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Lychee (*Lychee chinensis* Sonn.), composition and possible applications

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ABSTRACT

Objective: to mention the importance of the bioactive compounds and fatty acids (FA) present in lychee, in addition to their possible applications Lychee is a fruit originally from Asia, which has sweet pulp and juice, presents an attractive appearance and pleasant flavor, in addition to high nutritional value, so that it is quite accepted by consumers. Lychee is a great source of bioactive compounds such as tannins and vitamin B1. Because of its functionality, it has various uses as in the preparation of teas and medicinal remedies. Because of the functionality it has, it is important to research this fruit in detail and to find possible applications. Therefore, the objective of this study.

Keywords: Lychee, bioactive compounds, fatty acids, functional foods.

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INTRODUCTION

Presently, it is known that the benefits of a balanced diet are not limited solely to its content in nutrients, but also in seeking other compounds that contribute protection in the presence of oxidative stress and carcinogenesis; they are specially contained in foods of plant origin, the so-called bioactive compounds. Bioactive compounds are components of the foods that influence the cellular activity and the physiological mechanisms with beneficial effects for health (Martínez and Carbajal, 2012).

Fatty acids (FA) are among these bioactive compounds. It is known that these constituents provide biological activity, action mechanisms, structure and molecular formula; they are found in various isolated parts of the plant and fruit. Among them, there is the lychee, which is a fruit of subtropical climate originally from southern China and northern Vietnam (Zhou *et al.*, 2008). It is very popular internationally due to its characteristic flavor and attractive appearance, which makes it a fruit with high commercial value (Cabral *et al.*, 2014). The objective of the study is to understand the importance of the bioactive compounds and FA present in lychee, in addition to their possible applications.

Characteristics of the lychee

The lychee is a fruit originally from Asia that has an attractive appearance and a pleasant flavor, in addition to high nutritional value, so it is quite accepted by consumers (Hajare *et al.*, 2010; Jiang *et al.*, 2004). Because of its functionality, it has various uses, although this functionality differs due to many elements such as the way of harvesting, the cultivar, fertility, and soil type (Lee and Kader, 2000). Lychee is a good source of bioactive compounds. It has a high content of flavonoids, bioactive chemicals, tannins, vitamin B1, good antioxidant activity at the cellular level, and anti-cancer activity (Wen *et al.*, 2015). In addition, it presents a high nutritional value, pharmacological effects such as hepaprotector activity, and antioxidant activity (Bhoophat *et al.*, 2011).

Although some of the properties of lychee are already known, the knowledge about its composition is still limited, since it could have other secondary metabolites in low concentrations, since it is attributed to have many health benefits (Yang *et al.*, 2016).

Bioactive copounds and bioactivity detected in lychee

Presently, it is known that the benefits of a balanced diet are not limited to its nutrient content, but also to other factors that provide protection in face of oxidative stress and carcinogenesis, such as the bioactive compounds contained especially in foods of plant origin. Bioactive compounds are components of foods that influence cellular activity and physiological mechanisms with beneficial effects for health (Martínez and Carbajal, 2012). It is estimated that a mixed diet can contain between 60,000 and 100,000 different bioactive components, potentially effective to reduce the risk of chronic disease, and this is why these elements have been of vital importance in recent studies.

Lychee is a fruit that has a great number of bioactive compounds. Because of these bioactive compounds, the fruit is used in the preparation of teas and medicinal remedies (Wei *et al.*, 2011). It has a high content of flavonoids and lignans detected in the pericarp, in addition to good antioxidant and anti-cancer activity (Wen *et al.*, 2015). It has numerous pharmacological effects such as hepatic protection activity, although it presents reduced levels of phenol compounds. The pulp is mainly composed of carbohydrates and could be responsible for the benefits that it gives to health (Yang *et al.*, 2016).

It has also been found that lychee contains flavonoids (Wen *et al.*, 2014; Jiang *et al.*, 2013), phenolic acids (Wen *et al.*, 2014; Zhang *et al.*, 2013; Sun *et al.*, 2010), proanthocyanidins (Castellain *et al.*, 2014; Xu *et al.*, 2010; Sun *et al.*, 2010), anthocyanins (Li *et al.*, 2012), coumarins (Wang *et al.*, 2011), lignans (Wen *et al.*, 2014; Jiang *et al.*, 2013), chromanes (Lin *et al.*, 2015), sesquiterpenes (Warg *et al.*, 2011; Xu *et al.*, 2010), sterols (Malik *et al.*, 2010), triterpenes (Jiang *et al.*, 2013; Malik *et al.*, 2010), and fatty acids (Xu *et al.*, 2011; Stuart and Buist, 2004). It is known that these constituents provide biological activity, action mechanisms, structure and molecular formula.

Oils and fats

Fatty acids are carboxylic acids with hydrophobic aliphatic chain, and they are divided into four groups according to the number of carbons or length of their chain: volatile, with 2-4 carbons; short chain with 6-10 carbons; medium with 12-16 carbons; and long starting at 16 carbons (FAO, 2008). If they do not have any double links in their molecule, they are called saturated (SFA). When they have double links, they are called unsaturated (MUFA), differentiating between mono-, di-, tri- or poly-unsaturated (PUFA), depending on whether they have one, two, three or more, respectively (Murray *et al.*, 2012; Voet and Voet, 2010; FAO, 2008).

In the case of unsaturated fatty acids, they can be classified depending on the position of the first double bond counting from the terminal methyl group. For the same chemical formula, unsaturated fatty acids can have multiple isomers of structural nature, according to the placement of the double bonds in the chain and depending on whether hydrogens united to the carbon atoms of the double bond are found on the same side (cis) or on both sides (*trans*) of the double bond (FAO, 2008).

Some FA that are consumed have shown to have interesting properties for consumers' health. Among the most important FA, we can count linoleic acid (C18:2, omega-6, AL) and α-linolenic acid (C18:3, omega-3, ALN), and some of long chain such as the docosahexaenoic acid (DHA, 22:6n3) and arachidonic acid (AA, 20:4n6) (Makrides *et al.*, 2011).

Among its positive effects, some that stand out are anti-cancer, anti-atherosclerotic, anti-diabetic (type 2 diabetes) activity, anti-inflammatory and immune activity; in addition to increasing the immune response without muscular catalysis, bone mineralization, lipolysis and anti-lipogenic effects (Molkentin and Giesemann, 2010; Ruggiero *et al.*, 2009; Hunter, 2008). It has also been reported that FA improve the evolution of cardiovascular diseases; and it has been suggested that the consumption in adequate amounts, especially EPA (eicosapentaenoic acid) and DHA (docosahexaenoic acid), has a fundamental role on the prevention and/or decrease in risk of developing chronic diseases such as type 2 diabetes, high blood pressure, and even colon cancer (Gutiérrez *et al.*, 2011a; Ozyilkan *et al.*, 2005). It has also been found that conjugated linoleic acid (CLA) has shown to have an important role in regulation of the immune system, as well as in reducing the risk of certain types of cancer and atherosclerosis. Therefore, an increase in the consumption of these fatty acids could have the same beneficial effects for health (Gutiérrez *et al.*, 2011b).

To determine the different fatty acids that make up a sample, various analysis tests must be made and among these there is the fatty acids profile (FAP). The FAP is the study that determines the different fatty acids that are found in a sample analyzed and, thus, to understand or find different acids with nutritional contribution or benefit to the human organism, since numerous experimental studies have suggested a linear relationship between their consumption and their effects on health (Ron, 1986). The FAP of fatty acids has three main stages, which are: extracting or obtaining oil, obtaining methyl esters, and analyzing the sample through instrumental techniques.

Oil extraction methods

When it comes to the oil extraction methods, there are several methods, each with different equipment and reagents. Among the most well-known methods, there is extraction by solvents using the Soxhlet method, extraction by microwave, extraction by ultrasound, extraction with sub and super critical fluids, by hydraulic press, among others (Domingues *et al.*, 2016).

In the extraction by Soxhlet method, different solvents are used such as hexane (Moser *et al.*, 2016; Santos *et al.*, 2013), heptane (NMX-F-490-1987), petroleum ether (Santos *et al.*, 2013; AOAC, 2000), and ethanol (Debora, 2011). The solvent chosen is placed with the sample in question in presence of heating for a certain period of time that can vary between 2-8 h, to obtain the oil and eliminate the solvent by evaporation. The extraction by microwave is also done through solvents, but in this case microwave equipment is used and the oil is obtained by filtering. In the extraction method by sub and super critical fluids, it is done through a continuous flow at high pressure, where carbon dioxide and the solvent is used (mixture of CO_2 and CO_2 with propane), which is pumped to the extractor with a membrane pump with a flow of 1.0-1.5 L/min, at a pressure that ranges between 100-250 bar and a temperature of 35 and 28 °C, respectively, where the extract obtained is cooled in a container for 15 min to eliminate the CO_2 (Illes and Otto, 1997).

Fatty acid extraction methods

After the extraction, there comes a phase of obtaining the methyl esters. This phase consists in the degradation of fatty acids to units of low molecular weight that ease the identification of fatty acids. Among the most well-known methods, there are the methods by Hartman and Lago (1973), Ichihara *et al.*, (1996), Samios *et al.*, (2009), to mention a few. The most frequently used method is the one by Hartman and Lago, where a methanol solution with sodium hydroxide is used and then an esterification reagent; later, filtering is conducted, where the organic phase is dried and filtered using anhydrous sodium sulfate, thus obtaining the methyl fatty acids that will by used to carry out the FAP.

Fatty acids profile

There are different pieces of equipment that may be used to conduct the FAP, among them fine layer chromatography (FLC), high performance liquid chromatography (HPLC), gas chromatography (GC), and other more complex ones such as gas chromatography coupled with mass spectrometry (GC/MS), which help to understand the concentration of each FA present in the sample (Aued-Pimentel *et al.*, 2010).

FLC serves to determine saturated and unsaturated fatty acids (Touchstone, 1995; Nikolova-Damyanova, 2010), and it is a classical method for separation, identification and quantification of fatty acids, due to the simplicity in its use; it is cheaper, with reduced expense in solvents compared to other methods and several samples can done in parallel; in addition, there is the possibility of visualizing the FA with the use of adequate coloring agents (Fuchs *et al.*, 2011).

When it comes to the HPLC, lately it has been used for the determination of FA related to biological, dietary and medicinal samples (Brondz, 2002; Lima and Abdalla, 2002; Rezanka and Votruba, 2002). The use of this equipment dates back to 1950 and its nature is based on its stationary state (solid and liquid). This stationary state is divided into liquid-liquid chromatography, absorption chromatography and reversible phase chromatography, which is a combination of the two previous ones (Brondz, 2002). The parts that are very important to consider in this equipment are the polarity of the stationary phase, the mobile phase, and the chemical structure of the FA. In general, the retention time is proportional to the length of the chain and the number of double bonds present in the FA examined (Rao *et al.*, 1995). This method is used because of its simplicity, reproducibility, and credibility.

GC is the most frequently used method today for the determination of FA. This method uses the sample when it suffers esterification, causing a better yield in the detection of FA. Here, many types of columns can be used that vary according to their properties, such as the polar (commonly used in FA analysis) and non-polar. There are also different types of detectors and among the most common ones in FA analysis, there is the nitrogen detector sensitive to phosphorus, the photometric flame detector, the photoionization detector, the flame ionization detector, and the mass detector (Seppanen-Laakso *et al.*, 2002). However, the most powerful equipment in the detection of FA is the GC/SM, since it detects saturated and unsaturated FA with more accuracy.

In the case of GC/MS, it also serves to determine the molecular weight of the FA present in the sample, in addition to locating double bonds or other functional groups. The basic principle of these instruments is to subject the sample to an impact with electrons, causing the rupture of the aliphatic chain in an indefinite number of fragments, which is why the ramification point and structure of the ring cannot be identified, although the molecular weight of the FA is obtained from the molecular ion and therefore the number of atoms of carbon, hydrogen and oxygen. With this, it can be determined whether the FA is saturated or unsaturated, as well as the ramification point or another constituent (Christie, 1998). With all these data, a better reference of the structures present in the sample can be determined (Dolowy and Pyka, 2014; Christie, 1998).

Recent research

Among the plant samples that have been studied most to determine the FAP, seeds stand out. Table 1 shows some of the seeds about which the FAP has been determined.

As can be seen in the table, the most frequently used extraction method has been Soxhlet, using hexane as solvent. However, there are methods that have better yield in obtaining oils such as the extraction by super critical fluids, by microwave, and the accelerated extraction by solvent which, as has been shown in previous studies (Salvador *et al.*, 2016; Krulj *et al.*, 2016; Ling *et al.*, 2016), present better yield than the method mentioned previously. In addition, these methods reduce the extraction time and energy expense (Golmakani and Rezaei; 2008; Yamini *et al.*, 2008; Kimbaris *et al.*, 2006; Danjanovic *et al.*, 2005).

Another factor that affects the yield of oil extraction is the state of maturity of the seed (Bozdogan and Mungan, 2016; Shan-Shan *et al.*, 2015), since according to some studies, different FA will be found as the fruit is more mature, or FA at higher concentrations in the seed (Tan *et al.*, 2016). Other factors that have an influence are the different types of cultivars (Salvador *et al.*, 2016; Zhang *et al.*, 2016; Shan-Shan *et al.*, 2015), the growth region, and the sample harvest (Zhang *et al.*, 2016), as well as the post-harvest management. These factors should be considered and serve as point of comparison depending on the study or innovation that will be made referring to the study sample, seeking to obtain better results.

Table 1. Determination of FAP of diverse seeds.

Sample	Author/s	Type of extraction	Equipment used	Major acids found (%)	Relevant Data
Jaboticaba	Neuza *et al.*, 2011	Soxhlet (Ethanol)	Gas chromatography	Linoleic (37.01) Palmitic (28.02) Oleic (13.67) α-Linoleic (7.07) Stearic (3.57)	Rare stearic acid.α Linoleic acid is more common from cereal samples.
Water mallow	Moser *et al.*, 2016	Soxhlet (Hexane)	Gas chromatography	Linoleic (53.10) Palmitic (20.70) Oleic (13.70) Malvalic (5.20) Stearic (1.80)	Malvalic acid can be harmful to health.
Palm jelly	Vieira *et al.*, 2016	Soxhlet (Hexane)	Gas chromatography	Lauric (39.17) Oleic (20.73) Capric (11.02) Myristic (7.88) Palmitic (5.19)	This oil can be used as fuel.
Tomato	Botinestean *et al.*, 2012	Cold pressed	Gas chromatography mass spectrometry	Linoleic (54.91) Palmitic (13.52) Oleic (18.85) Octadecenoic (3.54) Linolenic (2.94)	The PAG can tell us the applications that these oils can have.
Olive	Bozdogan y Mungan, 2016	Press	Gas Chromatography	Oleic (62.34-71.53) Palmitic (13.87-16.7) Linoleic (5.02-11.93) Palmitoleic (0.75-1.67) Arachidic (0.56-1.06)	Seed maturation stage is involved in PAG variation.
Nut	Salvador *et al.*, 2016	Low pressure and supercritical fluid extraction	Gas chromatography	Oleic (49-69) Linoleic (19-40) Palmitic (5-11) Stearic (1-6) Linolenic (0-3)	Higher extraction yield was found with the low pressure method. The variety of the sample also influences the PAG.
Amaranth	Krulj *et al.*, 2016	*Soxhlet (petroleum ether) *Supercritical fluids *Accelerated solvent extraction	Gas chromatography	Linoleic (37.29-48.67) Oleic (24.53-33.53) Palmitic (18.68-21.29)	Sample size determines extraction efficiency. Accelerated solvent extraction shows the highest extraction yield.
Pistachio	Ling *et al.*, 2016	*Cold pressing *Microwave	Gas chromatography mass spectrometry	Oleic (55.37-56.05) Linoleic (30.46-31.32) Palmitic (10.95-11.11) stearic (1.05-1.11) Palmitolellic (1.01-1.08)	Most efficient microwave extraction method. Pressing method is more susceptible to oxidation of bioactive compounds.
Lychee	*Gaydou *et al.*, 1993 *Gontier *et al.*, 2000	Soxhlet (petroleum ether)	* Gas chromatography with mass spectrometry * Gas chromatography	Cyclopropanoic (45.10) Palmitic (42.90) Palmitoleic (0.13-1.21) Stearic (0.10-10.50)	Cyclopropanoic acid was found which is usually synthesized by bacteria.

It has been found that most of the samples contain FA such as linoleic, oleic, palmitic and stearic (Zhang *et al.*, 2016; Yang *et al.*, 2016; Vieira *et al.*, 2016; Salvador *et al.*, 2016; Moser *et al.*, 2016; Ling *et al.*, 2016; Krulj *et al.*, 2016; Domingues *et al.*, 2016; Bozdogan and Mungan, 2016; Shan-Sahn *et al.*, 2015; Santos *et al.*, 2013; Botinestean *et al.*, 2012; Neuza *et al.*, 2011; Szentmihalyi *et al.*, 2002; Gontier *et al.*, 2000; Gaydou *et al.*, 1993), in addition to these being found in higher concentration and presenting several positive effects on health (Simopoulos, 2008).

In the case of the oleic acid, values have been found that range from 10.55 to 71.53% (Zhang *et al.*, 2016; Yang *et al.*, 2016; Vieira *et al.*, 2016; Salvador *et al.*, 2016; Moser *et al.*, 2016; Ling *et al.*, 2016; Krulj *et al.*, 2016; Domingues *et al.*, 2016; Bozdogan and Mungan, 2016; Shan-Shan *et al.*, 2015; Santos *et al.*, 2013; Botinestean *et al.*, 2012; Neuza *et al.*, 2011), and canola (63.50%) and olive (71.53%) oils show the highest values. This FA has positive effects at the vascular level, decreasing the systolic and diastolic pressure, and also shows positive effects on the digestive system, in gastric, biliary, pancreatic and intestinal functions (Serra and Aranceta, 2006).

According to studies carried out, levels of linoleic acid that range from 5.02 to 54.91% have been found (Zhang *et al.*, 2016; Yang *et al.*, 2016; Salvador *et al.*, 2016; Moser *et al.*, 2016; Ling *et al.*, 2016; Krulj *et al.*, 2016; Bozdogan and Mungan, 2016; Shan-Shan *et al.*, 2015; Botinestean *et al.*, 2012; Neuza *et al.*, 2011), with the highest value found in tomato (54.91%). This FA has beneficial action on the cardiovascular system (Serra and Aranceta, 2006; Das, 2000), reducing the risk of diseases, and also helping to regulate the production of low-density lipoproteins and to accelerate their dissolution in the organism; and at the same time, helping the healthy function of the brain, hair growth, skin regeneration, energy production, and health of reproductive organs (Patterson *et al.*, 2012; Uauy and Dangour, 2006). Therefore, its consumption is highly advisable for its medicinal properties (Simopoulos, 2008).

When it comes to palmitic acid, it has been found at concentrations that range from 3.60 to 42.90% (Zhang *et al.*, 2016; Yang *et al.*, 2016; Vieira *et al.*, 2016; Salvador *et al.*, 2016; Moser *et al.*, 2016; Ling *et al.*, 2016; Krulj *et al.*, 2016; Domingues *et al.*, 2016; Bozdogan and Mungan, 2016; Shan-Shan *et al.*, 2015; Santos *et al.*, 2013; Botinestean *et al.*, 2012; Neuza *et al.*, 2011; Gontier *et al.*, 2000; 2002; Gaydou *et al.*, 1993) found in lychee seeds (Gaydou *et al.*, 1993; Gontier *et al.*, 2000). This FA has good nutraceutical properties and can be used in the elaboration of functional foods, because it presents medicinal properties such as cardio-protection, anti-inflammatory, among others (Orsavova *et al.*, 2015).

Lastly, stearic acid is one of the most common FA in oils although it is found in low concentrations of 0.10-10.50% (Yang *et al.*, 2016; Salvador *et al.*, 2016; Moser *et al.*, 2016; Ling *et al.*, 2016; Shan-Shan *et al.*, 2015; Neuza *et al.*, 2011; Gontier *et al.*, 2000; Gaydou *et al.*, 1993), with the lychee seed showing the highest value. This FA helps in skin care, so it is widely used in the cosmetic industry and in lubricant additives or the rubber industry (Álvarez and Molina, 1995).

These oils can have various applications in different industries, such as the cosmetic industry (elaboration of soaps, perfumes, fragrances), in rubber production (Álvarez and Molina, 1995), and even in biodiesel production (Domingues *et al.*, 2016; Vieira *et al.*, 2016; Yang *et al.*, 2016). However, where there should be the highest interest is in the food industry, since due to their properties and functionality, these FA can be used in food production as additives, thickening agents, breading product, production of fried foods, giving certain added value to the final product desired.

Medicinal properties of lychee

Thanks to the bioactive compounds found until now in lychee, knowing the contribution that it can give the organism, this fruit has been used medicinally. In Asia many parts of the plant (bark and flowers) are used to relieve throat pain. It is also known that the seed has been used to deal with neurological disorders, hernias, ulcers and intestinal pains (Ahmad and Sharma, 2001). It has been reported that consuming or ingesting moderate amounts of the raw or cooked fruits can relieve cough, in addition to having positive effects in illnesses such as tumors, gland enlargement, cough, diarrhea, stomach ulcers, dyspepsia, obesity, and as treatment to eliminate intestinal parasites (worms). Likewise, the skin tea has been used to cure eruptions caused by smallpox and diarrhea (Castellain *et al.*, 2014; Cohen and Dubois, 2010; Li, 2009).

The tree leaves have also been used for the treatment of flatulence and to detoxify the organism (Wen, 2014). In addition, in the region of Asia and the Pacific, it has been used as promoter to heal wounds (Wiart, 2006).

As had been mentioned before, lychee presents many medicinal properties due to its various nutritional or bioactive compounds (vitamins, dietary fiber, amino acids, oligo elements, linoleic acid, and other unsaturated fatty acids); it can be considered as a functional food and can also be used for the elaboration of functional foods (FFs) (U. S. Department of Agriculture, Agricultural Research Service, 2012; Wall, 2006).

Efects of fa in the human body

Presently, maintaining human health is being sought through the consumption of foods with nutritional contribution that can supply the physiological needs of the organism, and among these foods there are functional foods (FFs). FFs are defined as modified foods or which contain ingredients that increase the welfare of the individual or decrease the risks of diseases, beyond the traditional functionality of ingredients they contain (American Dietetic Association, 2009). Because of the inclusion of FFs, now food also seeks to fulfill the requirements of the diet and the conservation of health (Robertfroid, 2002).

It has been sought for these FFs to be consumed in a healthy and balanced diet, in the same amounts in which typical foods are consumed. The positive effects on health from these foods are because of the bioactive compounds they contain. Among the bioactive compounds, there is AGP n-3 in fish, CLA in ruminant meat, dairy peptides, lutein in egg yolk, and phytochemical substances from vegetables (Biesalski *et al.*, 2009).

Among the positive effects of FFs from the influence of bioactive compounds, there is modulation of the immune system, increasing the phagocytic activity of monocytes and granulocytes, and increasing the levels of cells that secrete antibodies (González-Gross *et al.*, 2004). Positive effects to the digestive system (intestinal tract) have also been found, where these foods help to stimulate the growth of beneficial bifidobacteria. Among these foods there are lactic beverages enriched with fiber, which help to maintain and develop the bacterial flora that is important in the defense mechanisms of the individual. Their intake can prevent or even avoid bacterial translocation (passage of germs of gastrointestinal origin to other tissues such as mesenteric ganglia, liver, spleen and lung), since the final products of fiber are trophic for epithelial intestinal cells, maintaining the balance of the intestinal flora through fermentation and bacterial production of short-chain fatty acids (Sies *et al.*, 2005).

Another positive effect of FFs is as anti-inflammatory agents (they can be used as treatment in acute and chronic inflammation), and this is given by poly-unsaturated fatty acids. This FA is recommended to treat diseases such as rheumatoid arthritis and in the prevention of cardiovascular diseases, due to its beneficial effects against hypercholesterolemia (Platt, 2000). As has been mentioned, due to the properties of FFs, their development promises to increase life quality, especially in risk groups such as children and the elderly. In addition to this, the scientific evidence is the only guarantee that will allow the knowledge of the true functions of FFs, as well as their correct use (Instituto de Nutrición y Transtornos Alimentarios, 2007).

CONCLUSIONS

Lychee presents many bioactive compounds of great biological interest that could be used for diverse applications.

These bioactive compounds can serve to treat various illnesses and diseases, improving the life quality and health of those who consume them.

Many of these compounds should be analyzed further to better determine their functionality.

REFERENCES

Ahmad, S. A. and Sharma, S. C. S. (2001). Fruit and Vegetable Juice Therapy. Pustak Mahal, New Delhi, India.

Álvarez, C. E. y Molina, D. F. (1995). Producción de ácido esteárico a partir de estearina o grasas refinadas mediante el proceso de hidrólisis. Universidad Nacional de Colombia. Santa Fé de Bogotá. Facultad de Ingeniería Química.

American Dietetic Association. (2009). Position of the American Dietetic Association: Functional foods. *Journal American Dietetic Association*. 109: 735-46.

Aued-Pimentel, S., Markievicz M. K. M., Kumagai, E. E., Ruvieri, V. and Zenebon O. (2010). Comparison of gas chromatographic and gravimetric methods for quantization of total fat and fatty acids in foodstuffs. *Quim. Nova. 33*(1): 76-84.

Bhoopat, T., Bhoopat, L., Srichairatanakool, S., Kanjanapothi, D., Taesotikul, T. and Thananchai, H. (2011). Hepatoprotective effects of lychee (*Litchi chinensis* Sonn.): A combination of antioxidant and anti-apoptotic activities. *Journal of Ethnopharmacology. 136*(1): 55-66.

Biesalski, H. K., Dragsted, L. O., Elmadfa, I., Grossklaus, R., Muller, M., Schrenk, D. and Weber, P. (2009). Bioactive compounds: definition and assessment of activity. *Nutrition. 25*(11-12): 1202-1205.

Bozdogan, K. D. and Mungan, B. (2016). Effects of Variety, Maturation and Growing Region on Chemical Properties, Fatty Acid and Sterol Compositions of Virgin Olive Oils. *Journal Ametican Chemical Society*. 93: 1499-1508.

Brondz, I. (2002). Development of fatty acid analysis by high-performance liquid chromatography, gas chromatography, and related techniques. *Analytica Chimica Acta*. *465*(1-2): 1–37.

Cabral, T. A., Morals, C. L. and Pinheiro, S. H. M. (2014). Chemical composition, vitamins and minerals of a new cultivar of lychee (*Litchi chinensis* cv. Tailandes) grown in Brazil. *Fruits*. 69: 425-435.

Castellain, R. C. L., Gesser, M., Tonini, F., Schulte, R. V., Demessiano, K. Z., Wolff, F. R., Delle-Monache, F., Netz, D. J. A., Cechinel-Filho, V., deFreitas, R. A., deSouza, M. M. and Meyre-Silva, C. (2014). Chemical composition, antioxidant and antinociceptive properties of *Litchi chinensis* leaves. *Journal Pharmacy Pharmacology*.66: 1796–1807.

Christie, W.W. (1998). Gas chromatography-mass spectrometry methods for structural analysis of fatty acids. *Lipids*. 33: 343-353.

Cohen, A. and Dubois, L. J. (2010). Raw Food for Everyone: Essential Techniques and 300 Simple to Sophisticated Recipes. Penguin group (USA) Inc., New York, USA.

Danjanovic, B., Lepojevic, Z., Zivkovic, V. and Tolic, a. (2005). Extraction of fennel (*Foeniculum vulgare* Mill.) seeds with supercritical CO_2: Comparison with hydrodistilation. *Food Chemistry*. 92: 143-149.

Das, U. N. (2000). Benefical effect (s). of n- fatty acids in cardiovascular diseases: but, why and how? *Prostag. Leukotr. Ess*. 63: 351-362.

Dolowy, M and Pyka, A. (2014). Chromatographic Methods in the Separation of Long-Chain Mono- and Polyunsaturated Fatty Acids. *Journal of chemistry*. 2015: 1-20.

FAO. (2008). Grasas y ácidos grasos en nutrición humana. Estudio FAO alimentación y nutrición. 91: 204 p.

Fuchs, B., S¨uß, R., Teuber, K., Eibisch, M., and Schiller, J. (2011). Lipid analysis by thin-layer chromatography—a review of the current state. *Journal of Chromatography A. 1218*(19): 2754–2774.

Gaydou, E. M., Ralaimanarivo, A. and Bianchini, J. P. (1993). Cyclopropanoic fatty acids of litchi (*Litchi chinensis*) seed oil. A reinvestigation. *Journal Agritulture Food Chemistry*. 41: 886-890.

Golmakani, M. T. and Rezaei, K. (2008). Comparison of microwave-assisted hydrodistilation with the traditional hydrodistilation method in the extraction of essential oil from *Thymus vulgaros* L. *Food Chemistry*. 101: 1558-1564.

Gontier, E., Boussouel, N., Terrasse, C., Jannoyer, M., Ménard, M., Thomasset, B. and Bourgaud, F. (2000). *Litchi chinensis* fatty acid and diversity: occurrence of the unusual cyclopropanoic fatty acids. *Biochemical Society Transactions. 28*(6): 578-580.

González-Gross, M., Warnberg, J., Álvarez, R., Medina, S. y Marcos, A. (2002). Los Alimentos Funcionales y su relación con el sistema inmune. En: Marcos A, editor. Actualización en Nutrición, Inmunidad e Infección. Madrid: Panamericana. 57-65.

Gutiérrez, R., Vega, S., Radilla, C., Radilla, M., Coronel, S. y Coronado, M. (2011b). The importance of the fatty acids of milk in human nutrition. In: Publishers, N. Y. N. S. (ed.) Milk Production.

Gutiérrez, R., Vega, S., Radilla, C., Radilla, M., Díaz, R., Pérez, J. y Ramírez, M. (2011a). The consumption of fish oil and some benefits in human health. In: Publishers, N. S. (ed.) Fish Oil: Production, Consumption and Health Benefits.

Hajare, S.N., Saxena, S., Kumar, S., Wadhawan, S., More, V., Mishra, B.B., Narayan, P. M., Gautam, S. and Sharma A. (2010). Quality profile of litchi (*Litchi chinensis*) cultivars from India and effect of radiation processing. *Radiat. Phys. Chem*. 79: 994–1004.

Hunter, J. E. (2008). Safety and health effects of trans fatty acids. In Chow, C.K., ed. Fatty Acids in Foods and Their Health Implications. London, CRC Press (Taylor Francis Group). (3rd ed). 757-790.

Instituto de Nutrición y Transtornos Alimentarios (INUTCAM). (2007). Alimentos funcionales, aproximación a una nueva alimentación. Comunidad de Madrid. Salud de Madrid. 238 pp.

Jiang, G., Lin, S., Wen, L., Jiang, Y., Zhao, M., Chen, F., Prasad, K.N., Duan, X. and Yang, B. (2013). Identification of a novel phenolic compound in litchi (*Litchi chinensis* Sonn.) pericarp and bioactivity evaluation. *Food Chemistry*. 136:563–568.

Jiang, Y., Duan, X., Joyce, D., Zhang, Z. and Li, J. (2004). Advances in understanding of enzymatic browning in harvested litchi fruit. *Food Chemistry*. 88: 443–446.

Kimbaris, A. C., Siatis, N. G., Daferera, D. J., Tarantilis, P. A., Papas, C. S. and Polissiou, M. G. (2006). Comparison of destillation and ultrasound assisted extraction methods for the isolation of sensitive aroma compounds from garlic (*Allium sativum*). *Ultrasonics Sonochemistry*. 13: 54-60.

Krulj, J., Brlek, T., Pezo, L., Brkljaca, J., Popovic, S., Zekovic, Z. and Bodroza, S. M. (2016). Extraction methods of *Amaranthus* sp. Grain oil isolation. *Journal Science Food Agriculture*. 96: 3552-3558.

Lee, S. K. and Kader, A. A. (2000). Preharvest and post-harvest factors influencing vitamin C content of horticultural crop. *Postharvest Biology Technology*. 20: 207-220.

Li, W., Liang, H., Zhang, M., Zhang, R., Deng, Y., Wei, Z., Zhang, Y. and Tang, X. (2012). Phenolic profiles and antioxidant activity of Litchi (*Litchi chinensis* Sonn.) fruit pericarp from different commercially available cultivars. *Molecules*. 17: 14954–14967.

Lima, E. S. and Abdalla, D. S. P. (2002). High-performance liquid chromatography of fatty acids in biological samples. *Analytica Chimica Acta. 465*(1-2): 81–91.

Lin, Y., Chang, J., Cheng, S., Wang, C., Jhan, Y., Lo, I., Hsu, Y., Liaw, C., Hwang, C. and Chou, C. (2015). New bioactive chromanes from *Litchi chinensis*. *Journal Agriculture. Food Chemistry*. 63: 2472–2478.

Ling, B., Yang, X and Wang, S. (2016). Physicochemical properties, volatile compounds, and oxidative stability of cold pressed kernel oils from raw and roasted pistachio (*Pistacia vera* L. Var Kerman). *European Journal Lipid Technology*. 118: 1368-1379.

Makrides, M., Collins, C. and Gibson, R. (2011). Impact of fatty acid status on growth and neurobehavioural development in humans. *Maternal and Child Nutrition*. 7: 80-88.

Malik, I., Ahmad, V. U., Anjum, S. and Basha, F. Z. (2010). A pentacyclic triterpene from *Litchi chinensis*. *Natural Product Communications*. 5: 529–530.

Martínez, R. C. y Carvajal, A. A. (2012). Componentes bioactivos de los alimentos. Manual práctico de nutrición y salud. *Conceptos generales*. 31-36.

Molkentin, J. and Giesemann, A. (2010). Follow-up of stable isotope analysis of organic versus conventional milk. *Analytical and Bioanalytical Chemistry*. 398: 1493-500.

Moser, B. R., Seliskar, D. M. and Gallagher, J. L. (2016). Fatty acid composition of fourteen seashore mallow (Kosteletzkyapentacarpos) seed oil accessions collected from the Atlantic and Gulfcoasts of the United States. *Industrial Crops and Products*. 80: 20-26.

Murray, R., Botham, K. M., Kennelly, P. J. and Harper's. (2012). Illustrated Biochemistry, McGraw-Hill Education. Toronto, Canada. 29th edition.

Neuza, J., Bertanha, B. J., Moreno, L. y Debora, M. (2011). Actividad antioxidante y perfil de acidos grasos de las semillas de jabuticaba (*Myrciaria cualiforia* BERG). *Acta biologica colombiana. 16*(2): 75-82.

Nikolova-Damyanova, B. (2010). Fatty acids: silver ion TLC. in Encyclopedia of Chromatography. J. Cazes, Ed. 846–848. Taylor and Francis, New York, NY, USA. 3rd edition.

NMX-F-490-1987. Alimentos para humanos. Determinación de la composición de ácidos grasos a partir de c6 por cromatografía de gases en aceites y grasas. Foods for humans. Oils and fats. Determination of fat acids composition from c6 by gases chromatograpy. Normas mexicanas. Dirección general de normas.

Ozyilkan, O., Colak, D., Akcali, Z. and Basturk, B. (2005). Olive: fruit of peace against cáncer. *Asian Pacific Journal of Cancer Prevention. 6*(1): 77–82.

Platt, R. (2000). Current concepts in optimum nutrition for cardiovascular disease. *Prevention Cardiology*. 3: 83-87.

Rao, M. S., Hidajat, K. and Ching, C. B. (1995). Reversed-phase HPLC: the separationmethod for the characterization and purification of long chain polyunsaturated fatty acids-a review. *Journal of Chromatographic Science. 33*(1): 9–21.

Rezanka, T. and Votruba, J. (2002). Chromatography of very long-chain fatty acids from animal and plant kingdoms. *Analytica Chimica Acta. 465*(1): 273–297.

Robertfroid, M. (2002). Global view on functional foods: European perspectives. *British Journal Nutrition.* 88: S133-8.

Ron, M. (1986). Lípidos marinos y arterioesclerosis. *Medicina interna. 2*(4): 221-225.

Ruggiero, C., Lattanzio, F., Lauretani, F., Gasperini, B., Andres-Lacueva, C. and Cherubini, A. (2009). Ω-3 polyunsaturated fatty acids and immune-mediated diseases: Inflammatory bowel disease and rheumatoid arthritis. *Current Pharmaceutical Design. 15*(36): 4135-4148.

Salvador, A. A., Podesta, R., Block, J. M. and Ferreira, S.R.S. (2016). Increasing the value of pecan nut [Carya illinoinensis (Wangenh) C.Koch] cake by means of oil extraction and antioxidant activityevaluation. *Journal of Supercritical Fluids*. 116: 215-222.

San-Shan, L., Ru-Yu, Y., Li-Guang, Ch., Liang-Sheng, W., Xiang-Hong, H., Li-Jing, W., Xu-Chen, Z. and Hui, D. (2015). Systematic qualitative and quantitative assessment of fatty acids in the seeds of 60 tree peony (Paeonia section Moutan DC.) cultivars by GC–MS. *Food Chemistry*. 173: 133-140.

Sayre, J. K. (2001). Ancient Herb and Modern Herbs: A comprehensive reference guide to medicinal herbs, human ailments, and possible herbal remedies. Bottlebrush Press, Auburn, Washington, USA. 156 p.

Seppanen-Laakso, T., Laakso, I. and Hiltunen, R. (2002). Analysis of fatty acids by gas chromatography, and its relevance to research on health and nutrition. *Analytica Chimica Acta. 465*(1-2): 39–62.

Serra, L. y Aranceta, J. (2006). Nutrición y salud pública: métodos, bases científicas y aplicaciones. 2 ed. Bacerlona, Masson. 826 p.

Sies, H., Stahl, W. and Sevanian, A. (2005). Nutritional, dietary and postprandial oxidative stress. *Journal Nutrition*. 135: 969-972.

Simopoulos, A. P. (2008). The importance of the omega-6/omega-3 fatty acid ratio in cardiovascular disease and other chronic diseases. *Exp Biol Med*. 233:674–688.

Stuart, L. J. and Buist, P. H. (2004). The absolute configuration of methyl dihydrosterculate: an unusual phyto fatty acid isolated from these ed oil of *Litchi chinensis*. *Tetrahedron: Asymmetry*. 15: 401–403.

Sun, J., Jiang, Y., Shi, J., Wei, X., Xue, S.J., Shi, J. and Yi, C. (2010). Antioxidant activities and contents of polyphenoloxidase substrates from pericarp tissues of litchi fruit. *Food Chemistry*.119: 753–757.

Tan, H., Xiang, X., Tang, J. and Wang, X. (2016). Nutritional functions of the funiculus in *Brassica napus* seed maturation revealed by transcriptome and dynamic metabolite profile analyses. *Plant Molecular Biology*. 92: 539-553.

Touchstone, J. C. (1995). Thin-layer chromatographic procedures for lipid separation. *Journal of Chromatography B: Biomedical Applications. 671*(1-2): 169–195.

U. S. Department of Agriculture, Agricultural Research Service. (2012). USDA National Nutrient Database for Standard Reference, Release 25. Nutrient Data Laboratory. Home Page: ɑhttp://www.ars.usda.gov/ba/bhnrc/ndlɑ

Uauy, R. and Dangour, A. D. (2006). Nutrition and brain development and aging: role of essential fatty acids. *Nutrition Review*. 64: 24-33.

Vieira, B. M., Elicker, C., Nunes, C. F. P., Bairros, A. V., Becker, E. M., Müller, O. D., Piva, E., Fontoura, L. A. M. and Pereira, C. M. P. (2016). The synthesis and characterization of *Butia capitata* seed oil as a FAME feedstock. *Fuel*. 184: 533-535.

Voet, D. and Voet, J. G. Biochemistry, John Wiley and Sons. (2010). New York, USA. 4th edition.

Wall, M. (2006). Ascorbic acid and mineral composition of longan (*Dimocarpus longan*), lychee (*Litchi chinensis*) and rambután (*Nephelium lappaceum*) cultivars grown in Hawaii. *Journal Food Composition Analisys*. 9: 655–663.

Wang, L., Lou, G., Ma, Z. and Liu, X. (2011). Chemical constituents with antioxidant activities from litchi (*Litchi chinensis* Sonn.) seeds. *Food Chemistry*.126:1081–1087.

Wei, B., Huang, L., Teng, J. and Jia M. (2011). Chemical compositional characterization of ten litchi cultivars. *New Technology of Agricultural Engineering* (ICAE), Zibo, Chine.

Wen, L. R., You, L. J., Yamg, W. M., Yang, J. L., Chen, F. and Yiang, Y. M. (2015). Identification of phenolics in litchi and evaluation anticancer cell proliferation activity and intracellular antioxidant activity. *Free Radical Biology and Medicine*. 84: 171-184.

Wen, L., Wu, D., Jiang, Y., Prasad, K.N., Lin, S., Jiang, G., He, J., Zhao, M., Luo, W. and Yang, B. (2014). Identification of flavonoids in litchi (*Litchi chinensis* Sonn.) leaf and evaluation of anticancer activities. *Journal Functional. Foods*. 6: 555–563.

Wiart, C. (2006). Medicinal plants of Asia and the Pacific. CRC Press Taylor and Francis Group, USA. 171 p.

Xu, X., Xie, H., Wang, Y. and Wei, X. (2010). A-Type Proanthocyanidins from Lychee seeds and their antioxidant and antiviral activities. *Journal Agriculture. Food Chemistry*. 58: 11667-11672.

Xu, X., Xie, H., Xu, L. and Wei, X. (2011). A novel cyclopropyl containing fatty acid glucoside from the seeds of *Litchi chinensis*. *Fitoterapia*. 82: 485–488.

Yamini, Y., Khajeh, M., Ghasemi, E., Mirza, M. and Javidnia, K. (2008). Comparison of essential oil composition of *Salvia mirzayanii* obtained by supercritial carbon dioxide extraction hydrodistilation methods. *Food Chemistry*. 108: 341-346.

Yang, B., Nagendra, P. K. and Jiang, Y. (2016). Structure identification of a polysaccharide purified from litchi (*Litchi chinensis* Sonn.) pulp. *Carbohydrate Polymers*. 137: 570-575.

Zhang, R., Zeng, Q., Deng, Y., Zhang, M., Wei, Z., Zhang, Y. and Tang, X. (2013). Phenolic profiles and antioxidant activity of litchi pulp of different cultivars cultivated in Southern China. *Food Chemistry*.136:1169–1176.

Zhang, Z., He, C., Zhu, R., Shen, J., Yu, Y., Peng, Q., Gao, J., Li, Y. and Wang, M. (2016). Seeds oils of five black tartary buckwheat cultivars with biochemical characterization and antioxidant properties. *Journal American Oil Chemistry Society*. 93: 1127-1136.

Zhao, M., Yang, B., Wang, J., Liu, Y., Yu, L. and Jiang, Y. (2007). Immuno modulatory and anticancer activities of flavonoids extracted from litchi (*Litchi chinensis* Sonn.) pericarp. *International Immunopharmacology*. 7: 162–166.

Zhou, B., Chen H., Huang, X., Li, N., Hu, Z., Gao, Z. and Lu, Y. (2008). Rudimentary leaf abortion with the development of panicle in litchi: changes in ultraestructure, antioxidant enzymes and phytohormones. *Scientia Horticulturae* 117:288-292