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Review Article

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Therapeutic Potential and Utilization of Fruit Derived Waste: A Review

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ABSTRACT

Fruits have a significant role in the diet of human. Wastes are the unconsumed or unused fractions of a fruit and vegetables due to their morphological characteristics. Many fruits as well as vegetables produce up to 25- 30% of waste. The lack of proper infrastructure and methods are responsible for massive losses of important food components, by-products and residues. This review focuses on presence of bioactive compounds of some fruit by-products and possible utilization in various industries. Studies from 1986 to 2018 were reviewed from books, research paper and review articles. Currently, thousands of bioactive molecules have been isolated as well as identified from different fruit waste. The horticultural by-products are good sources of phenolic compounds, pigments, dietary fibers, organic acids, sugar derivatives, minerals and other constituents. These bioactive molecules have beneficial properties like cardioprotective, antibacterial, antimutagenic, antitumor, antiviral properties. Fruit and vegetable wastes can be utilized by isolation potential bioactive molecules and can be utilized in pharmaceutical, food, cosmetics industries. Research should be encouraged to explore the therapeutic and toxic effects, pharmacokinetics of bioactive molecules.

Key Words: Bioactive Molecules, Food-Components, Pharmacological Effects, Fruit Waste, Therapeutic Potential, Beneficial Properties

INTRODUCTION

Vegetables and Fruits have a significant role in the diet of human. Therefore, the demand of these main food commodities has increased with the growing population of world.[1] The significant amounts of fruits produced worldwide are citrus fruits, grapes, bananas, apples, mangoes, guavas, and pineapples. Similarly, production of vegetables includes cauliflower, potato, cabbages, tomatoes, broccoli and peas.[2]

Food waste is part of fruits and vegetables that is not consumed and discarded due to lack of proper infrastructure and methods. The big amounts of wasted food products cause environmental problems when they decompose and emit unsafe greenhouse gases.[3] Next to household garbage, fruit and vegetable processing units generate highest wastes in atmosphere.[4]

The horticultural by-products are good sources of phenolic compounds, pigments, dietary fibers, organic acids, sugar derivatives, minerals and other constituents. These compounds have beneficial properties like cardioprotective, antibacterial, antimutagenic, antitumor, antiviral properties.[5] Fruits and vegetables like pineapples, oranges, peaches, potatoes, apples, are used for jams, juice and frozen pulp producing considerable amounts of waste materials.[6]

The Washington State Department of Ecology report exposes that decrease of waste increases profit and reduces liability. Fruit and vegetable wastes can be utilized to isolate molecules for pharmaceutical, food, cosmetics industries. So, the proper use of wastes from horticultural products may start a plan for development to reduce environmental crisis and to develop health of human being through foods having phenols, pigments, vitamins and carotenoids.[7]

Wastes are unconsumed or unused fractions of a fruit and vegetables due to their morphological characteristics. They are discarded due to lack of proper utilizations and constitute a considerable waste.[8]

Many fruits and vegetables produce up to 25- 30% of waste and are not utilized.[9] They are rich in phenolic compounds, dietary fibers and other bioactive molecules.[10] Investigations have exposed that considerable quantity of phytochemicals and necessary nutrients are available in seeds, peels those are not used as food.[11] Fruit peels such as lemons, grapes, oranges and jackfruit seed, longans, avocados, mangoes have above 15% more phenolic compounds than that of in pulp.[12]

Phenolic compounds are the secondary metabolites of plants responsible sensory characteristics. They add nutritional

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quality of fruits and vegetables.[13] Phenolic compounds are leading bioactive molecules with important biological functions.[14] The compounds contain aromatic rings along with one hydroxyl groups.[15] Several phenolic compounds include antioxidant property.[16] The flavonoids have many subclasses like flavonols, flavones, flavanones, flavanonols, flavanols, anthocyanidins and isoflavones.[17] The peel, rind, and seeds of vegetables and fruit contain high quantities of phenolic compounds.[18]

The wastes of fruits and vegetables contain biomolecules utilised as source of flavours and aromas. The Solid State Fermentation (SSF) is a process by which potential products are extracted.[19] The market for aromas, and flavours is more due to increased demand for natural in addition to safe products. Vanillin (4-hydroxy-3-methoxybenzaldehyde) is obtained from vanillic acid. It is vital and vastly used flavour in pharmaceutical, food, cosmetic and detergent units.[20] Natural vanillin extraction is done from fermented pods of vanilla orchids *Vanilla planifolia.*[21]

Enzymes Amylases are of 3 types, namely *α*-amylase, *β*-amylase, and glucoamylase. Amylases are used in food processing units for products like juices, starch syrup and cakes. These are used in processes like brewing, baking, preparation of digestive aids.[22] Many fruit residues are used for production of amylases.[23]

Cellulases contain exo-1, 4-*β*- glucanase, endo-1, 4-*β*-d-glucanase, and *β*-d-glucosidase. These are utilized in food industries for extraction of aroma rich molecules and phenolic compounds from grapes pomace and others.[24]

Similarly, invertase is employed to produce invert sugar. It has a low crystallinity in comparison to sucrose. So, it keeps the product soft and fresh for a longer period.[25] A peel combination in the ratio of 1 sapota: 2 pineapples: 2 bananas were used, less invertase produced in comparison to fructose as the carbon source. Invertase is exclusively used to produce jam, candies and pharmaceutical products.[26]

Similarly, production of pectinase is done by solid-state fermentation from grape pomace using *A. awamori* yeast.[27] It is produced from peel of pineapple using *Penicilliim chrysogenum,* pectinolytic molds and *A. Niger.*[28] It is produced from 6 different substrates like orange peel, lemon peel, wheat bran, banana peel, rice bran and sugarcane bagasse production using *A. niger* in solid-state fermentation.[29]

Proteases are the principal enzymes as these are mainly used in the dairy and detergent industries.[30] Many agro industrial wastes also have been investigated for protease production from wastes of vegetables and fruit.[31]

Organic acids such as Citric and lactic acids are main biomolecules employed in food, cosmetic as well as pharmaceutical industries. Citric acid is produced using various molds, yeasts as well as bacteria through fermentation. But, *A. niger* is the favourite mold for industrial production of citric acid.[32]

In this review, the phytochemistry, pharmacology, traditional as well as possible industrial uses of some waste of widely used fruits are being discussed.

BANANA

Waste- Banana peel

Banana is the fruit of plant *Musa* sp. of family *Musaceae.* India is the largest producer of banana (27% of banana of world). Banana peel is main waste part of fruit. It holds nearly 30–40% (w/w)fresh. Peel composition of ripe banana is 8% protein, 6.2% ether extract, 13.8% sugars in addition to 4.8% phenolic compounds. Major components of banana peel include chlorophyll, pectin,cellulose, hemicellulose.[33]

Banana pulp of *Musa Cavendish* contains 232 mg/100 g dry matter of phenolic compounds. It is about 25% of that found in peel.[34] It contains catecholamines, l-dopa and dopamine.[35] Banana waste is used as source for amylases production.[36] The peel contains Carotenoids like palmitate, xanthophylls, laurate. The bract contains Cyanidin and anthocyanidins like delphinine, pelargonidin , peonidin, petunidin, malvidin.[37]

COFFEE

Waste- Coffee husk

Coffee is obtained from the cherries of plant *Coffea arabica* L. and *Coffea canephora* Pierre ex A. Froehner. The production of coffee in industry produces significant quantities of cherry husks, silver skin, cherry pulps and spent coffee.[38]

They can be used as sorbent for the removal of heavy metals and dyes from aqueous solutions, fuel pellets production for preparing ion exchange material, spirit beverage production. They can also be used as substrate for edible mushrooms production and source of natural phenolic antioxidants, substrate for biogas, production of alcohol, biodiesel production, and biomaterial in the pharmaceutical industry.

Coffee cherry husk represents about 12 % of the berry on dry-weight basis. It contains insignificant amounts of bioactive molecules like almost 1% caffeine, 2- 5% chlorogenic acid and 5% tannins in the residue.[39]

The high concentration of caffeine and tannins in coffee husks could be isolated for “energy drinks”. Coffee husk is used for brewed tea is called coffee cherry tea. It is useful substrate for mould, yeast and enzyme production, for its high quantity of fermentable sugars.[40]

Spent coffee grounds (SCG) are the waste product from brewing coffee. These are composed of cellulose, hemicellulose, 23.9% lignin, fat, protein, and 60.46% of total dietary fibres. Spent coffee grounds is a source for biodiesel, bioethanol, steam production, spirit beverage production as source of sugars, as composting material, sorbent for metal ions removal, adsorbent for dye removal, substrate for mushroom production. It can be used as resource of phenolic antioxidant in pharmaceutical industry, food industry, polymer industry.[40]Coffee generates by-products with very rich biomolecules.[41] Citric acid is cultivated from coffee husk using *A. Niger.*[42]

PINEAPPLE

Waste- Pineapple peel, Pomace

Pineapple is the fruit obtained from plant *Ananas comosus* of family *Bromeliaceae*. India is the fourth leading producer of pineapple in world. It contributes almost 9% of total production of world of fresh pineapple.[43]

Pineapple processing yields about 14% peels, 9% core, 15% pulp, 15% top, and 48% total final product. Pineapple peel is processed with *Penicillium chrysogenum* to get pectinase. Also acetic acid is produced form the peel by processing with *Acetobacter aceti* and *Saccharomyces cerevisiae.*[44] Pineapple peel waste has ferulic acid, which is a precursor of vanillic acid.[45] The Vanillin production from waste of pineapple is a process of 3-step.[46]

Maximum amount of citric acid produced from waste of pineapple by using the yeast *Yarrowia lipolytica*, and using *A. niger*as the acting fermentater.[47]

MANGO

Waste- Seed, Peel

Mango is a juicy stone fruit of *Mangifera indica L.*belongs to family *Anacardiaceae*. It has more than 1000 varieties worldwide.[48]

Processing of mangoes produces about 11% peels, 13.5% seeds, 18% inoperable pulp, and 58% of finished product.[49] Hepatoprotective activities in mango seed kernels were studied by Nithitanakool et al. in 2009.[50] The anti-diarrheal activity of extracts of seeds of *M. indica* was investigated.[51] Mango kernel aqueous extract has anti-diarrheal activity at 0.25 - 0.50 mg/ml dose.[52]

Mango peel has 51.2% dry matter of Total Dietary Fibers. It contains 32% dry matter insoluble fibers and 19% dry matter soluble fibers.[53] The dietary fiber of mango peels contains Total Dietary Fibers content 40.6- 72.5%, with glucose, galactose, and arabinose as chief neutral sugars in insoluble and soluble dietary fibers.[54] “Tommy Atkins” variety mango has 28.05% dry matter of dietary fibers, in which 13.80% dry matter insoluble and 14.25% dry matter soluble fibers.[55]

The mango kernel contains 2% crude fiber.[56] Ashoush et al. found nearly 0.26g/100 g crude fiber in mango kernel powder and nearly 9.33 g/100 g crude fiber in mango peel powder. Mango kernels are used as resource for amylases production.[57]

GRAPE

Waste- Seed, Pomace

Vitis vinifera is a perennial, woody climbing vine. Its processing industries produce about 5 to 9 MMT of solid waste every year worldwide. It constitutes 20- 30% of processed materials.[58] Grapes pomace is a rich source of dietary fibers, like hemicelluloses, cellulose, and small amount of pectins.[59]

Grape seeds as well as skins are by-products of wine and juice industries. They contain monomeric, oligomeric, as well as polymeric proanthocyanidins.[60]

Grape seeds contain flavonoids (4- 5%), including kaempferol-3-O-glucosides, quercetin- 3-O-glucosides, quercetin and myricetin. 60-70%of polyphenols are found inseeds of grape. The grape seed polyphenols are flavan-3-ol derivatives. The major compounds are (+)-catechins, (dimmers (B1-B5), procyanidins C1, and procyanidinB5- 32 -gallate. Grape seeds contain procyanidins or proanthocyanidins.[61]

Grape seeds contain 6-20% oil utilized as edible oil, soaps, linseed substitute. *Amalagma* made from the seed is a folk remedy for condylomata of the joints.Grape seed extract has antioxidant as well as free radical scavenging property.[62]

The sparing or recycling effect of procyanidins from *V. Vinifera* seeds on alpha-tocopherol was established in phosphatidylcholine liposomes and red blood cells. Other than free radicals scavenging nature, Procyanidines also inhibit xanthine oxidase activity. Xanthine oxidase enzyme triggers the oxy-radical cascade.[63]

APPLE

Waste- Peel, Pomace

Apple is the fruit obtained from plant *Malus domestica* belongs to family *Rosaceae.* It is cultivated commercially in 91 countries.[64]

Apples generate 89.09% final products and 10.91% seed and pulp as waste during slicing.Apple peel has 0.91% FW more dietary fiber content than pulp. The insoluble and soluble dietary fibers are 0.46% FW and 0.43% FW respectively.[65] Apple peels contain up to 3300 mg/100 g dry matter of phenolic content.[66] The pineapple flavour constituent is ethyl butyrate.

Apple pomace is used as substrate with *A. niger* to generate citric acid.[67]

The apple peels contain compounds such as catechin, procyanidins, epicatechin. It also contains chlorogenic acid, quercetin conjugates, phloridzin. Though apple flesh contains catechin, epicatechin, procyanidin and phloridzin, these molecules are present in lower concentrations than in peels. Only Chlorogenic acid found is higher in flesh than in peel.[68]

Apple peels contain higher antioxidant compound, quercetin. The peel has more antioxidant activity and more bioavailability than the apple flesh. Whole apples with peels are better capable for inhibition of cancer cell proliferation compared to apples without peels. Apple peels contain two to six times more phenolic compounds than in flesh.2-3 times more flavonoids present in peels as compared to flesh depending on variety.[69]

BER

Waste- Seed

Ber fruit is obtained from the plant *Ziziphus mauritiana* of family *Rhamnaceae*. The seed is sedative, hypnotic, narcotic, stomachache as well as tonic. It is administered internally in the treatment of insomnia, palpitations, nervous exhaustion, night sweats in addition to excessive perspiration.[70]

There are 2 types of domestic jujubes,i.e.*Z. mauritiana* Lam. the Indian jujube (Ber), and *Z. jujuba Mill*, (common jujube).

Flavonoid glycosides spinosins was extracted from seeds of *Z. jujuba* var. Three types of acylated flavone-C glycosides were isolated. These molecules have sedative activityin rats. The saponins found from of *Z jujube* seeds are Jujubosides A and Jujubosides B.[72] Sedative flavonoids like Swertisin as well as spinosin were extracted from fruit and seeds of *Z.jujuba*.

The leaves and seeds of several *Ziziphus* species have anxiolytic and hypnotic-sedative property. They depress the activity of CNS and reduce anxiety, induce sleep. It concludes to produce sleep, but not muscle relaxant or anticonvulsant.[71] The inhibitory potential of Jujuboside A on rat hippocampus is revealed.[72] Anxiolytics effect of a polyherbal formulation having seed extract of Z. jujuba is reported in mice.[73]

JACKFRUIT

Waste- peel

Jack fruit is obtained from the plant *Artocarpus heterophyllus* belongs to family *Moraceae*. It is native to India.[74] In addition to India, the fruit is commonly cultivated in Sri Lanka, Bangladesh, Burma, Indonesia, Philippines, Thailand, Brazil, Malaysia.[75] In India, it is distributed in many states.[76] It is considered as the Poor man food.[77]

Polyphenol as well as flavonoid are present in spine, skin and rind, respectively. All the three extracts have anti-inflammatory properties comparable to diclofenac in both *in-vitro* and *in-vivo* models. The skin revealed maximum anti-inflammatory property. The rind of fruit had favoured cyclooxygenase-2inhibition. The spine as well as skin reduced both cox-1 as well as cox-2 *in-vitro*.[78] Jackfruit peel can be employed as adsorbent for removal of cadmium.[79]

JAMUN

Waste- Seed

Jamun is obtained from the plant *Syzygium cumini* of family *Myrtaceae*. It is termed as Jambolan, amblang, Kala Jamun, Jambul in India. It is advised as a safe drug in different diseases by health organizations.[80] This plant is also used for treatment, prevention of many diseases in Homoeopathy practice in different countries.

The seed of fruit is used as alternative natural healing medicine in Unani, Chinese and Ayurvedic system of medicines. The bark and seeds are famous in Far East for treatment of dysentery. They are used in the control of hyperglycaemia, glycosuria in patients of diabetes.

Syzygium cumini seeds are used for various disorders as antiinflammatory, hypolipidaemic, antidiabetic, antioxidant, neuroprotective. Seeds proved to have the DNA protection effect against radiation.[81] The cardioprotective property of seeds of *Syzygium cumini* (Jamun) revealed against the DOX induced acute myocardial stress in rats.[82]

Ethanolic extract of seed kernel of *Syzygium cumini* reduces thiobarbituric acid reactive substance (TBARS), glutathione (GSH), superoxide dismutase (SOD) and catalyse (CAT) activity.

The seeds contain crude fiber (16.9%), Protein (6.3 to 8.5%), Fat (1.18%). It contains Magnesium 17 mg, Phosphorus (2%), Potassium 79 mg (2%), Sodium 14 mg (1%). More anti-inflammatory activities are in stem and seeds of *Syzygium cumini.*[83] The chloroform extracts of dried seeds showed antipyretic activity. The seed extract is active versus yeast induced pyrexia.[33]

The *Syzygium cumini* seed extracts contain alkaloids, glycosides, steroids, triterpenoids, saponins, tannins, flavonoids and carbohydrates.[84]

LITCHI

Waste- Peel, Seed

Litchi fruit is obtained from the plant *Litchi chinesis Sonn* of the family *Sapindaceae*. The peel of fruit is tough, inedible, covered with sharp protuberances and possesses a profound pink-red colour when ripe. Processing and consumption of the fruit generates by-products such as epicarps and seeds, which are often discarded.

The seeds may be used as a food additive in pharmaceutical drugs. Studies on plant extracts and fruit based wastes as antioxidants for preserving foods as well as neutralizing free radicals in the human body are being developed.[85]

Peel and seed of litchi possess high energy and nutritional value. They are loaded in antioxidants like ascorbic acid and phenolic compounds particularly gallic acid, flavonoids like procyanidin B4, procyanidin B2, epicatechin cyanidin-3-retinoside, cyanidin-3-glucoside, quercetin-3- retinoside and quercetin-3-glucoside.[86] They also contain anthocyanins.[87]

By-products of litchi possess antioxidant, anti-inflammatory, anti-hyperlipidemia, anti-hyperglycaemic, hepatic and cardioprotective properties.[88] The ethanomedicinal use of L. Chinensis kernel oil on cardiovascular disorder may be because of its capability of reducing total cholesterol, LDL and increasing HDL values.[89] Aqueous extract isolated from seed increases insulin sensitivity and decreases blood glucose levels, triglyceride, leptin, tumor-necrosis factor in Type-2 diabetes mellitus in rat model.[90]

TAMARIND

Waste- Seed

The fruit Tamarind is obtained from the plant *Tamarindus indica.* It is a famous as well as common tree found in India.[91] It is used as a stabilizer, flavour and binder in preparation of food. Generally, people use Imli to prepare pickles, curries, jam and sauce.

The seeds are used to make flour for making bread in famine seasons. The seeds are fried and consumed by poorer.[92] It is very useful for people of hot area and near to equator.[94]

Tamarind seed powder was used for tannase production by *A. niger.,* and the seeds act as anti-asthmatic, antiulcer as well as antioxidant agent.[93] Vaginal Atony is treated by a pessary of seed kernel. The fried seed paste was used on anus after setting the tract in proper position for treatment of rectal prolapse. In Unani system, spermatorrhoea, nocturnal emissions as well as seminal debility are cured by use of roasted kernel and seeds. Homeopathic system uses seed for the treatment of stomachache.[94] It is used in treatment of cough and for uvula relaxation.[95] The urethral discharge and polyuria are treated by administration of seed kernel with milk.[96]The red outer covering of seeds is very useful in diarrhoea and dysentery.[92] The seeds are used for treatment of colitis and other disorders of intestine.[97] Seeds are helpful in vaginal discharges as well as ulcers.[98]

Seeds are rich in phenolic compounds, polymeric tannins, glycosides, fatty acids, flavonoids, saponins, alkaloids.[94] There is also presence of fatty acids, essential amino acids in seeds.[99] Tamarind seeds contain 2-hydroxy-3', 4'-dihydroxyacetophenone (TAO), 3, 4-dihydroxyphenylacetate (TA2) and (-)-epicatechin. Seed consist of acetic acid, arabinose, dihydroxylphenyl acetate.[100] Oil obtained from seeds consists of lauric acid, myristic acid, palmitic acid, stearic acid, arachidic acid, lignoceric acids in addition to linoleic acids. roasted kernel includes calcium 121 mg and phosphorous 237 mg per 100 gm. It also containsproteins like prolamines and albumins.[95]

Methanolic extract of seeds of *Tamarindus indica* showed analgesic as well as anti-inflammatory effects in inhibiting carrageenan induced paw edema in rats.[94] The seed aqueous extract of *Tamarindus indica* proved to have potent anti-diabetogenic activity which reduces blood sugar concentration in streptozotocin induced diabetic male rat. Aqueous extract 80 mg/100 g body weight / day in streptozotocin induced diabetic rat showed reduction of fasting blood sugar concentration after 7 days of continuous treatment.[100] Anti-inflammatory activity is supported by presence of saponins, flavonoids and tannins in seeds of *Tamarindus*.[94]

The ethanolic extract of *Tamarindus indica* seed coat revealed potent antioxidant property. Antiulcer property discovered in methanolic extract of seed coats of Tamarind. The result revealeddiminution in total gastric juicevolume and total acidity in ulcer by pylorus ligation method. Also, there was significant decrease in ulcer index.[101] Aqueous extract of various parts of *Tamarindus indica* like fruits, leaves as well as unroasted seeds revealed significant hepatoprotective activity in Paracetamol induced hepatotoxicity in rats.[102]

ORANGE

Waste- Peel

Orange is the fruit obtained from the tree *Citrus sinensis*. The production of orange is about 70% of the total production of Citrus fruit.[103] It is indigenous to Asia. Now it is widespread all over the world.[104]

The orange peel contains 57% Dry Weight Total Dietary Fibres, of which 9.41% is soluble fraction and 47.6% insoluble fraction. The chief components of fibers are cellulose as well as pectin polysaccharides.[105]

L-Rhamnose is the chief component of cell wall pectins. It is used for the generation of the strawberry flavour “furaneol” as raw material.[106]

Orange peel gives the best result for pectinase production. The Enzyme Pectin has many important uses in fruit juices industries as well as wines industries for extraction, clarification and concentration. Also, extraction of flavours, pigments, and essential oils is achieved by these enzymes from the residues of plant.[107]

Silver nanoparticles were synthesized using aqueous extract *of* peel *of C. Sinensis*. It demonstrated zones of inhibition against *Escherichia coli, Pseudomonas aeruginosa* and *Staphylococcus aureus*.[108]

Hexane extract of Peel of *C. sinensis* revealed antimycobacterial activity against drug-sensitive, Isoniazid-resistant, and ethambutol-resistant variants of *M. tuberculosis*.[109]

Polymethoxylated flavones obtained from *Citrus sinensis* peel extract such as flavone-7-O-[6-acyl]-glucoside, natsudaidai, tetramethyl-O-scutellare in, nobiletin, tangeretin, heptamethoxy flavone revealed activity against *Aspergillus Niger* using a microbroth dilution assay.[110]

Essential oil obtained from peels of *Citrus sinensis* obtained by cold-pressing method revealed activity against *Mucor hiemalis*, *P. expansum*as well as *F. proliferatum.*[114]

Polymethoxy flavones obtained from *C. sinesis* peels showed activity on lung cancer cells of human. The four flavonoids showed similar action in lung cancer cells H441 in addition to H460 of human.[110]

Orange peel oil obtained by Cold-pressed method contains mixture of 75.1% non-hydroxylated Polymethoxy flavones in addition to 5.44% hydroxylated Polymethoxyflavones. A mixture of 97.2% hydroxylated Polymethoxyflavones trigger apoptosis of breast cancer cells MCF-7.[111] 5% of orange peel extract containing 30% Polymethoxyflavones treated to mice it decreases the tumors development.[112]

Flavonoid content of some fractions of methanolic extract of peel of Navel orange has antioxidant property *in vitro*. The major flavonoids were O-glycosylated flavones, Polymethoxylated flavones, O-glycosylated flavanones, C-glycosylated flavones, O-glycosylated flavanols in addition to phenolic acids with their ester derivatives. Hesperidin is chief flavonoid glycoside ofpeel of orange. Antioxidant property of fractions of methanolic extract of orange peel was estimated. It was proved that the fractionshave moderate antioxidant activity in comparison to the activity given bythe aglycones, diosmetin and hesperetin. Aglycones revealed a significant more hydroxyl scavenging activity as compared to quercetin.[113]

LEMON

Waste- Peel

Lemon is the fruit of *Citrus limon* which is a small evergreen tree originated from Asia. This flowering plant belongs to family *Rutaceae*. Nearly 1300 species are available in genus *citrus*.[114]

In both the leaves and peel of the *citrus limon*, essential oils, limonene is the chief element. Peel oil contains μ-terpinine, β-pinene, myrcene.[115]

Nearly 8.452 % w/w Ca is present in lemon peel which helps in bone formation, controls several cell procedures and plays important structural functions in living organisms.[116]

Lemon peel eating reduces cholesterol effectively.[117] The research reveals that lemon peel is also a useful antimicrobial agent and an astringent.[118]

The dietary fiber amount is more in the pulp (77.93%) than peels (53.02%). The soluble fraction is 27.91% in pulp and 18.48% in peels. Soluble fraction in range of 34.5% in the peel and 35.8% in pulp of the TDF is best for human consumption.[119] Citrus waste is used as substrate for amylase production.[120]

PAPAYA

Waste- Peel, Seed

Papaya is the fruit obtained fruit *Carica papaya* Linn belongs to family *Caricaceae*. It is recommended for consumption for prevention of vitamin A deficiency.The unripe fruit is good source of vitamin A.[121]

The fruit produces about 8.5% peel, 6.5% seeds, 32% unusable pulp and nearly 53% final product during dicing. Flavonoid, Sterol isavailable in unripe papaya peel extract however not in unripe papaya seed extract. Steroids, saponins, sterols and flavonoid are present in unripe papaya peel extracts. Saponins, tannins, steroids and terpenoids seemed to be positive in unripe papaya seed extracts. Extract of papaya seed (unripe)is richer in total phenol content in comparison to papaya peel. Also the unripe papaya seed is rich in total flavonoid in comparison to unripe papaya peel extract. But the results showed that unripe papaya peel extract has more ferric reducing antioxidant nature in comparison to extract of unripe papaya seed. The results revealed that more total phenolic compound in unripe papaya seed as compared to unripe papaya peel. So extract of unripe papaya seed maybe excellent sources of dietary antioxidant.[122]

DATE

Waste- Seed

Date is obtained from the plant *Phoenix dactylifera* belongs family *Arecaceae.* Seeds of Date are good source of antioxidants as well as phenolic compounds.[123] Seed oil has more phenolic content in comparison to other edible oils except olive oil.[124] Waste obtained from Date is used as substrate for amylases production.[125]

Date seeds are proved to contain higher amounts of flavonoids, alkaloids, anthraquinone, saponin, tannin and terpenoids. The mineral contents of seeds of date are significant. Date seeds have high potassium content than sodium content.[126]

The higher potassium to sodium ratio can give health benefit in patients with cardiovascular disorder who take extract of date palm seed as coffee.The antioxidant activity of date seeds is less than leaf extracts of Algeriandate palm.[127] The cerebroprotective effects of date seed extract were examined in rats affected by cerebral ischemia. Seed extract decreases neuronal damage. Ultra structures of cortical neurons were protected by seed extract. This cerebroprotective capability of Date seed is due to its antioxidant activity. Date seed extract attenuates muscle weakness which proved protective efficiency against damage due to ischemic reperfusion.[128]

POMEGRANATE

Waste- Peel

Pomegranate fruit is obtained from the plant *Punica granatum* belongs to family *Lythraceae.* It is indigenous to Iran and it extended to India. It is commonly known as Anaar in native language.[129]

Pomegranate seed oil contains Punicic acid, ellagic acid, fatty acids and sterols. Pomegranate pericarp such as rind, peel contain Phenolic molecules such as punicalagins, catechin, quercetin, rutin, anthocyanidins, gallic acid, other flavonoids.[130]

The pomegranate seedscontain poly unsaturated fatty acids such as linoleic acid, palmitic acid, oleic acid, other lipids punicic acids, stearic acid and linolenic acid.[131]

Peel of pomegranate is about half of total fruit weight which is contain bioactive compounds, potassium, nitrogen, magnesium, calcium like minerals, phosphorus, sodium, proanthocyanidins, flavonoids, ellagitannins and phenolic molecules.[132] It also contains polysaccharide molecules.[133] The seeds contain sex steroid estrone, phytoestrogen coumestrol, pectin, minerals, crude fibers, proteins,vitamins, sugars. Seeds have isoflavones mostly polyphenols and genistein.[134]

Pomegranate peels extract triggers synthesis of type I procollagen as well as inhibits matrix metalloproteinase-1 enzyme and interstitial collagenase synthesis by dermal fibroblasts. Seed oil of pomegranate has stimulatory effect on proliferation of keratinocytes in monolayer culture. It indicates pomegranate peel aqueous extract increases the regeneration of dermis and seed oil of pomegranate improves the regeneration of epidermis.[135]

The antidiarrheal efficacy of peel extract of pomegranate was assessed in rats by administration of 400 mg/kg through oral route and concluded that it decreases number of defecations and weight of feces.[136] Another study revealed antidiarrheal activity of aqueous extract of peels of pomegranate in rats. [137]

DISCUSSION

The advantages of the bioactive compounds in these wastes are main reason for significant number of research studies. This review emphasizes the nature, types of waste obtained from fruits. The review discusses the bioactive molecules such as phenolic compounds, dietary fibers, vitamins, flavours, enzymes, minerals available in fruit waste.

Citrus peel contains more quantity of polyphenols as compared to the edible part of fruit.[15] It indicates that they could be inexpensive and readily available resources of bioactive compounds for use in the food and pharmaceutical industries.

The cerebroprotective effects of date seed extract were examined in rats affected by cerebral ischemia and found to decreases neuronal damage. Similarly, anxiolytic effect of a polyhedral formulation having seed extract of *Z. jujuba* is reported in mice.[75] In a study, the seed aqueous extract of *Tamarindus indica* proved to have potent antidiabetogenic activity.[100]

Extracted compounds can be used in food, pharmaceuticals, cosmetic, and chemical industries. They can also be used in food research in development of functional foods.

CONCLUSIONS

The researches in the field of by-products of fruit and vegetable have developed in past few years. Regarding pharmaceutical applications, numerous reviews related to bioactive compounds have been published.Understanding the benefits of polyphenols is difficult study. But it is essential for dietary recommendations. Numerous evidences have been generated by *in vitro* studies, animal studies in addition to epidemiological approaches. But the concrete proof from clinical trials is very limited.More data from well-designed long-term clinical trials are essential to confirm the results obtained from *in vitro* studies and animal studies.

It can be concluded that, by-products of fruit are important source of bioactive compounds. These could be better utilised instead of ending up as wastes. Besides utilizing them as animal feed or for methane production through anaerobic fermentation, these can be used in food, cosmetic as well as pharmaceutical industries. Interdisciplinary approaches must be carried out, correlated with efficient public awareness campaigns to reduce food waste.We will be able to prescribe the proper dietary recommendations in favour of a particular health benefit only after establishment of most effective concentration of a specific compound.

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