makes it a plant that propagates fast by cutting pups. Rather than cutting a single leaf, it provides more chance of the plant's propagation by growing the plant through offsets or so called "pups", resulting in rapid spreading (House Plants Expert, 2016).



Figure 7: Aloe Vera's pups/offsets
http://www.houseplantsexpert.com/images/aloe_with_four_offsets.jpg

4.2.1 Propagation from seed

Although the most common way of propagation of Aloe Vera is through cuttings, the seed process is viable, and just as easy. To start with, it is important to understand that the process starts by collecting the seeds from the mature and grown plant (Figure 1), which has to be four years old, even older, depending on the type of Aloe; since every species has its own timing to mature. However, a reliable signal of maturity is the plant's flowering, showing it is capable of producing seeds ready to grow as other independent plants.

4.2.1.1 *Pre- preparation and implication for germination*

As any other plant, the seeds have a selective process in which seeds have to be selected under certain conditions and characteristics that guarantee germination. Even if the plant is flowering and is healthy, some seeds do not have the right characteristics to germinate and then turn into a plant. Some characteristics to look for include their color, they shouldn't be light colored nor white instead, they should be brownish after being extracted from the dried pods.

4.2.1.2 *Sowing and the germination process*

After splitting dried pods these seeds must be planted within the same year they were harvested for better looking and beneficial plants. However, the way to keep the seeds is under dark, low temperature conditions to preserve the seeds. Once the process of germination starts, the seeds must be in a mist soil for about two to four weeks, which is the time of sprouting (depending on the species) but preserving some heat they need to generate roots. Aloe Vera sprouts have a delicate stage, specifically when they are about the two-leaf stage, when the plant has to be cared from drowning without falling into desiccation (Grant). According to Gardening Know How, "Once four or more leaves are observed, pot each into 2-inch pots with a sterilized mix of 3 parts organic material, 3 parts pumice and 1 ½ parts coarse sand. Grow on as you would adult plants" (Grant).

4.2.1.3 *Storage*

Aloe Vera has a healing characteristic, which is the production of a film when a wound is presented, which avoids oxidation. The way to store is to cut the gel from the leaf and keep in the refrigerator.

4.2.2 Vegetative propagation

To start with, is essential to identify the process of vegetative propagation as a formal definition, "A method of plant propagation not through pollination or via seeds or spores but by way of separating new plant individuals (Figure 3) that emerge from vegetative parts, such as specialized stems, leaves and roots and allow them to take root and grow." (Biology online, 2009). Additionally, this process is often used to improve productivity of valuable plants.



Figure 8: Dividing Aloe Vera plant <http://17.alamy.com/zooms/8537d59337a3407cb40eb53ec336312a/dividing-aloe-vera-pups-from-the-main-mother-plants-fye6kh.jpg>

4.2.2.1 Grafting

Although grafting is the least successful way of spreading Aloe Vera, it can be done by grafting a healthy leaf near the bottom or center of the rosette of leaves. Grafting is necessary for the plant's health, removing those leaves that aren't as healthy and are taking energy from the plant.

4.2.2.2 Cuttings

Aloe Vera plants are better to plant by offsets; usually cuttings can become difficult to sprout because the plant might become infected by cutting it. The leaves must be cut from below and left aside, so the plant makes its own process of healing the wound with its own film of gel, preventing any possible infections that may attack the plant. When the plant is ready for planting, soil must be placed loosely in a pot, preferable to make a mixture between soil and sand to prevent too much humidity in the plant's roots. If the plant turns brownish or deteriorate the cuttings were not successful. (House Plants Expert, 2016)

4.3 PLANTING

As explained before there are three main forms of Aloe Vera plant propagation; cuttings, offsets and seeds. However, they all end up being planted the same way and under the same conditions for better results. The plant must be planted in moist soil but carefully cared avoiding drowning the delicate sprouts; in other words, the soil must be let too dry between watering areas (University of California Davis Botanical Conservatory, 2009). Plus, the soil must be loose underneath but lightly pressed on top so the plant won't topple over once it is big enough. Afterwards, when the plant has reached certain level of maturity, it can be transplanted into a bigger pot or, even better, the ground.



Figure 9: Aloe vera plant: <http://plantedwell.com/wp-content/uploads/2016/01/aloe-vera-plant-care-problems.jpg>

4.4.1 Tending

Tending is known as the care of the plant, regarding Aloe Vera, it is a plant that can withstand high temperatures and poor conditions, adapting to the climate and geology. Different from other plants, it is known for its capacity of growing and spreading in dry and arid land that lack minerals and vitamins. However, the ideal soil for this plant is sandy loam with a pH up to 8,5 which is slightly alkaline, providing the perfect combination of minerals and nutrients (Das & Chattopadhyay, 2004). On the other hand, when growing a plant, it must be planted in loose soil, preferably cactus soil but if not, a mixture between normal pot soil and some sand, to balance it and avoid too much humidity. The soil must be watered before planting the aloe, and left to dry between watering paths.

4.4.2 Fruiting

The Aloe Vera plant will not grow any fruit but it grows a yellow flower that erupts from the center of the rosette of leaves creating a group of yellow, small and tubular flowers. (Peteler, 2007)

On the other hand, the rosette of leaves are the ones used as medical and esthetic reasons because of the gel produced which has particularly healing cellular properties. Additionally, the flowers are mainly for pollen production since the generation of green pods, that with time dry out, leave seeds ready for germination.

4.4.3 Pest and disease control

The main diseases that attack the Aloe family are: Aloe rust (*Phakopsora pachyrhizi*), Aloe Vera Aphid (*Aloephagus myersi*), Anthracnose disease (*Colletotrichum gloeosporioides*), Bacterial soft rot (*Pectobacterium chrysanthemi*), and Basal stem rot (*Fusarium* spp.) (Plant Village, 2014).

Aloe rust (*Phakopsora pachyrhizi*): Small, yellow spots start growing on the leaves expanding rapidly and turning brown caused by these bacteria.

Aloe Vera Aphid (*Aloephagus myersi*): The plant starts secreting honeydew, ending in sooty mold development, if the plant is really infested it will lead to stunting. It can be treated through insecticidal soap or organic methods.

Anthracnose disease (*Colletotrichum gloeosporioides*): The disease starts with spots which then turn in reddish brown and with time infecting the plant will become a necrotic area; however, it can be treated with fungicides.

Bacterial soft rot (*Pectobacterium chrysanthemi*): The symptoms include collapsing leaves, darker in color caused by over-watering the plant.

Basal stem rot (*Fusarium* spp.): When the plant starts to rot and their base starts turning reddish brown to black, the plants can be save by cutting just above the rotten part.

MARKETING AND ECONOMY

5.1 THE OVERALL PICTURE



Figure 10: Aloe Vera Gel

5.1.1 Emerging products, potential markets

Although the humans have the ability to cook, by the way the only species possessor of this skills endowment is the human species, which is dissipated by the industrialization of the food market. However, society is looking desperately for a healthier lifestyle where what they eat comes directly from organic means. This is where Aloe Vera comes into the picture, since aloe Vera provides various benefits to one's esthetic and body. With the "green wave", Aloe Vera usage has been rising every year which leads Future Market Insights to study the possibility of increasing the CAGR (Compound Annual Growth Rate) 7,7% between 2016 and 2026. ("Aloe Vera Extracts Market: Global Industry Analysis and Opportunity Assessment, 2016-2026," 2016).

5.2 FLAVOUR IN ALOE VERA

As explained before, the Aloe Vera after being cut suffers oxidation in a way the same plant protects itself. The gel, when needed as a nutritious meal has to be sweetened with other fruits, since its flavor is bitter.



Figure 11: Product Derived from Aloe Vera http://blog.naturessunshine.com/wp-content/uploads/2015/03/aloe_vera_juice.jpg

5.3 FOOD ITEMS BASED ON PULP, SKIN AND JUICE

Aloe Vera is recognized for possessing fatty acids, including lupeol, cholesterol, campesterol, beta-sitosterol; antioxidant vitamins, including vitamin B12, folic acid, vitamin A, vitamin C and choline; hormones consisting of auxins and gibberellins; enzymes, consisting of alliinase, lipase, bradykinase, amylase, carboxypeptidase, catalase, cellulase, and peroxidase ; minerals such as copper, calcium, chromium, zinc, sodium, potassium, magnesium, and manganese; and finally glucose and fructose, polysaccharides forming sugars within the plant. Furthermore, to understand the importance of antioxidants, it is important to know first that antioxidants fight against free radicals (“highly reactive chemicals that have the potential to harm cells” (Vita five, n.d.)). Although these free radicals are naturally created by the body and are necessary for the correct functionality of other cells, it creates the wrong effect when there are too much. On the other hand, fatty acids provide the ability to heal a wound by decreasing inflammation. Not only that, but Aloe Vera provides minerals, which are involved in giving strength to the bones, keeping the muscular and nervous system working correctly, even keeping your immune system strong and capable of defeating and fighting infections.

5.3.1 Fresh fruit

Because of the different properties of the gel when Aloe Vera is used over wounds or acne it will dry the outbreak of rosacea or cicatrize the open skin. However, the fruit can be used if consumed in juice with other fruits that make the taste easier to take.

5.3.2 Juice, nectar puree and flavored products

With the fit, healthy and green wave, Aloe Vera has come out strongly within the market and it is here to stay. The newest products have been offering different juices, waters, and flavored products that mix Aloe Vera with artificial essences, flavors and colors to advocate several other fruits.



Figure 12: Aloe Vera Drink Products



Figure 13: Aloe Vera Drink Products <https://s-media-cache-ak0.pinimg.com/736x/0b/fe/0f/0bfe0f571694ef65a55538a55ed49b27.jpg>

5.4 ITEMS BASED ON

5.4.1 Cosmetic and medical products

Because of all the healing properties Aloe Vera possesses, the esthetic and clinical industry are taking advantage of this succulent and producing creams, gels or even pills based on the plant. To start with, the regenerator properties of the plant make it a very popular product within the beauty industry, including hair and skin. Plus, the use of Aloe Vera benefits the digestive system and even fights against diabetes by decreasing glucose and serum, dealing with chronic hyperglycemia.

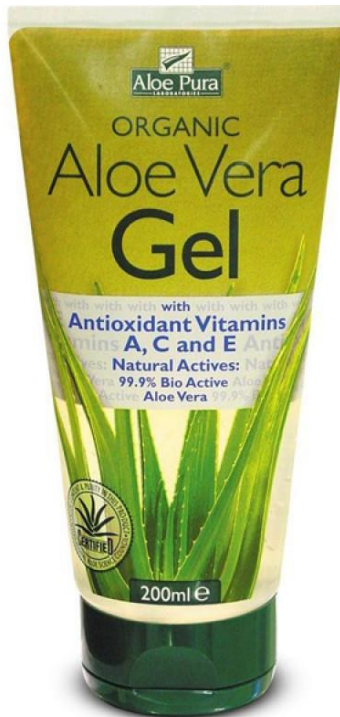


Figure 14: Aloe Vera in gel <http://www.naturalskincare.ie/image/cache/data/aloe-pura/aloe-pura-aloe-vera-gel-antioxidant-800x800.jpg>

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Grant, B. L. (n.d.-b). Can You Split an Aloe Plant: Tips for Dividing Aloe Plants. *Gardening Know How*. Retrieved from Aloe, from which we get an excellent burn ointment, is a succulent plant. Succulents and cacti are remarkably forgivable and quite easy to propagate. Aloe plants produce offsets, also known as pups, as part of their growth cycle. Dividing aloe plants away from the parent produces a whole new aloe to enjoy. Here is a brief tutorial on how to divide aloe plants. Read more at Gardening Know How: Can You Split An Aloe Plant: Tips For Dividing Aloe Plants <https://www.gardeningknowhow.com/houseplants/aloe-vera/dividing-aloe-plants.htm>

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