International Journal of Agricultural and Life Sciences

ISSN: 2454-6127(Online) Journal homepage: http://www.skyfox.co

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To cite this article : Pelle Morten Poulsen (2022). A Detailed Review of *Mangifera indica* (Mango): Secondary Metabolites and Important Functional Properties. Int J Agric Life Sci, 8(1), 358-365. doi: 10.22573/spg.ijals.022.s122000108.

To link to this article : https://doi.org/10.22573/spg.ijals.022.s122000108

Data Availability Statement : All relevant data are within the paper and its Supporting Information files.

Funding : The author(s) received no specific funding for this work.

Competing Interests : The authors have declared that no competing interests exist.

Published online: 31 March 2022.

International Journal of Agricultural and Life Sciences- IJALS (2022), Volume 8 (1) pp.358-365
http://dx.doi.org/10.22573/spg.ijals.022.s122000108
Available online at http://www.skyfox.co
ISSN: 2454-6127

REVIEW ARTICLE

A Detailed Review of *Mangifera indica* (Mango): Secondary Metabolites and Important Functional Properties

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Received: 28 Dec 2021/ Revised: 10 Jan 2022/ Accepted: 13 Feb 2022/ Published: 31 March 2022

Abstract: Mango is a fruit with nutritive assets and also with known therapeutic uses. This fruit is widely grown in tropical and subtropical countries as a source of food and income for people. As a seasonal fruit of Mango, about 21% of pulps are processed. Pulp Mango processing produces approximately 15,000,000 tons of bio-waste per year in the world. Currently, this byproduct management generates high costs and are a source of environmental contamination. However, the chemical composition of mango seeds could probable their use as a supportable source of high added value phytochemicals. Bioactive secondary metabolites in mango contain phenolic compounds, such as ellagic acid, pentagalloylglucose, gallic acid, methyl gallate and rhamnetin. These compounds have a particular interest in their pharmacologic and biological activities. Additionally, new research should be geared to evaluate activities of models that have not yet been evaluated. Therefore, in this work, we review the whole mango bioactive phytochemicals, looking in detail at their reported functional and biological activities, potential applications, and the technological aspects.
Keywords: *Mangifera indica L,*.Mango, Phenolic compounds, Antioxidant

INTRODUCTION

The mango is one crucial fruit, cultivated in several tropical and subtropical regions, enjoys the status of "the king of fruits" as a result of its unique flavor, fragrance, and nutritional value (Singh et al., 2013). The mango belongs to the genus Mangifera and has 69 recognized species (Mukherjee & Litz, 2009) in the Anacardiaceae family (Bompard, 2009). Although in specific parts of the world, various species of Mangifera are cultivated as Mangifera foetida (Horse mango) in Asia or Mangzora caesia (Ataulfo mango) in Mexico, Mangifera indica is the species commonly cultivated in the world. Mangoes have great nutritional importance in developed countries in Asia, Africa, and America. Mango pulp contains fiber, amino acids, carbohydrates, fatty acids, minerals, organic acids, protein, vitamins and polyphenolics (Singh et al., 2013). Mango is native to South Asia, wherefrom it has spread worldwide to become one of the most cultivated fruits (Fasoli & Righetti, 2013). Mango is grown over 5,500,000 ha in 94 countries, worldwide annual production of mango is estimated at 50,000,000 tonnes. India ranks first in mango production, followed by China, Thailand, Indonesia, Mexico, Pakistan and Brazil (FAOSTAT, 2017).

Approximately, 20 % of mango fruits are processed for products such as puree, nectar, leather, pickles, minimally processed, canned slices, and chutney (Ajila et al., 2007; Dussan et al., 2014; Ravani & Joshi, 2013), this generates high amounts of waste since 35 to 60% of the fruit is discarded after processing (Torres-Leon et al., 2016). For instance, there are about 300,000 tonnes of dry mango seed kernels available annually in India after consumption or industrial processing of mango fruits (Soong & Barlow, 2004). The seed is not currently utilized; it is discarded as waste and becoming a source of pollution. Additionally, millions of dollars are spent to dispose of mango waste in India; the average transportation cost was found to be $15 per tonne per trip (FICCI, 2010), which may indicate > $20 million for the total landfilling cost. However, ethnobotanical studies indicated that the plant of mango is widely used in traditional medicine to cure vomiting, dysentery and burning (Derese & Kuete, 2017; Rajan et al., 2012), and the mango seed could be used as a source of natural compounds with high added value.

The agro-industrial by-products have been recently posed as a source of active compounds (O'Shea, Arendt, & Gallagher, 2012), the parts discarded in the processing of fruits have more exceptional functional properties than the pulp or the finished product (Ayala et al., 2011). Therefore, the use of by-products as mango seed can have some important applications in the food industry and human health (Torres-Leon et al., 2018b). Interesting biological properties such as antioxidant, antimicrobial and anticancer activity have been reported in agro-industrial waste (Sema-Cock et al., 2016). Currently, there is a concern for the search for new natural sources of antioxidants (Sindhi et al., 2013), antimicrobial agents and anti-cancer agents. Al respect, in the year 2008, the ethanol extract of mango seed was listed as one of the four food extracts with the highest biological power, compared with 1-ascorbic acid (Saito et al., 2008). These biological activities can be attributed to the bioactive compounds naturally present in mango seed. Therefore, in this paper, we analyse and discuss several aspects related to the potential of mango seed as a source of bioactive phytochemicals, looking in detail at their reported functional and biological activities, potential applications and the technological aspects.

MANGO SEED

Mango fruit is a deliquescent drupe with a seed surrounded by a fleshy mesocarp (pulp) covered by an exocarp (peel) (Singh et al., 2013). the mango seed is composed of an endocarp and testa (MSET) that is thick and hard and encloses a kernel (MSK). Depending on the variety, the seed represents 10-25% of the total weight of the fruit, MSET and MSK represent approximately between 15-55% and 45-85% of the seed, respectively. Most of the research papers reported in the scientific literature regarding the extraction of active compounds have been developed in MSK. However, recent HPLC-MS studies have also reported the presence of interesting phenolic compounds in MSTE (Gomez-Caravaca et al., 2016). To facilitate the terminology, MSET and MSK will be named as mango seed in this document, with the excuse of the work of Gomez et al., (2016).

International Journal of Agricultural and Life Sciences- IJALS (2022), Volume 8 (1) pp.358-365
http://dx.doi.org/10.22573/spg.ijals.022.s122000108
Available online at http://www.skyfox.co
ISSN: 2454-6127

VALORIZATION OF MANGO SEEDS

The use of agro-industrial by-products and food wastes to obtain bioactive compounds depends on different aspects such as the type of biological waste, the compounds, and their nature. However, a general strategy should include a drying pre-treatment to guarantee the microbiological and biochemical stability of the material, the separation of the compounds of the biological matrix with extraction processes, the measurement using spectrophotometric techniques (content of compounds and biological activities), and finally the identification the profile of compounds by HPLC-MS (Figure 2.2).In this chapter of the book, the drying and separation will be discussed in Section 2.6 (technological aspects). hr Section 2.3, we will present the reported results of total phenol content (Spectrophotometric analysis) and then the mass spectrometry (MS) results.

PHYTOCHEMICAL IN MANGO SEED

The Polyphenol

Mango seed contains an assortment of phytochemicals in varying concentrations, usually determined by genotypic, environmental factors, and the interaction of both factors (Dorta et al., 2014). The content of total phenols has been investigated in diversity mango varieties in countries such as Thailand, Nigeria, India, Egypt, EEUU, Brazil and Mexico., the mango seed has a high total phenolic content ranging from 21.9 to 598 mg g-1 dry weight. Variations in chemical composition may be due to country origins, varieties used, culture conditions, drying method and extraction conditions (Figure 2.2) (Wang & Zhu, 2017). The way in which phenolic compounds are found in the biological matrix also has a great influ¬ence (in the separation operation). Phenolic compounds in mango seed may exist infree, conjugated, or bound forms. The free compounds are linked to sugars (glucose) and the bound phenols are bound to other constituents of the cell-matrix such as proteins, hemicellulose, cellulose, and lignin, so their separation is not as simple as in the case of free phenols.

The use of high performance liquid chromatography (HPLC) and gas chromatography (GC) coupled to mass spectrometry (MS) has allowed identifying phytochemical compounds in mango seed. 20 compounds were identified for Dorta et al. (2014), from the mango seed using HPLC-ESIQTOF-MS (Table 2.2). Berardini et al. (2004) reported a total of 21 phytochemicals in mango seed (Tommy Atkins) using high-performance liquid chromatography/elec- trospray ionization mass spectrometry (ESI-HPLC/MS). Gomez-Caravaca et al. (2016), analyzed the free and bound phenols in Keitt mango seed, using HPLC-DAD-q-TOF-MS. The authors also analyzed separately and MSET; forty-three free phenolic compounds and eight bound phenolic compounds were identified in mango MSK, and thirty-seven free polar compounds and nine bound compounds were identified in mango MSET. Finally, twelve phytochemicals were identified in the Waterlily mango seed using Gas chromatography-mass spectrometry (GC-MS) (Abdullah et al., 2014). Dorta et al. (2014), reported that the identified compounds belong to 5 families: gallates and gallotannins; flavonoids (mainly quercetin derivatives); ellagic acid and derivatives; xanthones (principally mangiferin); and in six mango cultivars of Brazil was penta-O-galloylglucoside (PGG). In general, mango seed polyphenols primarily consist of phenolic acids, tannins (gallotannins and ellagitannins), flavonoids, xanthones.

PHENOLIC ACIDS

Hydroxybenzoic and hydroxycinnamic acids are the two main types of phenolic acids in mango seed. Gallic acid (GA) is a hydroxybenzoic acid that possesses various functional properties (antioxidant, anti-inflammatory, antibiotic, anticancer, antiviral and cardiovascular protection) (Govea-Salas et al., 2016). In plants, gallic acid occurs in free form or the form of esters (e.g., pentagalloylglucose) (Figure 2.3). Ellagic acid is a hydroxycinnamic acid with beneficial characteristics in the human and animal physiology and health (anti- mutagenic, antimicrobial and antioxidant properties, and inhibitors of human immunodeficiency virus). This compound has generated commercial interest in recent years due to its properties, applications, and benefits to human health (Sepulveda et al., 2011). Gomez-Caravaca et al. (2016), reported that ellagic acid was the most abundant bound compound in the mango seed from Spain (650 mg 100 g^{-1}). Soong and Barlow (2006), reported that mango seeds from Singapore are a potential source of Gallic acid and ellagic acid.

TANNINS

Tannins are secondary metabolites in plants and food and are generally classified into four groups: gallotannins, ellagitannins, condensed tannins and complex tannins (Ascacio et al., 2011). Gallotannis are the dominant group of phytochemical compounds in mango seed (Barreto et al., 2008; Berardini et al., 2004; Dorta et al., 2014). Berardini et al. (2004) report that mango kernels contained 15.5 mg g^{-1} of gallotanins and thus proved to be a rich source of gallotannins. The main gallotannin reported in the mango seed was penta-O-galloylglucoside (PGG) (Barreto et al., 2008; Berardini et al., 2004; Dorta et al., 2014; Torres-Leon et al., 2017a).

FLAVONOIDS

Flavonoids are low molecular weight compounds, consisting of fifteen carbon atoms, arranged in a C6-C3-C6 configuration. Flavonoids have two aromatic rings A and B,joined by a heterocyclic ring, C (Balasundram et al., 2006). The antioxidant, anti-inflammatory and anticancer capacities of these compounds are well documented(Chen & Charlie, 2013). Commercial applications of flavonoids include food additives, nutraceuticals, pharmaceuticals, and cosmetics. The global market for flavonoids was valued at over 840 million USD in 2015 and is expected to surpass 1 trillion USD beyond 2020 (Ng et al., 2019). In the mango seed has been reported the presence of flavonoids as Quercetin and Rhamnetin. Quercetin (3,30,40, 5,7-pentahydroxyflavone), is a flavonoid that has attracted significant interest because it is a potent antioxidant with proven anticancer effects (Moskaug et al., 2004) and Rhamnetin ((2-(3,4-dihydroxyfenyl)-3,5-dihydroxy-7-methoxychromen-4-one)) has also important antioxidative, antihepatotoxic, anti-carcinogenic, antiviral and antiinflammatory properties (Ramesova et al., 2017). Dorta et al. (2014) reported that rhamnetin derivative was the principal compound in Gomera 3 seeds.

XANTHONES

Xanthones are heterocyclic compounds with a yellow coloration and all of them have dibenzo-*y*-pyrone as the basic skeleton (Diderot et al., 2006). Mangiferin is the main Xanthona present in the mango seed (Dorta et al., 2014). Mangiferin (l,3,6,7-Tetrahydroxy-2-[3,4,5-trihydroxy-6-(hydroxymethyl) oxan-2-yl] xanthen-9-one) is a polyphenolxanthone with strong antioxidant activity; it has demonstrated effects against Alzheimer's disease (Sethiya et al., 2014).

FUNCTIONAL PROPERTIES AND HEALTH BENEFITS

ANTIOXIDANT

An antioxidant is any substance that, at low concentration, delays the oxidation of DNA, proteins, carbohydrates or lipids (Sindhi et al., 2013). Research in antioxidants has intensified in recent years since these compounds can reduce free radicals and prevent oxidative stress and their deleterious effects on the human body and health. Free radicals are molecules containing one or more unpaired electrons (Poprac et al., 2017). The adverse health effects reported in synthetic antioxidants used in food have also motivated the search for natural antioxidants. The habits of healthy consumption and the good approval of natural compounds in the diet have increased the search for new natural antioxidants.

Mango seed extracts have been classified with high biological activity (Saito et al., 2008), which has enhanced the determination of antioxidant activity in various varieties of mango in the world. As shown in Table 2.1, the mango seed has a high antioxidant potential (expressed in DPPH radical scavenging

International Journal of Agricultural and Life Sciences- IJALS (2022), Volume 8 (1) pp.358-365
http://dx.doi.org/10.22573/spg.ijals.022.s122000108
Available online at http://www.skyfox.co
ISSN: 2454-6127

activity) and IC (concentration when scavenging 50% of the DPPH free radical, lower IC value represents the higher activity) with values in the range of 94-95% and 4.1—143 pg mL'1, respectively. The DPPH assay is the most used spectrophotometric technique to express the antioxidant activity (in *vitro)* in natural extracts. The high antioxidant activity has been correlated with the presence of important phenolic compounds. Polyphenols inactivate free radicals by to the hydrogen atom transfer (HAT) and the single electron transfer (SET) mechanisms (Leopoldini et al., 2011).

ANTICANCER

Cancer is a generic term for a large group of diseases that can affect any part of the body (Torres-Leon et al., 2017a). Cancer is one of the major challenges facing human health care, in 2015 caused about 8.8 million deaths (WHO, 2017). As we discussed earlier, Phenolic compounds have pharmacological properties and promote protection against the damage of reactive oxygen species, which results in a beneficial activity against cancer (Farinetti et al., 2017). Scientific investigations *in vitro* have demonstrated good anticancer activity of mango seed in breast cancer, liver cancer and leukemia cancer cell lines (Table 2.3). It is most likely that the cytotoxic effects of the mango extract on breast cancer cells are due to the action of the polyphenolic compounds present in the extracts. The phenolic compounds found in the extract have been reported to have anticancer activity (Torres-Leon et al., 2017a), and these compounds can have synergistic effects (Abdullah et al., 2014). This shows that mango seed has a wide potential as a source of anticancer compounds. New investigations are necessary to evaluate bioavailability (biological availability) of antioxidants after ingestion, to identify the specific amount that can prevent carcinogenesis and act in advanced stages of cancer. Clinical evaluations are needed to identify the precise concentration and path of administration (Farinetti et al., 2017), the proven preventive factors suggest promising future applications for mango seed.

ANTIMICROBIAL

Antimicrobial resistance is a severe problem in the world. Adverse effects of available antibiotics and the constant development of bacterial resistance (against antibiotics) motivate a search for new natural antimicrobial products (Stankovic et al., 2016). The food industry also demands new antimicrobial agents. Organic acids such as malic, succinic, acetic, citric, and tartaric naturally present in fruits are used as preservative agents. However, these organic acids can be replaced by bioactive compounds of the mango seed. The antimicrobial potential is defined as the ability of a compound or extract to inhibit the growth of microorganisms of interest. Mango seed has shown high antimicrobial activity against Gram-positive and Gram-negative bacteria. Generally, the researchers have associated the antimicrobial activity with the compounds present in the mango seed; these compounds play an important role in the cell membrane of microorganisms, causing cell lysis (Asif et al., 2016). Variations in antimicrobial activity between Grampositive and Gram-negative bacteria were associated with the difference in the cell walls of the microorganisms. Mango seed has broad potential in the development of new natural antibacterial agents in food and against resistant microorganisms. New works is also needed to evaluate the effect on new resistant bacteria that are emerging with danger to public health.

OTHER POTENTIAL BIOACTIVITIES AND TOXICITY

The phytochemical constituents of mango seed (described in Section 2.2) suggest that there are other potential bioactivities. For example, PGG derived from other botanical sources showed a range of bioactivities such as antidiabetic, antiviral, anti-inflammatory and improving cognitive disorders (Torres-Leon et al., 2017a). Gallic acid (GA) possesses anti-inflammatory, anti-biotic, anti-viral and cardiovascular protection activities (Govea-Salas et al., 2016). It may be expected that the phenolic compounds of mango seed have similar bio-functions.

ANTIHEMOLYTIC

Hemolysis is the best-studied aspect of mechanically induced erythrocytes (red blood cells) damage and is defined as the release of hemoglobin into the plasma due to a mechanical compromise of the erythrocyte membrane (Fraser, 2015). Abdel-Aty et al. (2018) determined the antihemolytic activity of mango seed on crude venom, the IC_{50} and 100% inhibition of *Cerastes cerastes and'Eicus coloratus* hemolytic activity were observed at 21, 19 and 40 pg of mango seed, respectively. Mango seed did not induce hemolysis in red blood cells. The authors state that this activity can be explained by the ability of the phenolic compounds present in the seed to inhibit proteases and Phospholipase A2. This research demonstrates the antihemolytic property of mango seed.

ANTIDIABETIC

Currently, diabetes is a big problem in public health. According to the World Health Organization (WHO), about 422 million people have diabetes globally (WHO, 2016). Although insulin injection and hypoglycemic agents are effective drugs for diabetes, these compounds possess some adverse effects and have no effects on diabetes complications in the long term (Bahmani et al., 2014). A study by Irondi et al. (2016), showed that mango seed inhibits some key enzymes linked to the pathology and complications of type 2 diabetes *(in* vitro). Mango seed could, therefore, be a promising nutraceutical therapy for the management of type 2 diabetes and its associated complications.

ANTIDIARRHEAL

Diarrhea is caused by inflammation of the intestines. 526,000 deaths due to diarrhea in children younger than 5 years were estimated in 2015 (Wierzba & Muhib, 2018). Mango seed extracts significantly reduced intestinal motility and fecal score in Swiss albino mice (Rajan et al., 2012). Secondary metabolites such as polyphenolic compounds present in the seed have been implicated as having antidiarrheal activity. This study is in accordance with traditional medicine and confirms that mango seed is an effective antidiarrheal.

POTENTIAL USES

FOOD/FEED INGREDIENTS

Bioactive compounds have a wide application as a preservative in the food processing industry. The natural phenolic antioxidants inhibit oxidation reactions by itself being oxidized and also prevent the production of off-odors and tastes. Antioxidants delay the onset of oxidation and slow the reaction rate of food lipids. Mango seed retains oil stability against rancidity for up to 12 months (Abdalla et al., 2007). The mango seed can also be used to preserve the oxidative quality of meats and meat products.

Antimicrobial activity of mango seed, suggests their possible uses as antimicrobial food preservatives: 5000 ppm of mango kernel extract prevented the growth of bacteria in milk when stored at room temperature for 15 days (Abdalla et al., 2007). There are many types of food matrices to which these antioxidant compounds might be added; more studies are necessary to elucidate that substances are effective in what systems and under what condition (Brewer, 2011).

MEDICAL APPLICATION

The bioactive characteristics of the mango seed indicate that it has a wide potential in their development into new nutraceutical/pharmaceutical formulations. The bioactive compounds have applications as hepatoprotective agents, prevention, and treatments for Neurodegenerative diseases such as Alzheimer's disease, Parkinson's disease, and amylotrophic lateral sclerosis. They also have potential use in several pathological conditions associated with oxidative damage in cells such as rheumatoid, arthritis, cardiovascular disorders, ulcerogenic and acquired immunodeficiency diseases (Sindhi et al., 2013).

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http://dx.doi.org/10.22573/spg.ijals.022.s122000108
Available online at http://www.skyfox.co
ISSN: 2454-6127

FORMULATION OF ACTIVE PACKAGING

Mango seed have recently aroused the attention of the scientific community in the formulation of active edible films and coatings (Belizon et al., 2018; Klangmuang & Sothomvit, 2018; Maryam et al., 2018; Maryam Adilah & Nur Hanani, 2019; Nawab et al., 2018; Nawab, Alam, & Hasnain, 2017; Torres-Leon et al., 2018a). The incorporation of mango seed extracts increases the antioxidant and antimicrobial potential of the formulations. Also, the extracts improve the technological properties of edible films and coatings, this effect is attributed to the properties that polyphenols have to interact with constituents of formulations (such as proteins and polysaccharides) and the surface of fruits, respectively (Torres-Leon et al., 2018a).

TECHNOLOGICAL ASPECTS

In the processing of agro-industrial by-products such as mango seed, the drying and extraction methods are essential unit operations that affect the activity and stability of phenolic compounds. The drying treatment may cause an enhancement of the extractability of different compounds. Freeze-drying and oven-drying with forced air led to an increase (1.6 times) in anthocyanin content compared to non-dried peel (Dorta, Lobo, & Gonzalez, 2012). Conventional drying methods rely on conductive and convective heat transfer methods, which are highly energy demanding, lead to losses the bioactive compounds (Tontul & Topuz, 2017). However, other drying techniques more efficient and reliable such as explosion puff drying (Zuo et al., 2017), combined microwave vacuum drying, infrared drying, ultrasound freeze-drying and refracting window (Kaur et al., 2017; Ochoa et al., 2012; Zotarelli, Carciofi, & Laurindo, 2015), have been proposed for the drying of mango pulp. It is important to note that these techniques have not been tested in mango seed.

In the extraction of bioactive compounds from residues of mango the drying technique, and the temperature influences to a greater extent the extraction performance, while the drying time is a less relevant factor. Sogi et al. (2013), dried mango peel and seed (Tommy Atkins variety), using different techniques (freeze-drying, hot air, vacuum and infrared). The best results were found with freeze-drying. Ekorong et al. (2015), combined the effect of drying temperature and time on total phenolic compounds and antioxidant activity of mango seed; the increase of drying temperature increased antioxidant activity while total phenolic components decreased. On the other hand, conventional extraction techniques (soxhlet extraction, maceration, and hydrodistillation) are being used to extract bioactive components from the mango byproducts. The extraction efficiency depends on the choice of solvents. In this sense, Dorta et al. (2012), evaluate the effect of solvent (methanol, ethanol, acetone, water, methanol: water, ethanol: water, and acetone: water) on the efficiency of the extraction of antioxidants from mango peel and seed. The solvents that best obtained extracts with high antioxidant capacity were methanol, methanol: water, ethanol: water, and acetone:water. Although the highest content of phytochemicals was obtained with acetone, from food security (good manufacturing practices), the authors recommend using ethanol/water.

However, conventional extraction presents a series of disadvantages such as high working times, high costs, and damage to active compounds. To overcome these limitations, non-conventional extraction techniques are used (Gil-Chavez et al., 2013; Selvamuthukumaran & Shi, 2017). Some of the most promising extraction non-conventional techniques are supercritical fluid extraction (SFE), enzyme-assisted extraction (EAE), microwave-assisted extraction (MAE), ultrasound-assisted extraction (UAE), pressurized low polarity water extraction, pulsed electric field (PEF) extraction, pressurized liquid extraction (PLE), and molecular distillation. Some of these techniques comply with standards set by the Environmental Protection Agency (2015), which is why they are called green extraction techniques (Selvamuthukumaran & Shi, 2017).

Yoswathana & Eshiaghi (2013) to optimized conditions for extracts yield and total phenolic content extraction from mango seed kernel using SFE and conventional techniques such as maceration and soxhlet. The authors reported a total phenol content of 40.4 mg of tannic acid equivalent per gram of seed (six times of that from conventional techniques). SFE has also been used to obtain premium-grade cocoa butter from the waste of mango using supercritical carbon dioxide and the Soxhlet method like comparison. The total fat contents of a waste of mango varieties ranged from 64 to 135 g kg^{-1} using supercritical CO_2 extraction and from 76 to 137 g kg^{-1} using Soxhlet extraction methods (Jahurul et al., 2014). EAE has very good results in the release of phenolic compounds.

Nevertheless, the use of enzymes is limited by instability and high associated costs (Navarro-Gonzalez et al., 2011). Alternative technologies such as solid-state fermentation (SSF) have been proposed for the valorization of agro-industrial waste and byproducts (Martinez et al., 2012). In the SSF, microorganisms such as fungi naturally produce enzymes that degrade the cell wall (Jamal et al., 2011), generating hydrolysis (Jamal et al.., 2011) and mobilization of compounds towards the extraction solvent. Recently, our research group (bio-uadec.com) evaluate the effect of SSF with the fungus *Aspergillus niger* GH1 in the content of phenolic compounds and the antioxidant activity of Mexican mango seed. The results showed that SSF of mango seed increased the polyphenol content in the extracts by 235%. Analysis of the free and bound fractions showed that SSF to release the bound phenols to the plant matrix, also increasing the antioxidant potential of the extracts (Torres-Leon et al., 2019).

Concerning MAE, our research group (bio-uadec.com) also optimized the extraction conditions of phenolic extracts of mango seed with high antioxidant activity using microwave technology (Torres-Leon et al., 2017b). MAE significantly increased the antioxidant activity of the extracts compared to the control. Under optimal conditions, high values of antioxidant activity (1738.2 mgTroloxg', IC50 of 0.07 mg g-') and phenolic compounds (598.4 ± 25.80 mg AG g *) were obtained. Results superior to those reported m mango seed of other varieties and commercial antioxidants such as Trolox, Vitamin E, and BHT. The results demonstrate that MAE can be recommended as an effective non-conventional technology for the extraction of active compounds from the mango seed.

The techniques of drying and extraction are highly relevant to preserve the active compounds present in mango byproduct. Non-conventional technologies of extraction have advantages such as higher extraction yield, greater antioxidant activity, less processing time. In the same way, drying treatments influence the extraction performance of bioactive mango compounds. Methods such as explosion puff drying, refracting window, and heat pump have not been investigated in the drying of bioactive compounds, and these technologies could be a research focus. Also, the Incorporation and development ofhybrid methods should be investigated.

CONCLUSION

Mango seed is a source of important phytochemicals. Mainly, polyphenolic compounds (gallotannins) such as PGG and its derivatives, it is also rich in phenolic acids such as gallic acid and ellagic and flavonoids as rhamnetin derivatives. The presence of these phytochemicals could be responsible for a range of bioactivities of mango seed as revealed by *in vitro* chemical and biological assays. Mango seed has been reported to possess antioxidative, antimicrobial, anticancer, antihemolytic, antidiabetic and antidiarrheal properties. Research should continue to identify the profiles of the phytochemicals and the functional potential available from different seed varieties grown in the world, the effect of the extraction method on profiles of phenolic compounds and biological activities should be evaluated. New research projects are interested in the evaluation of the application. Mango seed extracts have potential as natural preservatives (antioxidant or antimicrobial) in foods. Studies of bioavailability of phenolic compounds in the body and the nutritional and sensory effects of

International Journal of Agricultural and Life Sciences- IJALS (2022), Volume 8 (1) pp.358-365
http://dx.doi.org/10.22573/spg.ijals.022.s122000108
Available online at http://www.skyfox.co
ISSN: 2454-6127

incorporating mango seed extracts in foodstuffs are necessary. The use of mango seed can bring important social, nutritional, environmental and economic benefits.

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http://dx.doi.org/10.22573/spg.ijals.022.s122000108
Available online at http://www.skyfox.co
ISSN: 2454-6127

How to cite this article
Pelle Morten Poulsen (2022). A Detailed Review of *Mangifera indica* (Mango): Secondary Metabolites and Important Functional Properties. Int J Agric Life Sci, 8(1), 358-365. doi: 10.22573/spg.ijals.022.s122000108.

CONFLICTS OF INTEREST

"The authors declare no conflict of interest".