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Biotechnological Potentialities and Valorization of Mango Peel Waste: A Review

(Potensi Bioteknologi dan Penaikan Harga Sisa Kulit Mangga: Suatu Ulasan)

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ABSTRACT

In recent years, by-products of fruit processing have received a great deal of attention, which is primarily due to their nutritional and economic exploitation through utilization of emerging technologies. Mango peel waste, a by-product from pulp processing units, is an important source of high quality antioxidant dietary fibre, pectin, polyphenols and carotenoids. It also possess significant biotechnological potential since it has been found suitable for several bioprocesses including ethanol, biogas, lactic acid, enzymes and single cell production. Valorization of mango peel through different routes not only can increase the profitability of fruit processing industries, but also help reduce environmental pollution. This review intends to provide a broad view on available technologies for mango peel waste utilization, with an emphasis on its biotechnological conversion into added value products beside other ways of utilization.

Keywords: Biotechnological potential; functional food; Mango peel waste; valorization

ABSTRAK

Sejak kebelakangan ini, hasil sampingan pemprosesan buah-buahan telah menerima banyak perhatian, terutamanya disebabkan oleh khasiat dan eksploitasi ekonomi melalui penggunaan teknologi baru. Sisa kulit mangga, hasil sampingan daripada pulpa pemprosesan unit, adalah merupakan sumber antioksidan berkualiti tinggi diet serat, pektin, polifenol dan karotenoid. Ia juga memiliki potensi bioteknologi yang besar kerana didapati sesuai untuk beberapa bioproses termasuk etanol, biogas, asid laktik, enzim dan pengeluaran sel tunggal. Penaikan harga sisa kulit mangga melalui pelbagai cara bukan sahaja boleh meningkatkan keuntungan industri pemprosesan buah-buahan, tetapi juga membantu mengurangkan pencemaran alam sekitar. Kajian ini bertujuan memberikan pandangan yang luas mengenai teknologi terkini untuk penggunaan sisa kulit mangga, dengan penekanan kepada penukaran bioteknologi produk tambah nilai selain daripada cara penggunaan lain.

Kata kunci: Bioteknologi; makanan fungsian; penaikan harga potensi; sisa kulit mangga

INTRODUCTION

Mango (*Mangifera indica* Linn.) is one of the important tropical fruits that usually found in Southern Asia (Eastern India, China, Thailand, Pakistan, Burma, Andaman Islands) and Central America. Mango trees are grown vastly in many tropical regions of the world. Mango fruit is extensively used for food, juice, flavor, fragrance and coloring purposes (Kittiphoom 2012). The period of development from flowering to fruit maturity is between 3-6 months depending on the cultivar, the size and color of ripe fruit. For year 2011, India is the largest mango producer in the world, with 15188000 tonnes (http://www.mapsofworld.com). Several varieties of mango are grown in India, which include Banganapalli, Suvarnarekha, Neelum, Totapuri, Kesar, Alphonso, Rajapuri, Jamadar, Chausa, Dashehari, Fazli, Gulabkhas, Kishen Bhog, Himsagar, Zardalu and Langra (www.apeda.gov.in). Ripe mangoes are processed into pulps, purees, jams and jellies, frozen mango products, canned products and dehydrated products (Berardini et al. 2005; Ramteke & Eipeson 1997). Nutritionally, mangoes are a good source of vitamins A, C, B6 and pigment antioxidants-carotenoids. Also, rich source of polyphenols and fiber. After pulp extraction from fruit (mesocarp part), peel and kernel are discarded as waste and becoming a source of pollution (Puravankara et al. 2000); they account for 35-55% of the fruit (Bhalerao et al. 1989) as shown in Table 1, depending on the variety.

MANGO PEEL CHEMICAL COMPOSITION

Fresh mango peel contains significant amount of moisture. Mango peel is rich in pectin, cellulose, hemicelluloses, lipids, proteins, polyphenols and carotenoids (Ajila et al. 2007). In general, the level of reducing sugars, non-reducing sugars, protein and cellulose varies depending on cultivar. Typical composition of fresh and dried mango peel is given in Table 2.

The dried mango peel contains high amounts of reducing sugars. Therefore, it can be used as substrate for fermentative production of ethanol, organic acids and other industrial bioproducts. In recent years, this fruit processing waste has received much attention as a potential source of

TABLE 1. Different components obtained during mango pulp extraction

Component	Percentage
Mango pulp	45-65
Peels	15-20
Pulpier waste	15-20
Stones	10-20

(Source: Central Food Technological Research Institute, 1985)

TABLE 2. Average composition (%) of fresh and dried mango peel (Reddy et al. 2011)

Content	Fresh mango peel	Dried mango peel
Moisture	70	10
Total solids	25	70
Reducing sugars	7	30
Non-reducing sugars	5	4
Protein	3.5	4
Cellulose and lignin	25	23

bio-energy and other value-added products. Value addition can be successfully achieved through biotechnological route.

PROBLEM OF WASTE DISPOSAL

Disposal of wastes from fruit-canning industries has been a problem due to high transportation costs and limited availability of landfills, as these by-products carry no commercial value, they are often disposed unscrupulously. Improper disposal of mango peel waste may appreciably increase the environmental pollution due to its rapid decay, eventually becoming a source of insect multiplication. A high level of BOD and COD in mango peel waste create a further problem in disposal. To a certain extent, vermicomposting technology could help the disposal of organic industrial wastes, including fruit waste, in a safe, economic and useful manner. However, valorization through different techniques will certainly eliminate the disposal problem.

BIOTECHNOLOGICAL POTENTIALITIES

PRODUCTION OF ETHANOL

Mango peel extract has been used for bioethanol production. Direct fermentation, without nutrient addition, yielded 5.13% (w/v) ethanol; however, upon supplementation with yeast extract, peptone and wheat bran, final ethanol yield was increased by nearly 40%, i.e. 7.14 % (w/v) (Reddy et al. 2011). This enhancement could be due to availability of sufficient nitrogen and other yeast nutrients in the supplemented medium since the mango peel contain scarce amount of protein. Mango peel bioethanol is economically and environmentally viable and can be a good substitute of petrol (Walia et al. 2013). Fruit processing wastes can be used as potential feedstock for bioethanol production and this could also be an attractive alternate for disposal of the polluting residues (Wyman 2001). Arumugam and Manikandan (2011) reported 9.68% ethanol yield using mango peel, however the yield and productivity was relatively low compared with mango pulp ethanol fermentation. Thermotolerant and alcohol tolerant yeasts, which are able to grow at 40°C, have been used for ethanol production from mango peel; a maximum ethanol concentration of 13 g/L was observed at 120 h (Somda et al. 2011).

EFFECT OF PRETREATMENT ON ETHANOL YIELD

Reddy et al. 2011 have reported enhanced yield of reducing sugars from pectinase treated mango peel. In this study, higher levels of solubilization of reducing sugars (30% w/v) was observed with crude pectinase treatment compared to simple aqueous extraction (20% w/v), in 24 h enzyme reaction time. Since mango peel is a rich source (10-15%) of pectin, a complex set of polysaccharides, pectinase treatment can be effective for release of fermentable sugars. Saravanan et al. (2012) have suggested alkaline pretreatment to decrease the crystallinity of mango peel and for simultaneous removal of lignin and other inhibitors. For pretreatment, 2% NaOH was added and autoclaved at 121°C for 30 min and excess alkali was neutralized with phosphoric acid.

WINE FERMENTATION

Mango wine fermentation using yeast-mango peel immobilized biocatalyst system has been reported recently (Varakumar et al. 2012). The operational stability of the biocatalyst system was found to be good with better ethanol productivities (1.53-3.29 g/L/h) and it can also be suitable for low temperature winemaking. The overall improved quality of wines has been noted using this system.

ENZYMES PRODUCTION

Mango peel at the level of 7% (w/v) has been used for carboxymethyl cellulose (CMCase) production using *Paenibacillus polymyxa* (Kumar et al. 2012a). Mango peel has been used for the production of cellulase enzyme (Saravanan et al. 2012) and a maximum cellulase activity of 7.8 IU/mL was reported under optimized conditions.

LACTIC ACID FERMENTATION

Potential of mango peel as a low cost substrate for the production of lactic acid has been investigated (Jawad et al. 2013). In this study, mango peel was directly fermented using bacteria having both amylolytic and lactic acid producing capabilities. A maximum production of 17.484 g/L lactic acid was obtained through statistical optimization of fermenting conditions. The mesophilic microbial system, which can operate at 35°C, that has been used in this study seems to have practical advantage because of low cost and therefore method is economically viable. In another study, lactic acid concentration of 63.33 g/L was obtained from mango peels fermentation by *Lactobacillus casei* (Mudaliyar et al. 2012). This increment in the final lactic acid concentration was due to the steam explosion pretreatment followed by acid hydrolysis of peel waste before fermentation, compared with the previous report. Therefore, pretreatment and hydrolysis before fermentation play a key role in the yield of lactic acid as these steps increase total fermentable sugars in the medium.

PECTINASES PRODUCTION

Pectinases production using mango peel as substrate has been reported (Kumar et al. 2012b). As mango peel rich in pectin, microorganisms (especially filamentous fungi) which are capable of degrading pectin can be used for fermentative production of pectinases. In this study, *Aspergillus foetidus* was used to produce polygalacturonase and pectin lyase using Totapuri mango peel and highest productivity was observed with solid state fermentation.

BIOGAS PRODUCTION

Anaerobic digestion has been widely used for the treatment of organic industrial wastes and agricultural wastes including fruit processing wastes. Mango peel has been used for biogas production; gas production at a level of 0.33 $m^3_{biogass}/Kg_{TS}$ with 53% methane content at hydraulic retention time (HRT) of 15 days has been reported (Somayaji et al. 2001). Ensilage of mango peel for 6 months has been shown to aid in the better conversion of major components of its carbohydrates into volatile fatty acids. This pretreatment effect has resulted in 58% more gas production as compared with control (Madhukara et al. 1993). Microbiological pretreatment of mango peel for 6 days was shown to increase the total gas production by 8-fold (Devi & Nand 1989). In a recent study, a higher specific gas production was observed for mango peel, co-digestion with cow dung at ratio of 1:10 and at 8% TS, compared with controls (Anhuradha & Mullai 2010).

SINGLE CELL PROTEIN PRODUCTION

Mango-peel extract has been used for single cell protein production using *Pichia pinus* yeast. In this study, a maximum yield of 6.2 g/L was observed at the third day of growth and cells contained 62.2% crude protein, 39% true protein and 12.9% nucleic acids (Rashad et al. 1990).

NUTRITIONAL VALORIZATION

SOURCE OF PECTIN

Mango peel is a good source of pectin i.e. around 10-15%. A maximum pectin yield of 21% was obtained by soaking finely ground defatted mango peels in sulphuric acid solution (pH2.5 at 80°C for 120 min) (Rehman et al. 2004). A pectin level of around 18% was reported in *Totapuri* mango peel (Kumar et al. 2012b). Mango peel pectins exhibited better gelling capacity than commercial citrus pectin (Koubala et al. 2012).

ANIMAL FEED

Mango byproducts can be used as livestock feed (de la Cruz Medina & Garcia 2002; Sruamsiri & Silman 2009) as they have a higher energy value than maize silage and could partly replace energy concentrations in diets for ruminants (Azevêdo et al. 2011). Mango peels are especially palatable to ruminants because of their high sugar content. A recent study showed that mango peels have promising potential for utilization as feed or feed additives due to their *in vitro* digestibility, chemical composition and favorable volatile fatty acid (VFA) composition and have the potential to attenuate rumen methanogenesis, thereby greenhouse gas emissions (methane) can be reduced (Geerkens et al. 2013). However, high moisture and acidity of fresh peels may limit their use (Sruamsiri & Silman 2009). In addition, supplementation of nitrogen or protein source to peels is necessary to allow an efficient utilization of energy since they contain low protein. Fermentation can greatly influence the nutritional composition of mango peels. An increase in the protein content and a decrease in the levels of antinutrients such as tannins and phytate were observed upon fermentation of the ripe mango peels (Ojokoh 2007). In addition, fermentation enhances the nutrient, vitamins, essential amino acids and fibre digestibility. Low quality of non fermented agro-byproducts can be upgraded after fermentation with selective microorganisms and such fermented products could be used as healthy animal feed.

PHENOLIC ANTIOXIDANTS

Mango peel is a rich source of phenolic compounds, which exhibit antioxidant activity (Palmeira et al. 2012). In addition, phenolic compounds also have antiviral, antibacterial and anti-inflammatory activity (Zgórka & Kawka 2001). The major phenolic compounds present in mango peel extract are reported to be syringic acid, quercitin, mangiferin pentoside and ellagic acid (Ajila et al. 2010a). Peels are good source of mangiferin (C-glucosyl xanthone), a heat-stable and pharmacologically active phytochemical. Mangiferin possess various bioactivities, such as anti-inflammation, anti-diabetic, immunomodulatory, anti-tumor and antioxidant (Luo et al. 2012). It showed high DPPH· free-radical scavenging capacity and thus has potential in the prevention of oxidative stress-associated diseases. Polyphenol rich fractions of peel extract could be used as natural antioxidants and functional food or feed supplements (Berardini et al. 2005). In a recent study, phenolic compounds from mango peels were successfully extracted using subcritical water (SCW) and this solvent is considered to be environmentally friendly for extraction of bioactive compounds (Tunchaiyaphum et al. 2013). The subcritical water extraction is considered to be time-saving, results in high yield and no toxic solvent residues yielding method and therefore can be applicable for the food industry.

FUNCTIONAL FOOD INGREDIENT

Mango peel flour can be used as a functional ingredient in developing healthy food products such as noodles, bread, biscuits, sponge cakes and other bakery products (Aziz et al. 2012). As mango peel is rich in source of polyphenols, carotenoids and vitamins with different health-promoting properties, there is enormous potential for developing functional foods based on mango peel. The solubility, water and oil absorption values of mango peel powders play key role for their utilization in foods. Different drying methods influence the functionality of mango peel. The cabinet dehydration method was found better over other drying methods in mango peel powder preparation, which intended for utilization in several food applications (Sogi et al. 2013). In a study, yogurt made with supplementation of 10% of mango peel powder showed a good texture, flavour and color characteristics and exhibited one month shelf life without adding preservatives (Ruiz et al. 2011).

DIETARY FIBRE

Dietary fibres and phytochemicals are gaining increased attention because of their antioxidant, anticarcinogenic and other health benefiting properties (Hertog et al. 1993). Mango peel fiber with high hydration capacities has potential in dietary fibre-rich foods preparation (Koubala et al. 2013). Mango peel dietary fibre has been shown to be associated with natural antioxidant components and therefore its antioxidant capacity is greater than that of DL-α-tocopherol and French Paradoxe (Larrauri et al. 1997). A recent study indicated the presence of significant amount of bound phenolics in dietary fibre, which adds additional health benefits of antioxidant property (Ajila & Prasada Rao 2013). Mango peel powder incorporation has increased the total dietary fiber content of macaroni significantly, from 8.6% in control to 17.8% in 7.5% peel powder incorporated macaroni and therefore it can be utilized for the preparation of macaroni with improved nutritional properties (Ajila et al. 2010b). In another study, beef burger samples incorporated with 3% level of mango peel dietary fiber exhibited satisfactory quality grade for all characteristics (Abdeldaiem & Hoda 2012).

RICH SOURCE OF CAROTENOIDS

Mango has been reported to contain high amounts of carotenoids (Chen et al. 2004). Carotenoids content is high in peel with advance physiological ripening compared with the peel with partial ripening (Ajila et al. 2007; Varakumar et al. 2011). Mango carotenoids have been shown to possess high vitamin A activity and antioxidative capacity, owing to its high beta-carotene content (Mercadante & Rodriguez-Amaya 1998).

OTHER VALORIZATION ROUTES

REMOVAL OF HEAVY METALS

Mango peel was used as biosorbent for the removal of Cd(II) and Pb(II) heavy metals from aqueous solution (Iqbal et al. 2009a). A fast biosorption rates i.e. reaching at equilibrium in 60 min, for both metals have been observed in this study and the mode of sorption was found to be ion exchange using X-ray spectroscopy (EDX). In a similar study, effective removal of Cu^{2+}, Ni^{2+} and Zn^{2+} from constituted metal solutions and genuine electroplating industry wastewater was observed using mango peel waste (Iqbal et al. 2009b).

SOURCE OF ANTIMICROBIAL COMPOUNDS

Strong antifungal activities against pathogenic fungus such as *Rhizoctonia solani Kühn* and *Rhizoctonia cerealis vander Hoven* have been reported with ethyl acetate fraction and ethanol crude extracts of mango peel (Qin et al. 2007a). However, in case of unripe mango peel, superior fungal inhibition was observed with 95% methanol extract than 95% ethanol extract and the inhibition of methylene chloride extract was greater than ethyl acetate (Qin et al. 2007b). The major component for antifungal activity was found to be 5- (12-heptadeconyl)-resorcinol (Cojocaru et al. 1986).

PHARMACEUTICAL EXCIPIENT

Mango peel derived pectin can be used as pharmaceutical excipient to prepare solid oral dosage form (Malviya & Kulkarni 2012). In a similar study, suitability of mango peel pectin as a super disintegrating agent has been tested (Malviya et al. 2010). The results of this study showed that mango peel pectin has relatively lesser drug release capacity compared to sodium starch glycolate; however, due to its good solubility in biological fluid and better swelling index, it can be used to prepare fast dispersible tablets.

Conclusion

Mango peel waste contains many nutritionally and economically valuable components. The wastes from mango pulp processing industries have significant exploitation potential. In recent years, mango peel dietary fibre has received a great deal of attention as functional food ingredient. The presence of associated phenolic compounds provides the peel fibre material with intrinsic antioxidant capacity. Therefore, it is capable of offering low-cost nutritional dietary supplement for lower income masses. Economic valorization of peel wastes could readily be realized through biotechnological utilization. Thus, through biotechnology route, environmentally polluting by-products of mango processing industry could be converted into products with a great economic importance. By using novel scientific and technological methods for extraction and processing, valuable products from mango peel could be obtained. Further technological developments in that direction are highly warranted.

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