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A novel approach towards the fruit specific waste minimization and utilization: A review

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Abstract
India is the key producer of fruits in word. Although, utilization of fruits for processing is hardly 1.8% of the total production unlike developed countries. The various sectors of food processing industries are engaged in the production of different types of processed products and generating various types of wastes. These wastes, weather solid or liquid, if these wastes are not properly manage then it is direct loss of producer and also creates environment pollution problems. The waste utilization of fruit processing industries has become one of the main challengeable aspects in the world as well as in India. The waste materials (plant by-products) are rich in valuable compounds which can be utilized in various industries as novel, low-cost, economical and natural sources of dietary fiber, antioxidants, pectin, enzymes, organic acids, food additives, essential oils etc. through different methods of extractions, purifications and fermentations. Waste product which is thrown into the environment has a very good antimicrobial and antioxidant potentiality. These are novel, natural and economic sources of antimicrobics and antioxidants, which can be used in the prevention of diseases caused by pathogenic microbes. Many of the industrial fruit wastes have been exploited for biogas production to compensate for electricity needs in industrial sectors. The full utilization of horticultural produce is a requirement and a demand that needs to be met by countries wishing to implement low waste technology in their agribusiness. Studies and research to be needed to characterize some of the important bioactive compounds present in the fruits residues and prepare formulations based on such compounds that can be used as health foods. Waste prevention refers to three types of practical actions, i.e., strict avoidance, reduction at source, and product re-use. This review is the collection of previous reports along with current affords in the direction of possibilities of utilization of by-products different fruit processing in industries and to promote the integral exploitation of the by-products rich in bio-active compounds also to highlight the potential applications of some selected fruit by-products which are generated in fruit processing.

Keywords: Fruit waste, industrial waste utilization, by-products, waste management low-cost substrate

Introduction

The “fruit processing” industry in India is a sunrise sector. The Indian government giving preference to the establishing fruit processing units and marketing of value-added products. The Indian market is rich of raw fruits material but due to unproper management of raw material we are lost about 30-35 percent fruits commodity annually an inadequate infrastructure facilities and poor postharvest management practices are considered as main reason of this lose, the post-harvest production losses in India during from maturity to processing have been assessed to tune of Rs 75,00-1,00,000 crore per annum (Bisht *et al.*, 2013) [14]. Utilization of fruits for processing is hardly 1.8 percent of the total horticultural production unlike other developed countries. India has few and small units of fruit processing infrastructures which are not able to processed large quantity of raw materials. There are only 5166 processing units till 1st Jan, 2019 of fruit and vegetables products throughout the country. These units have no proper management of waste martial and its disposal (Joshi and Sharma, 2011; Bisht *et al.*, 2015) [42, 12].

Sometimes, the raw fruit is not consumed directly by humans and require processing to separate the desired value product from other constituents and produce large quantity of waste materials (Nand 1994) [73]. Although, these by products usually have significant value and rich in nutritional content which generally being underutilized in developing countries like India (Ayala-Zavala *et al.*, 2010) [7]. During the processing of fruits and vegetables, large quantities of solid and liquid wastes are generated. The waste obtained from fruits and processing industry is extremely diverse due to the use of wide variety of fruits and vegetables. As an example, tropical and subtropical fruits processing have considerably higher ratios of by-products than the temperate fruits (Schieber *et al.*, 2001) [78]. Due to increasing production and processing of fruits and vegetables day by day, the disposal and utilization of waste material is a big challenging aspect in developing countries because un proper management of waste material invites numbers of microbial spoilage and environment pollution. Although, in developing countries costs of drying, storage, transportation and shipment of by-products are not economically suitable (Varzakas *et al.*, 2016; Arvanitoyannis and Varzakas, 2008) [6, 87].

The by-products of fruits and fruit industries are rich sources of bioactive compounds like phenolic, antioxidant compounds, which can be use in increasing the stability of foods by preventing lipid peroxidation (Makris *et al.*, 2007) [54, 55]. Some Studies have been shown that the residues of certain fruits rich in antioxidant activity than the fresh fruit pulp (Gorinstein *et al.*, 2001) [35]. Thus, these residues could be used as an alternative source of nutrients to increase the nutritive value of poor people's diets and to help reduce dietary deficiencies (Da Silva *et al.*, 2013) [25]. Apart from these bio-active compounds, many researchers have identified that food processing by-products have different potential applications in various industries (Kodagoda and Marapana, 2017) [46]. A large amount of fruit wastes of fruit processing industry are generally dumped in landfills or rivers which creates environmental hazards. So need to such disposal methods which recycle it and produce livestock feed resources or to extract or develop value-added products (Wadhwa and Bakshi, 2013) [89]. The generation of wastes not only cause economic losses but would also require additional cost for their management and disposal. As a matter of fact, it is often estimated that proper use of efficient machinery and careful handling during various operations can lead to more than 50% reduction in losses. In general, the wastes from the food processing industries are either not utilized or primarily utilized as animal feed, fertilizer and in preparation of by-products on a limited extent. Many of the wastes such as cutting and shreds from the fruit processing industry can be utilized as an animal feed. Fruit wastes can also be used for extraction of starch, pectin, natural colouring matter, fat, essential oil etc. (Helkar *et al.*, 2016) [37].

These review summaries the available information on the composition, conservation methods, nutritive value and utilization of fruit wastes in different forms. It also covers aspects related to use of fruits wastes and possible generation of value-added products. This review may be useful for making of guideline of waste use and its disposal opportunities to the government policy maker.

Waste management concept

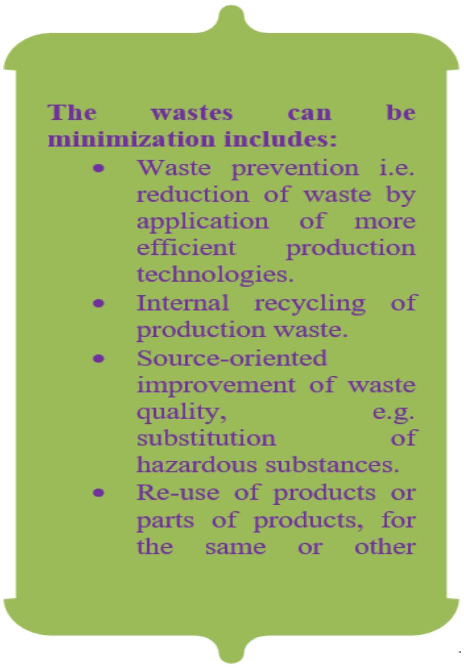

Fig 1: Waste minimization steps

Fig 2: Pre-information before the waste unit development

Waste: Waste is any materials which are unwanted and undesirable left-over after the completion of a certain process. There are many wastes types, i.e. municipal solid waste, commercial waste, hazardous waste, food processing waste etc. Management of waste and by-product of fruits and food industries can create problems within the areas of environmental protection and sustainability. The two general methods of traditional waste utilization are animal feed and as a fertilizer use.

Environmental legislation has significantly contributed to the introduction of sustainable waste management practices throughout the world. The objective of waste legislation is the prevention of waste generation. Waste prevention refers to three types of practical actions, i.e., strict avoidance, reduction at source, and product re-use. However, waste prevention does not only include the reduction of absolute waste amount but also avoidance of hazards and risks because safety is also of major concern.

Difficulties in waste disposal and management

Many types of waste material are produced by industries, either already loaded with large numbers of microbes or have potential to alter quickly through microbial activity e.g., maggots or molds. The breakdown of protein is always characterized by the generation of strong odors. The water content of fruits and vegetables ranged between 70 to 95% by mass. High water content increases transport costs of the waste and reduce the life of waste. Mechanically removing the water through use of a press can lead to further problems with waste water disposal, due to the high level of organic material in the water. Waste with a high fat content is susceptible to oxidation, which leads to the release of foul-smelling fatty acids. In many types of waste arising from vegetables and fruits, enzymes are still active, which accelerate or intensify the reactions involved in spoilage.

Fruit specific wastes and their products

Table 1: Quantities of various fruit processing wastes

Commodity	Percent weight basis
Apple	12-47
Apricot	08-25
Grape fruit	03-58
Orange	03.00
Peach	11-40
Pear	12-46

Source: Joshi and Sharma, 2011 [42].

Large amount of liquid and solid waste produced in fruit processing industries which may cause environment pollution problem if not utilized or disposed off properly. Unmanaged solid wastes have been seen to major threat to the environment and high risks to human health. Although, most of these solid wastes (peel, stone, rag, seed, core etc) are biodegradable and easily converted into valuable resources (William, 2005) [91]. The full utilization of horticultural produce is a requirement and a demand that needs to be met by countries wishing to implement low waste technology in their agribusiness. Although comprehensive information about the quantity of residue generated for different fruits is not available, some of the previous studies have indicated that banana peel accounted for about 30-40% of banana fruit weight. Kinnow peel, pulp and seeds account for more than 50% of the total fruit weight. Major wastes of mango processing industries are peels and stones, amounting for about 35-60% of the total fruit weight. Litchi seeds and pericarp account for about 19% and 13%, respectively of the fresh fruit weight. Waste from fruit processing industries are like Peel, rag and seed of citrus fruits; Pomace from apple and pear; Peel and stone in mangoes; Rind and seeds of jackfruit; Core and peel in guava; over ripe and blemished fruit from canneries; Stone from stone fruits (Gray, 2006).

Table 2: Fruit processing wastes available in India

Fruits	Nature of Waste	Production Content (tones)	Approximate waste (%)	Potential quantities of waste (tones)
Mango	Peel, Stones	6987.7	45	3144.4
Banana	Peel	2378.0	35	832.3
Citrus	Peel, rag and seed	1211.9	50	606.0
Pineapple	Skin, core	75.7	33	24.7
Grape	Stem, skin and seed	565	20	-
Guava	Peel, Core and seeds	565	10	-
Apple	Peel, pomace and seeds	1376.0	-	412

Source: Joshi and Sharma, 2011 [42].

Fruit waste utilization

Wastes of processing fruits are two types like solid waste (peel, skin, seeds, stones etc.) and liquid waste (juice and washed water). In horticulture, some fruit have high discarded portion like mango 30-50%, pineapple 40-50%, orange 30-50% and banana 20%. Therefore, in horticulture fruits waste disposal is very serious problem, which leads to problems with flies, unwanted microbial growth and rats around the processing unit. Therefore, there should be plans to use these waste otherwise it should be buried in soil away from the processing site.

The fruit wastes have huge microbial activity which create early spoilage of these waste in dumping area and highly prone to disease and harmful bacterial activity. Therefore, fruit waste should be disposed as early as possible by which we avoid disease problems. Further, it is not advisable to store-up wastes to use end of a week's production. Usually, seen that few fruits and vegetables contain mouldy fruit, insects, leaves, stems, soils etc, which will be contaminate any products made from it. Therefore, it is necessary to ensure that some preliminary separation takes place during processing (e.g. peel and waste pulp into one bin, mouldy parts, leaves, soil etc to another which is discarded, stones, seeds etc into a third bin).

Possible Product from fruit wastes

There are some possible new products which can be made through fruit waste. These products is highly rich in nutrient and minerals cotent and can be use in different ways. The six main possible products prepared by fruit wastes can be considered as candied peel, oils, pectin, reformed fruit pieces, enzymes and wine/vinegar

Candied peel

Citrus fruits peels can be use in preparation of candy and it further use either in baked goods or as a snack food. In addition, shreds of peel are used in marmalades and the process to make these is similar to candying. Candy of other fruit peels and shreds like melons and root vegetables can be use in baked goods.

Oils

Extract oil of stone of fruits like mango, apricot and peaches have good quality of oil content and desirable properties which can be use for culinary or perfumery/toiletry applications. Palm kernel oil is well established as both cooking and industrial oil. Moreover, seeds of fruits like grape, papaya and passion fruits have special quality of oil which may be use in medicinal industries. The crude oil may be sold for refining elsewhere, but it is likely that at least preliminary (or part) refining would need to be carried out by the producer. At present, we know of no detailed publications on the special refining requirements for these oils. It would seem necessary to contact the end-user to determine the quality required. It is also possible that the sale of seeds or stones to larger oil processors could generate additional income for small-scale fruit processors.

Pectin

There are major problems in extraction of pectin as follow:

a. In developing countries it has not been possible to produce pectin at a cost which is lower than the imported products.

b. It is difficult to produce pectin powder on a small-scale although liquid pectin is possible. There is not one type of pectin but many types - each of which has specific properties.

c. A detailed knowledge of pectin and its properties is needed to ensure that a producer is supplying the right product.

Fig 3: Limitations of pectin production

It is found in greater or lesser extent in most of fruits. Commercially, pectin is extracted from citrus peel and apple pomace. The high levels of pectin also reported in passion fruit. In most developing countries pectin is imported from Europe or USA and superficially at least there would seem to be a good market for supplying local fruit processors with pectin to substitute for imports.

Reformed fruit pieces

Fruit pulp can be recovered and formed into synthetic fruit pieces. It is a relatively simple process but the demand for this product is not likely to be high and evaluation of the potential market is strongly recommended before any work is undertaken. The process of this product involves boiling the fruit pulp to concentrate and sterilize it. Sugar may also be added. A gelling agent, sodium alginate is then mixed with the cooled pulp this is then mixed with a strong solution of calcium chloride. All ingredients are safe to eat and are permitted food additives in most countries. The calcium and the alginate combine to form a solid gel structure and the pulp can therefore be re-formed into fruit pieces. The most common way is to pour the mixture into fruit-shaped moulds and allow it to set. It is also possible to allow drops of the fruit/alginate mixture to fall into a bath of calcium chloride solution where they form small grains of reformed fruit which can be used in baked goods. Commercially, the most common product of this type is glace cherries.

Enzymes

The most common enzyme like papain, bromelain and ficin are extracted from papaya, pineapple, fig respectively and use in meat tenderizers, washing powders, leather tanning and beer brewing. However, it is unlikely to be economic to obtain these from waste fruit. Even the more efficient collection from fresh whole fruit is no longer economic and changes in both large-scale production (higher quality standards and use of biotechnology to produce 'synthetic' enzymes) mean that small-scale producers will be unlikely to compete effectively. In addition, there are moves to phase out the use of these enzymes in food products in Europe and USA and their market is therefore declining. In summary, these are not recommended as a means of income from waste utilization.

Wine/vinegar

Generally these products produced from fresh, high quality fruit juices in order to obtain high quality products, it is technically feasible to produce them from both solid and liquid fruit wastes. Solid wastes should be shredded and then boiled for 20-30 minutes to extract the sugars from the fruit and to sterilize the liquid. Several batches of waste may be boiled in the same liquid to increase the sugar concentration. This is then filtered through boiled cloth to remove the solids and cooled ready for inoculation with yeast. Liquid wastes should be separated during production to ensure that fruit juice is kept separate from wash water (e.g. the juice could be drained from a peeling/slicing table into a separate drum). The juice is then boiled for 10-15 minutes and treated as above.

Table 3: Utilization of fruit specific wastes

Fruits	References
Apple (*Malus domestica*)	
▪ Apples processing generates skin, stems, and residual flesh which are considered as a potential value-added food ingredient. ▪ Apple pomace of apple cider and juice processing industries accounts about 25% of fruit mass. Which is a rich source of dietary fiber and pectin (10-15% w/w dry basis)? ▪ Apple pomace has versatile functional properties like glucose diffusion retardation index, emulsifying activity, water-/oil-holding capacity, and antimicrobial activity. ▪ Various extraction methods have been developed over the past decade for the purpose of optimum pectin extraction from apple pomace as the demand for the fruit pectin are increasing due to their non-toxicity and biocompatibility. ▪ Apple pomace also contains a significant amount of non-starch polysaccharides (35–60% dietary fibre), with a high amount of insoluble fibre (36.5%) as well as soluble fibre (14.6%).	Wolfe *et al.*, 2003 [92] Sun *et al.*, 2007, Bushan and Gupta, 2013 [84, 18,] Younis and Ahmad, 2015 [93] Wang *et al.*, 2007, Bhushan *et al.*, 2008 [90, 11] Chen *et al.*, 1988 [22] Villas *et al.*, 2003, Sudha *et al.*, 2007 Masoodi *et al.*, 2002 [88, 83, [79, 16, 15] McCann *et al.*, 2007; Lu and Foo, 1997; [58, 51]

▪ A number of fibre enriched bakery products were prepared by adding dried apple pomace powder on a wheat flour replacement basis. ▪ Apple pomace is a good source of antioxidant like chlorogenic acid, phloretin glycosides and quercetin glycosides.	
Banana (*Musa acuminata*)	
▪ Peel is the main by-product of banana, which represents approximately 30% of the whole fruit, and is rich in phytochemical compounds, with high antioxidant capacity. ▪ Banana peels mix biscuits gives good colour, aroma, and taste, which make it suitable for the production of low-calorie food products with high dietary fiber content. ▪ Other notable innovations include the reported heavy metals sorption capacity of banana peels in removing chromium (III) and chromium (IV). ▪ Banana peels can be used to synthesise silver nanoparticles as it is rich in natural polymers such as lignin, hemicellulose and pectin. These bio-inspired silver nanoparticles displayed antimicrobial activity towards pathogenic fungi and most of the tested bacterial cultures.	Wadhwa and Bakshi, 2013 [89]; Mohapatra *et al.*, 2010; someya *et al.* [62, 81] Pranav *et al.*, 2017; Joshi, 2007 [70, 41] Memon *et al.*, 2008 [59,] Memon *et al.*, 2009; Bankar *et al.*, 2010 [60, 10]
Citrus (*Citrus* spp.)	
▪ The citrus peel contains a wide variety of secondary components with substantial antioxidant activity in comparison with other parts of the fruit. Citrus peel is a potential source of certain essential oils and yields about 0.5–3 kg oil/tonne of fruit. ▪ Food industry uses citrus peel as a source of molasses, pectin, oil and limone, and natural antioxidants for pharmaceutical, biotechnological and food industries. ▪ Orange peel comprises cellulose, hemicellulose, lignin, pectin, chlorophyll pigments and treated to obtain volatile and nonvolatile fractions of essential oils and flavouring compounds. Orange peel also showed germicidal, antioxidant, and anti-carcinogenic properties. ▪ Lemon (*Citrus limon*) peel's called flavedo, which is a rich source of essential oils that has been used since early times in flavoring and fragrance industries. ▪ The total phenolics content in peels of lemons, oranges, and grapefruit were 15% higher than those in the peeled fruits. ▪ Lime and lemon peel oils are widely used as aroma flavor and mask unpleasant tastes of drugs. Therefore, it has a higher market value per pound than orange, grapefruit, or tangerine oils. ▪ Lemon extracts used as anti-microbial packaging and enhance the self-life of mozzarella cheese.	Rafiq *et al.*, 2016; Mohapatra *et al.*, 2010 [72, 62] Seixas *et al.*, 2014; Braddock, 1995; Bocco *et al.*, 1998 [79, 16, 15] Khaskheli *et al.*, 2011; Feng *et al.*, 2009; Foo and Hameed, 2012; [44, 30,] Garcıa-Perez *et al.*, 2008 [33] Pranav *et al.*, 2017 [70] Gorinstein *et al.*, 2001 [35] Lota *et al.*, 2002 [50] Conte *et al.*, 2007 [24]
Grape (*Vitis vinifera*)	
▪ The wine-making industries produce millions of tons of residues (grape pomace) after fermentation, which represents a waste management issue both ecologically and economically. ▪ Grape pomace is considered as a valuable by-product for oil extraction, antioxidant and antibacterial agent preparation. Most grape dietary fibre and phenolics accumulate in the fruit skins, seed and pulp, which is generate as waste after making of juice. ▪ Grape pomace has been conducted as a potential functional ingredient in bakery products, seafood to reduce rancidity on ice storage, alternative fining agents for red wines, to remove red wine tannins and in dairy products to increase the dietary fiber, total phenolic content and to delaying lipid oxidation in yoghurt and salad dressings.	Fontana *et al.*, 2013 [31] Zhu *et al.*, 2015; 2013; Du *et al.*, 2011 [94, 29]
Mango (*Mangifera indica*)	
▪ Mango waste accounts about 75000 MT, and is on the rise due to growth in mango fruit production as well as processing industry. ▪ Mango seed kernel is major waste and ranged between 20 and 60%. The mango seed kernel oil has been reported to be a good source of polyunsaturated fatty acids such as oleic and linoleic acids which have health benefits. The mango peel powder is also rich sources of antioxidant and use in different value-added products. ▪ The carotenoid content was found to be 4–8 times higher in ripe mango peels compared to raw fruit peels. ▪ The total dietary fiber content in dry peel varied from 45 to 78%. The soluble dietary fiber content in both raw and ripe mangos peels are more than 35% of total dietary fiber. Insoluble dietary fiber relates to both water absorption and intestinal regulation whereas soluble dietary fiber associates with cholesterol in blood and diminishes its intestinal absorption. ▪ The mango kernel showed anti-microbial activity which represent rich sources of flavonoids and tannins. ▪ High antimicrobial and antifungal activity against *Staphylococcus aureus*, *Bacillus subtilis*, *Pseudomonas aeruginosa*, *Escherichia coli*, and *Candida albicans* has been reported in kernel powder of South African mango variety.	Dorta *et al.*, 2012 [28] Maisuthisakul and Gordon, 2009 [53] Oreopoulou and Tzia, 2007; Ajila *et al.*, 2011 [68, 4] Orijajogun *et al.*, 2014 [69] Kittiphoom and Sutasinee, 2013 [45] Ahmed *et al.*, 2005 [3]
Pineapple (*Ananas comosus*)	
▪ Pineapple by-products are mainly the residual pulp, peels, stem and leaves. Generally, processing residuals ranges between 45 to 65%. ▪ Peel is the major bio-waste of pineapple processing, which is potential substrate for methane, ethanol and hydrogen generation. ▪ The second major bio-waste is the core and can be used for the production of pineapple juice concentrates, alcoholic, non-alcoholic beverages or vinegar. ▪ Bromelain is already commercially available enzyme, which is often derived from the pineapple stem. Due to its strong proteolytic activity, this enzyme has been used in	Upadhyay *et al.*, 2013; Deliza *et al.*, 2005 [86, 27] Ketnawa *et al.*, 2012; Choonut *et al.*, 2014 [43, 23] Kodagoda and Marapana, 2017 [46] Arshad *et al.*, 2014; Bresolin *et al.*, 2013; [5, 17] Chaurasiya and Hebbar, 2013 [21] Huang *et al.*, 2011; Cassellis *et al.*, 2014; [38, 19] Dorta and Sogi, 2017.; Abdullah, 2008 [1, 28] Imandi *et al.*, 2008 [39]

numerous industrial applications such as a meat tenderizer, a bread dough improver, a fruit anti-browning agent, a beer clarifier, a tooth whitening agent, animal feed, and cosmetic substance and in textile industry. Bromelin can be extracted from different wastes of pineapple including stem, core and peel using different extraction and purification techniques. ▪ The pineapple by- products contain soluble and insoluble dietary fiber which may be used in the development of food reduced in calories and dietary fiber enriched food product. ▪ Pineapple waste has been used for the production of lactic and citric acids through submerged and solid-state fermentation. Lactic acid was produced from pineapple waste in a mini- fermenter having three litre capacities under anaerobic conditions with a stirring speed of 50 rpm, temperature of 40°C and pH of 6.0. ▪ Solid pineapple wastes also can be utilized as sole substrate for the production of citric acid using *Yarrowia lipolytica* through solid state fermentation. ▪ Vinegar can also be produced from the pineapple wastes using a two- stage fermentation process. ▪ Pineapple peels have been found to be promising feed for biogas generation, since they are rich in carbohydrates and proteins. ▪ Vanillin (4- hydroxy- 3- methoxybenzaldehyde) which is the main component in vanilla produced from the vanillic acid. Pineapple peel waste contains Ferulic acid, a precursor for vanillic acid. ▪ Pineapple peel wastes can also be used as a potential low-cost alternative adsorbent for Safranin-O removal from waste water.	Sossou *et al.*, 2009 [82] Rani and Nand 2004 [73] Tilay *et al.*, 2008; Lun *et al.*, 2014 [85, 52] Mohammed *et al.*, 2014 [61]
Pear (Pyrus communis)	
▪ The peel and core can be fermented into an alcoholic beverage called "Perry" which can also be converted into fruit vinegar by further acetic fermentation.	Joshi and Sharma, 2011 [42]
Apricot (*Prunus armeniaca*)	
▪ White apricot kernel is sweet and can be peeled and added to apricot jam to improve its appearance and consumer appeal. It can also be used in confectionery just like almond. ▪ The oil cake is very rich in protein and can be used as cattle feed. The cake oil may be also used in various cosmetic and pharmaceutical preparations such as massage oil, lotions etc.	Bisht *et al.*, 2015; Bisht *et al.*, 2016 [12, 13]
Jackfruit (*Artocarpus heterophyllus*)	
▪ Jackfruit tree produces around 200–500 fruits annually. At maturity, each fruit weighs approximately 23–50 kg. About 59% of the fruit's outer peel is composed of fiber, which is fairly rich in calcium and pectin.	Hameed, 2009; Foo and Hameed, 2012 [36, 32]
Peach (*Prunus persica*)	
▪ Peach kernel is used for extraction of the kernel oil in industrial.	Joshi and Sharma, 2011 [42]
Passion fruit (*Passiflora edulis*)	
▪ The thick hard rind of fruit and the seed is used for recovery of pectin and oil, respectively.	Joshi and Sharma, 2011 [42]

Fruit waste for animal feed and other purpose Mango peel

Pectin obtained from peel of mango provides good quality jelly and potential yield, hence can be commercially exploited to extract pectin (Chausa). Dashehari peel is rich in carotenoids and could be used for extraction of color.

Fig 4: Suitable mango varieties for pectin extraction

The peel and fibrous pulp are rich in sugars and can be used for preparation of wine and vinegar after fermentation. The polysaccharides of mango waste composing the major part of dietary fibers which are beneficial to diabetics and heart patients because the fibers lower blood sugar and serum cholesterol levels.

Mango seed kernel

Seed kernel contains 10% oil 9% pectin and 80-90% amino acid content. Therefore, it could be used to produce food mixtures of high nutritive value (Ravindran and Sivakanesan, 1996) [74]. The nutritive kernel cake may be used in animal feed. Mango seed kernel is rich source of carbohydrate and can be promote as chicken rations. Kernel fat can be as a substitute for cocoa butter (Narasimhachari & Azeemuddin, 1988)

Table 4: Possible by-products from solid wastes in fruit processing industries

Fruits	Waste (%)	Nature of waste	By products (%)
Apple	20-30	Pomace	Juice, wine, vinegar, pectin, cattle feed
Citrus			Essential oil, pectin, cattle feed, peel candy etc
1) Orange	50	Peel, seeds and pulp	
2) Lime	60	Peel, seeds and pulp	
Mango	40-60	Peel and pulp	Pectin, cattle feed, alcohol
Grape	12-15	Stem, skin and seed	Juice wine, syrup
Pineapple	30-60	Peel, core trimming, Shreds	Juice wine, syrup, bromiline Animal feed, seed oil etc

Banana waste

In India >30% banana production is rejected in market due to quality standard, these rejected produce could be use as livestock feed (Babatunde, 1992) [8]. Banana generates waste form of small-sized, damaged bananas, banana peels, leaves, young stalks and pseudo stems, which can be fed to livestock either chopped or directly in many tropical countries. Pseudo stems are easily ensiled if chopped and mixed with molasses or rice bran (Marie-Magdeleine *et al.*, 2010) [56].

Pine apple pomace

The pineapple fruit gives waste form of skins, crowns, fresh trimmings and the pomace after extracting the juice. Fresh pineapple cannery waste can be preserved either by drying or ensiling Pineapple bran is the solid residue of the pressed macerated skins and crowns. It can be fed either fresh, ensiled or after drying to the animals. Raw pineapple waste (on DM basis) contains 4−8 percent CP, 60−72percent NDF, 40−75 percent soluble sugars (70 percent sucrose, 20 percent glucose and 10 percent fructose) as well as pectin, but it is poor in minerals (Muller, 1978).

Potential future value-added products from horticultural wastes

The fruit and vegetable wastes or by-products of both in the organized and un-organized sectors are rich sources of bioactive compounds, which can be extracted and utilized in food, pharmaceutical and bio-fuel industries. Among them few are important and potential value-added products and their utilities are discussed below:

Essential oils

The citrus peels are a potential source of essential oil and yield 0.5 to 3.0 kg oil/tones of fruits (Sattar and Mahmud, 1986) [77], which is widely used in alcoholic beverages, confectioneries, soft drinks, perfumes, soaps, cosmetics etc (Njoroge *et al.*, 2005) [66]. It also enhances the shelf-life of fresh fruits due to broad spectrum anti-bacterial activity (Lanciotti *et al.*, 2004) [49].

Polyphenolic compounds

The concentration of total phenolic compounds in the peels, pulp/pomace and seeds of citrus fruits, apples, peaches, pears, yellow and white flesh nectarines, banana, pomegranate, mulberry, blackberry, tomatoes and sugar beet etc. is more than twice the amount present in edible tissue. Apple and grape pomace are rich in proanthocyanidins and flavonoids, banana in catechin and gallocatechin, carrot pomace in hydroxycinnamic derivatives like chlorogenic acid and dicaffeoylquinic acids (Puravankara and Sharma, 2000) [71]. The kinnow peel, litchi pericarp, litchi seeds and grape seeds can serve as potential sources of antioxidants for use in food and pharmaceutical industries (Babbar *et al.* 2011) [9]. The peel and pulp of guava fruits could be used as a source of antioxidant dietary fiber (Jimenez-Escrig *et al.*, 2001) [40]. Polyphenols reduce incidence of cardiovascular diseases and are thought to inhibit oxidation of LDL.

Edible oils

The mango seed kernel is rich source of edible oil and its fatty acid and triglyceride profiles are similar to cocoa butter. Seeds of Guava and passion fruit usually discarded during processing of juice have good amount of essential fatty acids (Adsule and Kadam, 1995; Cassia Roberta Malacrida and Neuza Jorge, 2012) [2, 20,].

Pigments

Pigments are rich sources of anthocyanin and carotinoids, which are easily extracted from banana bract and beet root pulp. They are free radical scavengers and preventactive oxygen-induced and free radical-mediated oxidation of biological molecules (Pedreno and Escribano, 2001; Canadanovic *et al.*, 2011) [95, 96].

Food additives

The uses of horticultural wastes for further exploitation of food additives or supplements with high nutritional value have gained increasing interest. It is well known that they are rich source of sugars, minerals, organic acid, dietary fibre and phenolics which have a wide range of action which includes anti tumoral, antiviral, antibacterial, cardioprotective and antimutagenic activities. In the food industry, synthetic antioxidants, such as butylated hydroxyanizole and butylated hydroxytoluene, have long been used as antioxidant additives to preserve and stabilize the freshness, nutritive value, flavour and colour of foods. Now it can be substitution by natural ones. The antioxidant compounds from waste products of the food industry could be used for protecting the oxidative damage in living systems by scavenging oxygen free radicals, and also for increasing the stability of foods by preventing lipid peroxidation (Makris, Boskou and Andrikopoulos, 2007) [54, 55].

Dietary fiber

Dietary fiber of fruits and vegetables has beneficial effect rather than cereals fiber because of horticultural fiber is soluble dietary fiber, whereas cereal fibers contain more insoluble cellulose and hemicelluloses. Fruit and vegetable wastes like apple, pear, orange, peach, blackcurrant, cherry, artichoke, asparagus, onion and carrot pomace, mango peels and cauliflower trimmings are used as sources of dietary fibre supplements in refined food. Citrus and apple fibers have better quality than other dietary fibers due to the presence of associated bioactive compounds, such as flavonoids, polyphenols and carotenes (Sharoba *et al.*, 2013) [80].

Enzymes

Trimmings and peels of horticultural residue might contain a range of enzymes which have a wide range of applications in food industries (Krishna and Chandrasekaran, 1996) [47]. The kinnow pulp and wheat bran may be used as filter paper cellulase (FPase) activity. Apple pomace may be use for production of lignin, manganese peroxidase and laccase production. Peels of sapota and citrus can be used for the production of pectinase (Saravanan and Viruthagiri, 2012) [76].

Citric acid

It is used mainly in foods and pharmaceuticals. Since many years, citric acid is manufacturing through fermentation of starch/molasses. Recently, citric acid production has been produced through fruit and vegetable pomace and cassava bagasse (Kuforiji and Odunfa, 2010) [48].

Bio-ethanol

The major quanties of waste can be use in production of biofuel in both the form like liquid and gases. Among them, ethanol is major important farm of waste production. it generally produced by use of many waste like patato peel, apple pomace, banana waste, beet waste and peach waste (Sandhu *et al.*, 2012; Oberoi *et al.*, 2011) [75, 67].

Bio-gas

Generally very minute quantity (0.5%) of fruit wastes are converted in useful products and others are disposed off. Fruit wastes are used to produce biogas by using anaerobic batch digester reactors with the help of rice bran and cow dung. Cow dung influences digestion of fruit wastes and showed highest yield (405 mg) of biogas production (Narayani and Priya, 2012) [65]. An effort made to utilize fruit and vegetable waste for generation of bio-methane by anaerobic digestion method by (Dasa and Mondalb, 2013) [26].

Single cell protein

The single cell protein can be making through the bio conversion of fruit waste, which may be helpful to solve the world wide food protein deficiency by obtaining an economical product for food and feed. The quality and quantity of single cell protein production depends on the type of substrate used and also on media composition. Single cell proteins can be produced from dried and pectin extracted apple pomace (Gautam and Guleria, 2007) [34].

Compost

The horticultural waste can be composted and used to replace a significant part of the mineral nitrogen fertilization with nitrogen recovery of 6–22 percent. The Long-term use of horticultural waste resulted add in significant amount of carbon accumulation in the top soil, which improve the nitrogen status of soil as well as availability of other essential nutrient (Tits *et al*., 2012).

Conclusion

The waste from fruit processing industry is a rich source of many utilizable components. This has become a serious problem as the production of fruits and vegetables increases, they influences environment and pollute it. Therefore, it is need to be managed and utilized in proper way. Further exploitation of the fruit processing by-products as sources of functional ingredients and possible applications has become a promising field and global requirement due to the increase in the concern towards the environment and increasing population of world. Natural functional compounds from fruit processing wastes can be used to replace synthetic additives adding multifunctional concepts by combining health benefits to technological use. Novel scientific and alternative technologies should be used to extract the optimum levels of bio-active compounds as well as other compounds of economic importance from the fruit wastes. The combined effort of waste minimization and sustainable utilization of the by-products would substantially reduce the large quantities of fruit wastes accumulated globally.

It has also proven by many researchers that a number of by-products i.e. pectin, alcohol, vinegar, animal feed, colours, essence etc. can be manufactured from various types of fruit waste, besides reducing pollution problems. Most of the Fruit wastes like citrus pulp; banana and mango peels etc. are a rich source of nutrients and these can be fed either as such, after drying or ensiling with cereal straws, without effecting the palatability, nutrient utilization, health or performance of livestock. The effective and efficient utilization of fruit wastes will reduce the cost of animal feeding thereby increasing farmers' profits, generate an array of value-added products and help in waste management and reduction of environmental pollution.

The primary aim of waste legislation is the prevention of waste generation. Waste prevention includes to three types of practical actions like strict avoidance, reduction at source, and product re-use. However, waste prevention does not only include the reduction of absolute waste amounts but also avoidance of hazards and risks.

Fig 5: Waste legislation and prevention

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