Trends in Food Science & Technology 55 (2016) 109–117

Contents lists available at ScienceDirect

Trends in Food Science & Technology

journal homepage: http://www.journals.elsevier.com/trends-in-food-science-and-technology

Review

Mango seed: Functional and nutritional properties

Cristian Torres-León [a], Romeo Rojas [b], Juan C. Contreras-Esquivel [a], Liliana Serna-Cock [c], Ruth E. Belmares-Cerda [a], Cristóbal N. Aguilar [a, *]

[a] *Food Research Department, School of Chemistry, Universidad Autónoma de Coahuila, Saltillo, Mexico*
[b] *Universidad Autónoma de Nuevo León, School of Agronomy, Research Center and Development for Food Industries – CIDIA, 66050, General Escobedo, N.L., Mexico*
[c] *School of Engineering and Administration, Universidad Nacional de Colombia, Palmira, Valle del Cauca, Colombia*

ARTICLE INFO

Article history:
Received 19 May 2015
Received in revised form
27 February 2016
Accepted 13 June 2016
Available online 16 June 2016

Keywords:
Byproducts
Natural additive
Biowaste
Mangifera indica L.
Antioxidants

ABSTRACT

Background: The mango (*Mangifera indica* L.) is an important tropical fruit with worldwide acceptance, extensive marketing, vast production, wide distribution, and benefits to human health. Mango wastes, such as the seed kernel and peel, have high functional and nutritional potential.
Scope and approach: In this paper, we describe the composition of the mango seed kernel, which is analysed from a critical point of view regarding the proper use of this waste product and the possibility of monetizing it for nutritional and environmental purposes. The nucleus contains important bioactive compounds that have high antioxidant activity, lipids that have acceptable physical and chemical characteristics (free of trans fatty acids), and a high protein content.
Key findings and conclusions: Food powders (prepared with a reduction of antinutritional factors) can be obtained from seeds, and these powders can include premium-grade fats or extracts with high functional power. Research should continue to identify the profiles of the phytochemicals available from different seed varieties, their bioavailability, and their health effects. Outreach strategies with the business sector should also be implemented to valorize the nutritional and functional potential of the seed kernel of the mango.

1. Introduction

The mango (*Mangifera indica* L.) is one of the most important tropical fruits in the world, thanks to its pleasant taste and aroma and high nutritional value (Ibarra, Ramos, Hernández, & Jacobo, 2015). It is rich in water, sugars, fibre, minerals, vitamins, and antioxidants (Tharanathan, Yashoda, & Prabha, 2006). Based on its chemical composition, it is regarded as the king of fruits, a distinction that makes it the second most traded tropical fruit in the world and fifth in total production (FAOSTAD, 2015). The world production of mango is estimated at 42 million tons per year; India is the largest producer of mango with 1,525,000 tons per year, followed by China, Kenya, Thailand, Indonesia, Pakistan, and Mexico. Mexico is the largest exporter with 287,771 tons per year (FAOSTAD, 2015).

Mango pulp can be consumed at ripeness or in immaturity, although most of the fruit is eaten fresh, and a wide range of foods can be prepared with the pulp (Sonia Ribeiro & Schieber, 2010). It can be canned, frozen as concentrates, mashed, dehydrated, minimally processed, or prepared as juices and jams (Masibo & He, 2009). It is estimated that 35–60% of the fruit is discarded as waste after processing (O'Shea, Arendt, & Gallagher, 2012); in the particular case of the seed, more than one million tons of mango seeds are annually produced as wastes, and these are not currently utilized for any commercial purposes (Leanpolchareanchai, Padois, Falson, Bavovada, & Pithayanukul, 2014).

The mango seed has aroused special scientific interest because it has been reported as a biowaste with high content of bioactive compounds (phenolic compounds, carotenoids, vitamin C, and dietary fibre) that improve human health (Jahurul et al., 2015). It is a good source of carbohydrates (58–80%) and protein (6–13%) and has an attractive profile of essential amino acids and lipids (6–16%); it is rich in oleic and stearic acids (Siaka, 2014). It has been reported to have anticancer activity against breast and colon cancer (Kathleen, 2010) and antimicrobial activity against Gram positive and Gram negative bacteria (Khammuang & Sarnthima, 2011),

* Corresponding author.
E-mail address: cristobal.aguilar@uadec.edu.mx (C.N. Aguilar).

http://dx.doi.org/10.1016/j.tifs.2016.06.009
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which is attributed to its high antioxidant capacity. An antidiarrheal effect has been reported and attributed to its high tannin content (Rajan, Suganya, Thirunalasundari, & Jeeva, 2012). Additionally, the physicochemical characteristics of mango seed fat are very similar to those of commercial cocoa butter (Jahurul et al., 2015).

Although the rational use of mango seed as an ingredient in balanced animal feed is well documented (Fontes et al., 2008; Odunsi, 2005), most of this byproduct is considered waste and becomes a source of environmental pollution (Ajila, Bhat, & Rao, 2007). The proper use of mango seed as raw material or a food additive could generate economic gains for industry, contributing to a reduction of nutritional deficiencies, promoting health, and reducing the environmental implications of this generated waste. At present, innovations seek to allow zero waste; residues generated would be used as raw materials for new products and applications (Da Silva & Jorge, 2014). In the case of the seed, it currently lacks the possibility to generate value. In this context, the main goal of this review article is to present an overview of the nutritional and functional potential of the mango seed kernel and alternative proposals for its use as an ingredient or additive in the food industry.

2. Mango seed

The mango fruit is classified as a deliquescent drupe; it contains a single seed surrounded by a fleshy mesocarp covered by a fibrous skin (Singh, Singh, Sane, & Nath, 2013). As shown in Fig. 1, the seed is composed of a woody outer shell (endocarp) that is thick and hard and encloses a kernel (seed proper) (Masibo & He, 2009). The mango seed can be monoembryonic (produce a seedling) or polyembryonic (produce various plants); most of the varieties in India are monoembryonic, whereas the polyembryonic varieties are abundant in Myanmar, Thailand, Indonesia, and the Philippines (Tharanathan et al., 2006). Depending on the variety, the seed represents 10–25% of the total weight of the fruit, and the kernel represents 45–85% of the seed, or approximately 20% of whole fruit (Arogba, 1997; Solís & Durán, 2011).

3. Valuation of mango seed

There is growing concern worldwide about the high number of byproducts created by the food industry, primarily including bagasse, peels, and seeds. In the majority of cases, byproducts represent greater mass (Ayala et al., 2011) and contain more active compounds than pulp or the end products (Morais et al., 2014). To fully utilize their biological potential, wastes with high nutritional content and functional value such as the mango seed can be used in the human diet (Da Silva & Jorge, 2014). To convey the full potential of this seed, the nutraceutical bioactive compounds (antioxidants) are presented separately from the nutritional compounds (proteins, carbohydrates, fats, vitamins, and minerals).

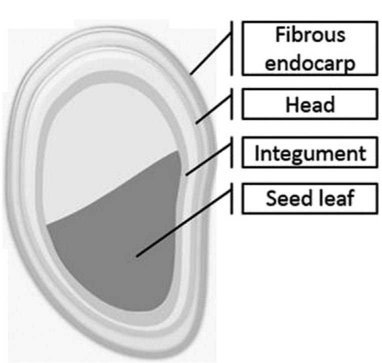

Fig. 1. Internal and external structure of Mango seed.

3.1. Bioactive or nutraceutical compounds

The bioactive compounds are natural constituents of foods that provide health benefits (Biesalski et al., 2009). In recent years the bioactive compounds present in fruits, especially antioxidant compounds, have aroused particular interest in the scientific community and from consumers (Opie & Lecour, 2007) due to beneficial effects against diseases such as cancer. At present, almost all processed foods have synthetic antioxidants originating from the oil industry such as butylated hydroxytoluene (BHT) and butylated hydroxyanisole (BHA) (Carocho & Ferreira, 2013). Harmful health effects have been reported due to the consumption of synthetic antioxidants (Lorenzo, González, Sánchez, Amado, & Franco, 2013; Sarafian, Kouyoumjian, Tashkin, & Roth, 2002), which can be avoided by their substitution with natural antioxidants such as those present in mango seed. The presence of phenolic compounds (mangiferin, isomangiferin, homomangiferin, quercetin, kaempferol, anthocyanins), phenolic acids (gallic, protocatechuic, ferulic, caffeic, coumaric, ellagic, 4-caffeoylquinic acids), and mineral antioxidants (potassium, copper, zinc, manganese, iron, selenium) is reported in mango seed (Ribeiro & Schieber, 2010).

3.2. Antioxidant compounds

The human body produces reactive oxygen species (ROS) by many enzymatic systems in conjunction with oxygen consumption (Dina, Nassima, Meriem, & Karima, 2009). In small amounts, ROS can have beneficial effects, but in large amounts, they are associated with aging, cancer, and cardiovascular and neurodegenerative diseases (Bagchi et al., 2000). For this reason, the body constantly requires exogenous antioxidants that balance the ROS (Ma et al., 2011). Natural antioxidants possess broad spectra of biological actions, including pharmacological and therapeutic activity against free radicals and oxidative stress (Bagchi et al., 2000); these antioxidants are widely available in fruits, vegetables, nuts, seeds, flowers, and the bark of trees.

Fruits such as mango (*Mangifera indica* L.) are considered a good source of antioxidants for humans (Ma et al., 2011); important bioactive compounds have been found in the seed kernel (Abdalla, Darwish, Ayad, & El-Hamahmy, 2007a; Abdullah, Mohammed, & Abdullah, 2014; Dorta, González, Lobo, Sánchez-Moreno, & de Ancos, 2014; Ribeiro & Schieber, 2010). Bioactive extract analysis revealed the presence of powerful antioxidants such as BHT (Abdullah et al., 2014).

In 2008, the ethanolic extract from mango seed (*Mangifera indica* L.) was listed as one of four extracts with the highest antioxidant capacity in addition to the ethanolic extracts of *Punica granatum* (Peel), *Syzygium aromaticum* (Bud) and *Phyllanthus emblica* (Fruit). The antioxidant capacity of these four extracts were similar to those of L-ascorbic acid (Saito, Kohno, Yoshizaki, & Niwano, 2008), However, active compounds must be removed for use as a food additive (Dorta, Lobo, & Gonzalez, 2012b).

3.3. Antioxidant analysis in the mango seed

The strategy for the analysis of antioxidants involves sample preparation, recovery (solvent extraction) from the sample matrix, separation, identification, and measurement (González & González, 2010). Drying is an essential step in sample preparation because it inactivates the enzymes responsible for the degradation of many active compounds and decreases the rate of microbial growth. The