Macadamia integrifolia Maiden & Betche
Macadamia

Agricultural Science

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Table of contents

Introduction

As part of Agriculture class we are required to develop new skills not only in the field, garden, but also in the formal research part. In the formal research part, each student had to choose a specific plant to research about, certain important points that would let that student get to know the plant. In this monograph the Macadamia nut was investigated. The investigation was guided based on certain benchmarks, so that students could develop a professional piece of research.

As focus points, the monograph contains five different chapters each one with individual subtopics.

Chapter two focuses on the plant´s ecology, analyzed from its origin. The chapter describes its genus and species, the group and the environmental factors which enable it to grow.

The third chapter consists of its biology in which the focus is on its molecular composition, life cycle, pollination, sexuality, phenology, anthesis, flowering and fruiting.

Chapter four focuses on propagation and management, analysis of the germination process, ovule development, vegetative propagation, planting and its storage. Finally, chapter five consists of information regarding the marketing and economics of the crop including an analysis of its emerging products, potential market and cosmetic and medicinal products.

2.0 Ecology

2.1 Distributional Context

2.1.1 Affinities

Macadamia or as it is recognised in the eastern hemisphere Australian nut and Queensland Nut, has three types of species: the smooth shelled (scientific name, *Macadamia integrifolia* Maiden & Betche), the rough shelled (scientific name, *M. tetraphylla* L. Johnson) and hybrids, species that exist between the two species (California Rare Fruit Growers, 1996).

Macadamia has evolved from the Helicia nut (*Athertonia diversifolia*), Chilean Hazel (scientific name, *Gevuina avellana*) and Australian Rosenut (scientifics name, *Hicksbeachia pinnatifolia*). (University of Hawaii, 2016)

2.1.2 Origin

Macadamia integrifolia originated from south-eastern Queensland, growing in the rain forests close to the streams. *M. tetraphylla* is also native to south eastern Queensland with the difference that it originated in northeastern New South Wales (California Rare Fruit Growers, 1996). These two species eventually joined, forming a natural hybrid called M. tetraphylla. Macadamia was first discovered in Hawaii, in the late 1880's, where it was first used for reforestation and as an ornamental plant.

The Hawaiian Agricultural Experiment Station introduced and named several selections that led to the modern macadamia industry. In California two seeds of macadamias were planted in the early 1880's that still stand on the campus of the University of California (California Rare Fruit Growers, 1996). Contributing importation of improved and named varieties of plants to California. Macadamia is also commercially important in South Africa, Australia and Central America.

2.1.3 Present distribution

Due to the Macadamia nut trees complicity it can only be grown on deep and drain soils that have a pH of 5.0-6.5. It can be also found on drained lava land that is sufficiently weathered to support natural vegetation. (University of Hawaii, 2016). Due to this Macadamia nut trees are found in Hawaii, Latin America, middle africa and southern asia. (California Rare Fruit Growers, 1996) **Figure 1.**

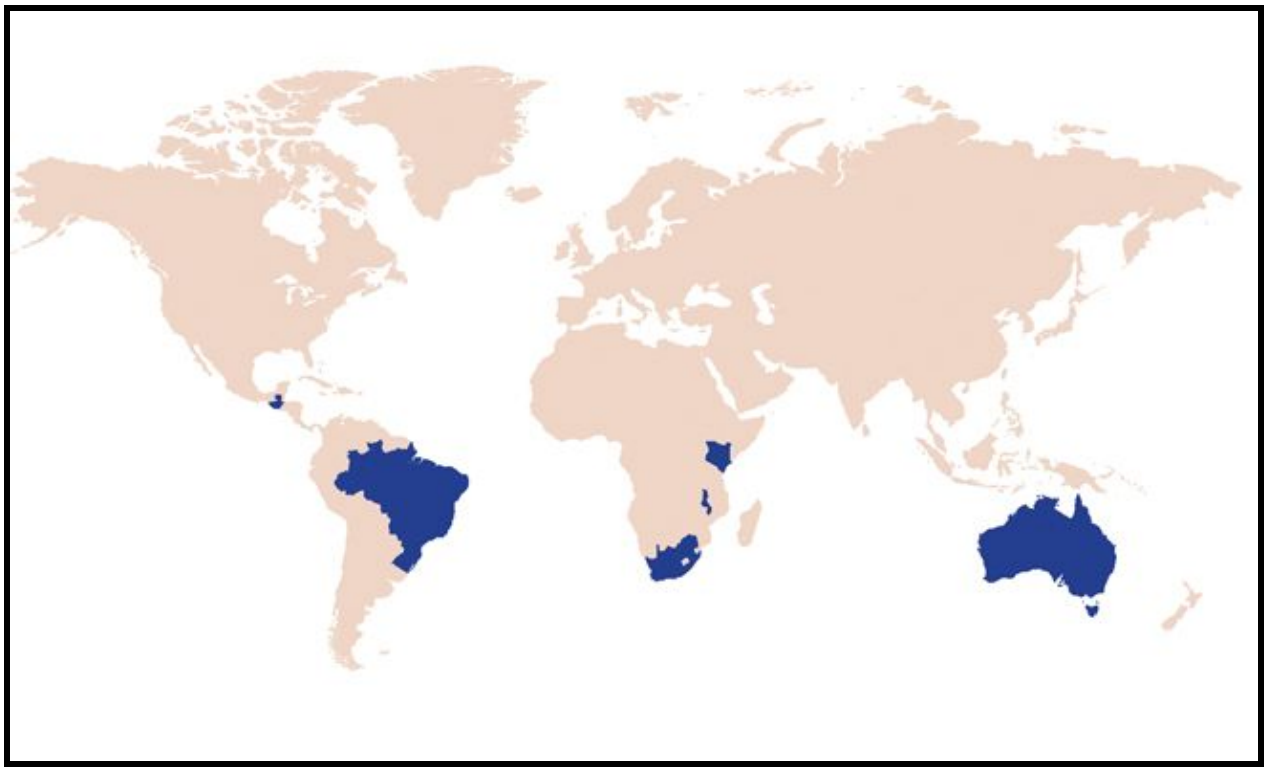

Figure 1: World macadamia growing regions (Kenkko, s. f.)

2.2 Environmental Factors in Distribution

2.2.1 Elevation and Climate

Mature macadamia trees tolerate temperatures as low as -4.4° C, although the flower clusters tolerated until the -2.2° C before they die (University of Hawaii, 2016). The ideal temperature for growth of macadamia trees is between 16°C and 25 °C. The Macadamia trees can be grown from sea level to an elevation of 762 meters. (University of Hawaii, 2016). Although of the tree registration the nut production decreases above 600m. Above 640m the tree growth is slower and it takes longer to produce nuts. (National Department of Agriculture of South Africa, 2001).

2.2.2 Geology & soils

For macadamia trees most of the soil types are suitable for its production. This means that it can grow in a range of soil types from sandy and lava-rock soils to heavy clay soils. (National Department of Agriculture of South Africa, 2001). Although it needs to provide a well drained for water, this means that poorly drained clay soils are not suitable.

2.3 Vegetation Components

2.3.1 Interactions & Effects

Macadamia trees are most commonly grow on deep, well-drained soils with a pH of 5.0-6.5 also in well-drained lava land that is capable to grow natural vegetation. But for the tree be able to grow it requires between 1524 to 3048 mm of rainfall a year. (University of Hawaii, 2016). The majors affects the soil suffers when Macadamia is planted the soil is thanks to the concentrated stemflow, also it destroy surface soil structure because of its organic matter loss and last it reduce the soil's ability to absorb rainfall and combat erosion. (Firth, 2007)

2.3.2 Interaction of Plant Roots and Relationship With Animals

Table 1: Lists of pests and diseases of Macadamia

Scientific Name	Effect on Macadamia	Type of pest disease	Reference
Amblypelta nitida	Causes deep-set breakdown of significant areas of tissue.	Bug	Australian Macadamia Society, 2011

Macademia integrifolia Maiden & Betche

Amblypelta lutescens lutescens	They insert their long mouthparts into plant tissue and cause deep set breakdown	Bug	Australian Macadamia Society, 2011
Cryptophlebia ombrodelta	larvae bore through the skin and into nut in search of the seed	Insect	Australian Macadamia Society, 2011
Homoeosoma vagella	Flowers are chewed and webbed together resulting in reduced fruit set.	Insect	Australian Macadamia Society, 2011
Nezara viridula	Sucks nutrients from the seed	Bug	Australian Macadamia Society, 2011

3.0 BIOLOGY

3.1 Chromosome Complement

Macadamia chromosome numbers have been determined from 19 genera and 53 species of Proteaceae in Australia (Symphionema, Grevillea, s.f). The chromosomes are small in all genera except Persoonia n = 7, Placospermum n = 7 (Johnson and Briggs 1963) and Bellendena n = 5 (Venkata Rao 1957), which have chromosomes comparable in size with those in the Liliaceae and Ranunculaceae. In other Australian genera chromosome numbers range from n = 14 (Cenarrhenes, Macadamia, Xylornelum, Lambertia, Banksia, Dryandra), n = 13 (Isopogon, Petrophile, Stirlingia, Adenanthos), n = 11 (Conospermum, Telopea, Lomatia, Stenocarpus) to n = 10 (Symphionema, Grevillea, s.f).

3.2 Life Cycles and Phenology

Macadamia tree beings his juvenile period when it reaches six years old then it reaches its maturity at around ten years old. The plant starts flowering in January through to March and from June to November. The fruit grows from November to January and from March to April (Barry & Thomas 1994; Forster et al. 1991). Macadamia tree begin to produce nuts at around 10 years old (Vock 1989 cited in Blundell 1998). The plant reproduce by its seeds, whats happen is that the seeds are eaten by mammals then dispersed by stream (Queensland CRA/RFA Steering Committee 1997).

3.2.1 Seeding protection

The Macadamia nut shells and the coats of seeds are hard to crack despite their relatively thin walls (Speck T, Speck O (2008). It requires an extra protection to protect the seed against deleterious environmental influences, for example UV radiation, water loss, mechanical damage when they fall or inadvertent crushing by animals seeking food. The shells of *Macadamia* nuts exhibit particularly high strength helping the Macadamia tree with its preservation. (Speck T, Speck O (2008).

3.2.2 Flower Production

Macadamia tree flowers are on average between 5 to 10 mm long. They are born on racemes, flower cluster with the separate flowers attached by short equal stalks at equal distances along a central stem. The flowers at the base of the central stem develop first (Raceme, 2003, p. 671), with 100 to 150 flowers. There are about 2,500 flowers on a tree. Each flower has 20 ovules, with four anthers attached to the petals and a long stigma. It takes around 7 days for all the flowers on the raceme to open. (Macadamias Bee Aware, s. f.). Cross pollination (transfer of pollen from the male reproductive organ to the female reproductive organ) has show an increase in the nut weight as well as the number of nuts (Firth, 2007).

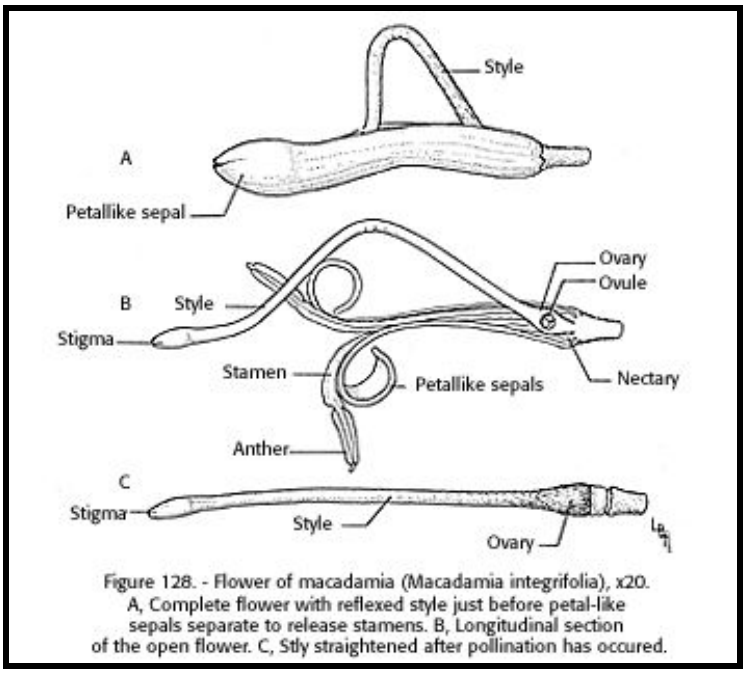

Figure 128. - Flower of macadamia (Macadamia integrifolia), x20. A, Complete flower with reflexed style just before petal-like sepals separate to release stamens. B, Longitudinal section of the open flower. C, Stly straightened after pollination has occured.

Figure 2 (HAMILTON, s. f.)

3.2.3 Foliage and Growth

Macadamia nut has a regular-shaped, a fast growing and medium-sized tree with heavy dark green foliage. Leaves develop in whorls of three, paired, or in fours. The leaves are rarely solitary. The leaves are blunt tipped, oblong, 1 foot in length or more, edged with fine teeth, and the petioles are about half an inch in length (Speck T, Speck O (2008). The flowers are small, whitish, tasseled, and grow on long spikes. The nuts ripen

in the fall, both the spring and fall, or through the year. The nut is encased in a leathery two valved case that is 1 inch in diameter (Macadamias Bee Aware, s. f.).

3.3 Productivity and Biology

3.3.1 Pollen

After the Macadamia tree starts flowering, the flower will produce both pollen and nectar. Its takes several days for the flower to open that's why the stigma of the flower takes time to be viable. The flower after it opens it will only attract insects for three days (Canberra, 2016). This flower attracts a variety of insects including the honey bee. But there is a special bee called the Trigona, this particularly bee is more attracted to macadamia flower. (University of Hawaii, 2016). Each flower produces small amounts of nectar that's why the pollen gatherers are reported to be better pollinators than nectar foragers as they are more likely to contact the stigma. (Canberra, 2016).

3.3.2 Sexuality and Reproduction

Macadamia tree is a seeded vascular plant, this means that it reproduces throughout seeds. Also the macadamia tree is a member of the the Magnoliopsida group, which is a group of plants that also have flowers and covered seeds. The plant has two different multicellular structures; The first one is the sporophyte which is the diploid multicellular structure and the second one is the gametophyte is the haploid multicellular structure. (Hartung, 2017). This means that each one have their own respective duties within the plant's life cycle as is shown in **Figure 3. (Hartung, 2017)**

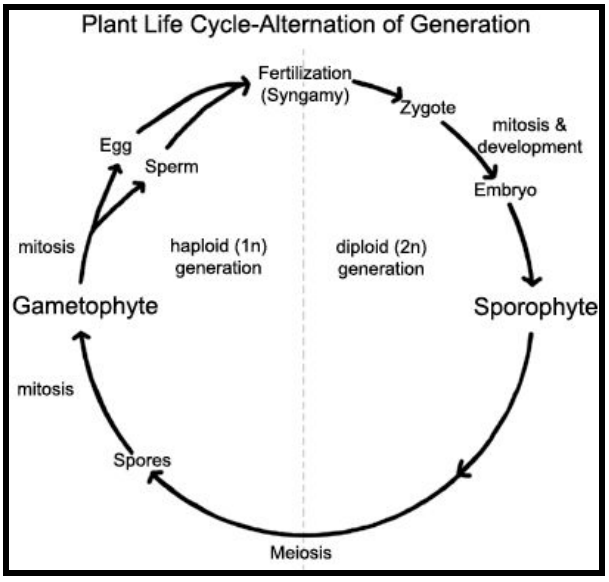

Figure 3 Life cycle of a plant (Hartung, 2017)

3.3.3 Anthesis

Base on the observation of Hawaii Agricultural Experiment Station, the macadamia tree it has young buds are green and usually become creamy white from 3 to 4 days before anthesis, although in some varieties of the plant, the caps remain green almost to anthesis, Then after the fifth day before anthesis, the styles begin to elongate and bend (URATA, 1954). Finally, on the eighth day they push through the abaxial suture between two sepals. After this the anthers begin to discharge the pollen 1 to 2 days before anthesis. Also the sepals begin to separate at the tip and curl back, exposing the anthers. The anthers are closed over the tip of the style (URATA, 1954). After the sepals have completely recurved the anthers begin to separate from the style, leaving the pollen masses on the style tip . In few minutes they pull entirely clear of the style tip. After this occurs the style break s through the last unopened portion of the abaxial suture and springs free. (URATA, 1954)

3.3.4 Ovule development

Based on data collected by Shaul. P Monselise the macadamia ovary contains two anatropous ovules. Each ovule has an outer and inner integument which do not envelope the nucellus completely so as to form micropyle (Monselise, 2018). The embryo sac of

both ovules contains an egg cell, two synergids with filiform apparatus, two polar nuclei and three antipodal cells (Monselise, 2018). The complete development period takes around 14 days.

3.3.5 Fruit development

The process starts when only one ovule develops after fertilization to form a single seed fruit. Then the ovule obtain a zygote nucleus and an endosperm nucleus, the endosperm cell formation begins 4 weeks after the fertilization has occurred. Each nucleus divides to form a free nucleate endosperm (Monselise, 2018). After further divisions a globular proembryo with a short suspensor is formed. This stage is reached about 8 weeks following anthesis when the fruit has a diameter of 7 to 8 mm (Monselise, 2018). The outer integument of the ovule develops into the hard seed coat, while the inner integument degenerates completely during fruit development after the anthesis. Finally the ovary wall develops after fertilization into the pericarp of the fruit. (Monselise, 2018).

4.0 PROPAGATION AND MANAGEMENT

4.1 Natural regeneration

Macadamia integrifolia counts with xerophytic characters, which includes the sclerophyllous leaves and proteoid roots; the proteoid roots are dense clusters of rootlets formed to explore poor soils low in phosphorus. Therefore the plant is relatively adaptable to harsh environments (Orwa, 2009). However, for optimum production the plant may require different conditions. Also the plant is capable of withstanding mild frosts, but only for short periods and the brittle wood makes trees susceptible to wind damage and the brittle wood makes trees susceptible to wind damage (Orwa, 2009).

4.2 Nursery Propagation

Macadamia is a difficult plant to work with because of its wood and bark structures and its habits. Therefore the side wedge and side paste methods of grafting seem to be the best adapted in the propagating plants (Orwa, 2009). Budding is almost impossible, the whip graft does not seem satisfactory and other means of multiplying a plant such as by cuttings and layering are tedious and expensive. (Beaumont, 1937) For these reasons, only propagation by means of the side-wedge and side-paste methods should be tried. (Beaumont and Moltzau, 1937). **Figure 4** represents the process

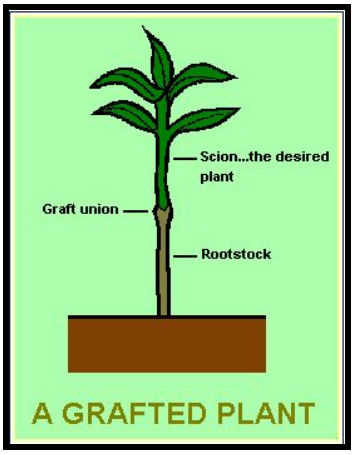

Figure 4 Grafted plant (Dawson, 1996)

4.2.1 Propagation from seed

The first step you will need for propagation is to obtain the seed and grow the seedlings on which to graft. Macadamia has two types of seeds. The two types of seeds are the rough-shell and the smooth-shell. Investigations are on-going to find out which type of seed produces the best rootstock. (Beaumont, 1937) Large seeds are not necessarily better, inasmuch as there are fewer per pound or per bushel than those of medium or small sizes, the number of seedlings is the chief consideration. (Beaumont, 1937)

4.3 Planting

Macademias can be produced successfully in areas where avocados, papayas, mangoes and bananas do well. The trees flower during spring from August to September and the further development of the fruit lasts 31 weeks. Also the size of the container is very important because if the container is too small, the tree becomes pot-bound and the taproot might be distorted. (National Department of Agriculture of South Africa, 2001). Therefore, the tree could appear healthy in the nursery, but will have a small chance of reaching its full potential in the orchard. The weakened root system cannot provide the growing tree with sufficient water and nutrients.(National Department of Agriculture of South Africa, 2001).

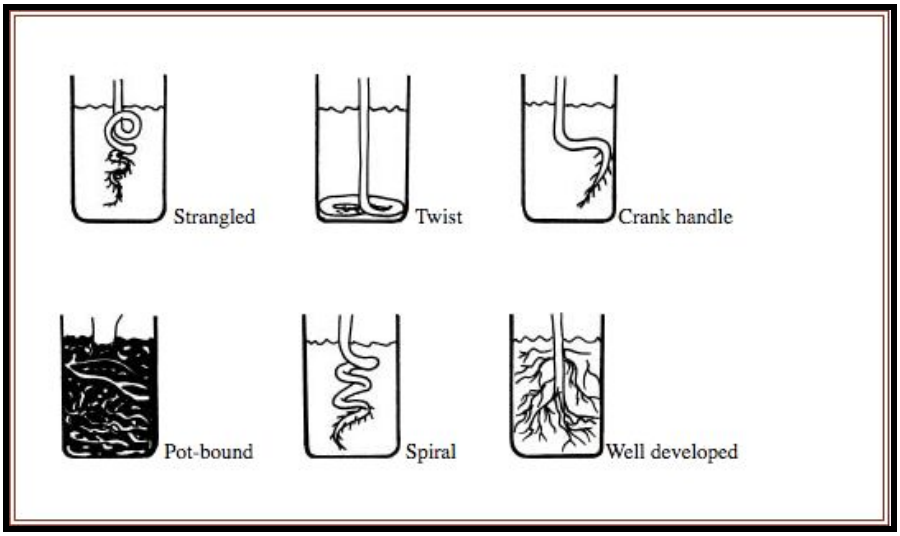

Figure 5: Weakened vs well developed root systems in macademias (National Department of Agriculture of South Africa, 2001)

4.4.1 Tending

Macadamia trees farms usually plant their trees during spring when the soil is warming up. The nut then pass through a process of selection of the most high producing commercial varieties of macadamia nut cultivars that suit our soil type and weather conditions to produce creamy premium quality nuts in 6 or 7 years (Hartung, 2017). Also the the pasture should be allow to grow long between rows for the first 2 years to reduce leaf damage and moisture loss from the prevailing wind. Lastly macadamia trees should be mulched annually to form a rich organic blanket that harbours beneficial fungi and insects. It is also a store of nutrients, feeding the trees and promoting a large population of birds that control the insects that cause damage to the trees and immature nuts (Australian Macadamia Society, 2011).

4.4.2 Fruiting

Growing a macadamia tree is difficult and it may not produce fruit or may produce a slightly inferior nut to the parent tree (Grant, 2016). However, it may start fruiting between 5 to 10 years. Seed viability is checked by putting it in water. If the seed sinks, has a tight kernel and a light caramel coated shell, the chances of germination are hugh (Grant, 2016).

5.0 MARKETING AND ECONOMY

5.1 Imports and Export

The top exporters of Macadamia nuts are; South Africa ($252M), Australia ($181M), Kenya ($66.4M), Hong Kong ($47.5M) and Malawi ($25.5M) (Simoes, s. f.). The top importers are the United States ($138M), Hong Kong ($119M), Vietnam ($97.6M), China ($76.9M) and Germany ($61.1M). According to the Product Complexity Index (PCI), Macadamia is the 4868th most complex product and the 2369th most traded product. (Simoes, s. f.).

5.2 Marketing

The Macadamia Market is divided in two. The first one is the food industry which is widely used in confectionery including chocolate bar, ice cream, chocolate covered candy and other baking products. The second market of macadamia is the cosmetics industry in which it used for producing soaps, shampoos, sunscreens and others cosmetic products.

5.2.1 Packing and Transportation

To able to sell macadamia products and distribute it companies need to create a packaging that meets with all of the following requirements. The labelling of the package is very important and it must contain the following information: name of the product, lot identification, name and address of the manufacturer, packer, distributor or importer, and storage instructions (storage and transport instructions are very important due to high oil content, which can negatively influence the quality of product if not handled properly) (CBI, 2017). Also there is no general rule for the export size of the packaging of macadamia nuts, but the most common type of export packaging are vacuum bags (poly liners or alufoil) placed in cartons (CBI, 2017).

5.2.2 Consumer

The major exports markets for macadamia are Japan, Europe and North America. The outlook for macadamia consumption in Europe is positive. There is an expected growth do to the increased interest in healthy eating, as macadamia nuts are a source of protein, fibre, vitamins, minerals and unsaturated fats. They are also considered a source of Vitamin A, iron, protein, thiamine, riboflavin, niacin and folates (CBI, 2017). In terms of value, apparent consumption of macadamia nuts in Europe is increasing by an average annual rate of 19% (CBI, 2017).

5.3 Uses

he macadamia nut has many ways in which it can be used other than as a food crop. The outer husk combined with other organic matter, makes an excellent mulch around young trees. The hard shell sustains high temperatures when burning and is mostly used as a fuel for fueling furnaces in local industries (Coast, s. f.). Also when the shell is ground to a fine powder the resulting granules are extremely hard. The powder can be used as an industrial abrasive and is superior to sand for sandblasting (Coast, s. f.). It is even marketed by the cosmetics industry as the active ingredient in facial skin scrubs (Coast, s. f.). But the most common uses are in the food industries and in the cosmetic industry where they produced several products from the macadamia nut.

5.4 Items Based on

5.4.1 Cosmetic and medical products

The principal cosmetic product based on the macadamia nut is the macadamia nut oil which it can be used for several treatments. The two major uses of the macadamia oil is for treating skin and hair damage. What makes the macadamia oil so attractive to scientists and consumers is that it is rich in essential fatty acids which helps to maintain skin health and also the heart thanks to its perfect balance in fatty acids. As the cosmetic industry, the pharmaceutical industry also takes advantage of its monounsaturated fatty acids (MUFA), to lower cholesterol (Penn State, 2005).

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