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Fruit and Vegetable Waste (by-Product) Utilization in Bakery Products-A Review

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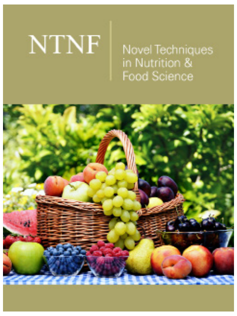

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Abstract

Household and industrial activities like peeling, cutting and sorting of raw fruits and vegetables prior to processing, eating, cooking produce regularly enormous waste and are the cause for the environmental & health problem if it is not disposed of properly. The pomace, leftovers, peels, seeds cut-off of whole fruit are the wastes of Fruit and Vegetable (FVW). These wastes are rich sources of dietary fiber, polyphenols, antioxidants, essential fatty acids and carotenoids etc., which exhibits health-promoting effect like protection against cardiovascular diseases, cancer, and other degenerative diseases. Bakery products such as cake, muffins, biscuits, bread, cookies etc. can be fortified with the FVW. Incorporation of different wastes in different forms and proportion alters the physio-chemical properties and improves their functionality. This paper presents the utilization of wastes (by-products) from Fruits & vegetables in bakery products. In addition, health benefits of polyphenols, ascorbic acid, carotenoids are addressed.

Keywords: Fruits and vegetable waste; Dietary fiber; Polyphenols; Carotenoids; Antioxidant activity; Ascorbic acid; Bakery products

Abbreviations: MPP: Mango Peels Powder; WSI: Water Solubility Index; WGP: White Grape Pomace; GSE: Grape Seed Extract; MKP: Mango Kernels Powder

Introduction

India ranks second after China in production of both fruits and vegetables in the world. As per the National Horticulture Database published by National Horticulture Board, during 2015-2016 (1st estimate) India produced 89018 (000'MT) of fruits and 168506 (000'MT) of vegetables. The processing of fruits and vegetable generates the substantial quantity of waste/by-products. According to the FAO, the food processing waste and the food losses roughly contributed to about 1.3 billion ton/year [1]. The 10-60% of raw material as the waste product is produced by fruits and vegetable processing industries can thus add value addition. As in *citrus* processing industry, *citrus* juice concentrate come out as a waste which is even more valuable than the main product. In fact, waste from one industry plant could become the raw material of another processing plant, and utilization of waste rather than disposal of waste should be the goal of the industry. The nutrients or the compounds present in the wastes have a positive effect on bowel health, management of weight, lowering of blood cholesterol and improving the control of glycemic responses. Hence baked goods which have high glycemic index can accommodate the wastes of fruit and vegetables [2-5].

Components of Waste

FVW (Table 1) range from pomace (leftovers), peels, seeds, to cut-offs and whole fruit and vegetable [6]. Usually, the peel, pomace, and seeds accounts for 20-45% in fruits & vegetables. Peel is the outer skin or the protective covering in fruits and vegetables. Peel a tough-layered skin is present in some fruits like pomegranate; passion fruit, mangosteen etc., have a tough layered skin called as rind whereas in *citrus* fruits like in oranges, it is termed as zest. The outer cover/Peel protects the underlying edible portion of fruit from the environment, micro, and macro-organisms and indeed has several phytonutrients which help to keep up our health. Moreover, peels have been demonstrated for antioxidants, anticancer, anti-inflammation, and antivirus activities, which can be associated to the presence of polyphenols. Pomace, a solid material remains of apple, grapes, olives or other fruit after extraction of juice or oil [6]. It consists of the skin, pulp, seeds, and stems of the fruit. The antioxidant property and rich source of fiber and polyphenols of pomace, plays an important role in the prevention of diseases. Grapes are processed for wine or juice production generates grape pomace which is approximately 20-50% of the fruit mainly consisting of pulp, skin, and seed [7]. Seeds, the unit of reproduction of a flowering plant, are usually small, round or oval in shape and when planted can produce another plant.

Table 1: Nature of wastes and possible by-products from the waste of fruit processing units: Swamy, 2008.

Fruit	Waste (%)	Nature of Waste	By-Product
Mango	40-60	Peels, stones, and wastes from pulping machines	Starch, fat, pectin, vinegar syrup, alcoholic beverages
Pineapple	30-60	Peel cores and trimmings	Vinegar syrup, citric acid, bromelain, biogas, candied cores, stock feed.
Grape	5-10	Stem seeds, seed hulls	Cream, tartar seed oil, tannin, culls vinegar, pectin, wines, stock feed
Apples	20-30	Pomace, cores, cull fruits	Pectin, cider beer, vinegar, soft drink, jelly base
Citrus Orange Lime	50-60	Peels, pomace, seed	Pectin, essential oil, seed oil etc.
Banana	24-46	Peels	
Peaches Apricot Almonds Cherries	-	Fruit piths, kernel	Fixed oil, bitter almond oil, stock feed
Tomato	20-30	Core, peel, and seeds	Animal feed and seed oil, meal
Potato	5-40	Peels & coarse solids	Animal feed, single cell protein

Benefits of Waste

FVW is an abundant source of antioxidants, polyphenols, carotenoids, dietary fibers etc. Consumption of these compounds have been demonstrated to have health-promoting effects and protection against cardiovascular diseases, cancer and other degenerative diseases [8,9] and also these waste have application in the pharmaceutical, cosmetics and food industry (Bucic-kojic et al. 2009) [10]. Apple pomace has shown to be a good source of polyphenols such as catechins, hydroxycinnamates, procyanidins, quercetin glycosides and phloretin glycosides are mainly present in peel [11-15], whereas *citrus* fruits exhibited a good source of flavonoids such as hesperidin, narirutin, naringin and eriocitrin and fiber-pectin, cold-pressed oils, essences, d-limonene, juice pulps and pulp wash, ethanol, seed oil, pectin, limonoids [16,17]. Grape pomace has been a source of catechins, phenolic acids, anthocyanins, proanthocyanidin, flavonol glycoside and stiblene, as well as calcium, iron and dietary fiber whereas grape skin and seed extracts are effective in scavenging DPPH free radical, hydroxyl radical, superoxide anion, and authentic peroxynitrite and preventing cataract, diabetes, and inflammation [18-21] reported that grape dietary fiber significantly reduced the lipid profile and blood pressure and these effects were significantly greater than those caused by either oat fiber or psyllium, and this might have been due to the combined effect of DF and antioxidants present in grape. Carrot pomace, the natural source of antioxidants, alpha and beta-carotene that can served as health-promoting effect [22]. Apple pomace exhibited a good source of polyphenols. The polyphenols namely catechins, hydroxycinnamates, phloretin glycosides, quercetin glycosides were found to be the major compounds identified or isolated from pomace and phenolic constituents which exhibit strong antioxidant activity. Onion peel being a major waste produced has abundant amount of polyphenol and flavonoids compounds. Dried onion peel had 422mg gallic acid equivalents/100g and 22212mg catechin equivalents/100g [23]. Also, it was effective in scavenging DPPH free radicals and inhibited polyphenol oxidase activity. Banana peel constitute up to 30% of fruit and the carotenoids found were demonstrated to be xanthophylls esterified with myristate, and to a lesser extent with laurate, palmitate or caprate. Banana peels are a good source of dietary fiber and contain mainly lignin (6-12%), cellulose (10-21%), hemicelluloses (6.5-9.4%) and galacturonic acid [24]. Mango peels have been a good source of dietary fiber, antioxidants, protein, vitamins and extractable polyphenolics and also contain considerable amounts of P, Ca, Mg, K, Cu, Fe, Zn and thus has potentials for future food supplements (Samia et al. 2012). Guava seeds, waste during guava juice processing, contain about 5-13% oil and is rich in essential fatty acids and also peel of guava has shown to be a good source of antioxidants and dietary fiber. Mango seed kernel fat can be used as source of edible oil. Mango seed kernel fat has been shown to have similar fatty acid and triglyceride profile as of cocoa butter, can be used as a cocoa butter equivalent. The phenolics were assumed to be mainly gallic and ellagic acids and were thus a rich source of natural antioxidants. Ethanolic extracts of mango seed kernels were to be more effective against Gram (+) than against Gram (-) bacteria (Table 2). The tomato seeds account which accounts for approximately 10% of the fruit and 60% of the total waste are a source of protein (35%) and fat (25%). Tomato seeds are good source of unsaturated fatty acids, especially in linoleic acid. Grape peel was found rich in minerals namely calcium, magnesium, phosphorus and potassium and vitamin A, while the seed had high values of vitamin C and total phenols. Jamun seeds contain micronutrients like Vitamin C, thiamine, riboflavin and niacin. It is also good source of essential minerals i.e., iron, potassium, and calcium, low in fat and cholesterol content and good for diabetes.

Table 2: The dietary fiber content in fruit wastes.

By-Products	Dietary Fiber (%)	References
Banana peel	35-50	Emaga et al. [58]; Wadhwa & Bakshi [70]
Lime peel	61.5	Larruari JA et al. [63]
Mango peel	9.33	Ashoush et al. [54]
Orange peel	69.1	Larruari et al. [63]
Orange peel	74.87	Nassar et al. [53]
passion Fruit Peel	57.93	Hernandez-Santos et al. [61]
Watermelon peel	33.8	Wadhwa & Bakshi [70]; Al-Sayed & Ahmed [25]
Muskmelon peel	59.3	Wadhwa & Bakshi [70]
Guava Peel	15.2	Bertagnolli et al. [55]
Apple pomace	51.10	Sudha et al. [34]
Carambola pomace	36.6	Pantaleon-Velasco et al. 2014, Sudha et al. [39]
Grape pomace	50.93	Mildner-Szkudlarz et al. [38]
Grape seed	40	Hussein & Abdrabba [62]
Papaya seed	5.19	El-Safy et al. [42]
Apple seed	8.32	El-Safy et al. [42]
Watermelon seed	3.47	El-Safy et al. [42]
Guava seed	64.67	El-Safy et al. [42]
Orange seed	5.50	El-Safy et al. [42]
Apricot seed	3.43	El-Safy et al. [42]
Pear seed	49.60	El-Safy et al. [42]
Paprika seed	33.83	El-Safy et al. [42]

Waste Utilization in Bakery Products

Peels

Mango Peel Powder (MPP) used in biscuit formulation having a total dietary fiber, total polyphenols and total carotenoids of 51% and thus the total dietary fiber content increased from 6.5 to 20.7% with a high proportion of soluble dietary fiber. 20% MPP increased the content of polyphenols and carotenoids from 0.54 to 4.50mg/g and 17 to 247µg/g respectively. Acceptable mango flavor biscuits were obtained by incorporating 10% MPP which were found high in dietary fiber and with improved antioxidant properties [9]. Hanan [25] studied the use of Watermelon Rind (WMR) and Sharlyn Melon Peel (SMP) powders at 2.5%, 5.0%, and 7.5% levels in cake batter. The increase in the levels of WMR results into the increase in the volume and specific volume of the baked cakes and sensory scores concluded that 2.5% substitution of flour with WMR and SMP powder produced an acceptable cake with no significant difference from the control cake. Cakes prepared by substituting fat with WMR and SMP had a comparable increase in peroxide and acid value with cakes containing BHA, indicating the potency of peels in inhibiting the free acids and peroxides formation. Similarly, banana peel which is high in phenolic content when used in Whole Meal Bread (WMB) showed higher inhibition of lipid peroxidation (16.55±5.04%) compared to that of control sample (6.99±2.80%) after seven days of storage and hence improved the product shelf life. [26,27] studied the incorporation of pomegranate and banana peel flour in the preparation of bread and found the bread was rich in antioxidant, stable to staling and also contained 10-fold higher dietary fiber when compared to the control bread sample, hence nutritionally and sensorily accepted bread could be prepared by replacing 10% of flour. Banana peel in wholemeal bread at 7% incorporation increased the dietary fiber and phenolics, which in turn inhibited the lipid peroxidation during storage of bread [26]. Control and banana peel breads showed similar growth of yeast and mould on 7-day storage period. The antimicrobial activity of the peel was due to the presence ß-sitosterol, malic acid, succinic acid, palmitic acid, 12-hydroxystearic acid, glycoside and d-malic acid, which are mostly active against Bacillus subtilis, Staphylococcus aureus and Pseudomonas aeruginosa [28,29] and the presence of 3,4-Dihydyoxybenzaldehyde played as an antifungal compound [30]. [31] sprayed essential oils of citrus peels on all slices of bread and proved to be most effective inhibitory treatment against the bacterial and fungal spoilage. Similarly, [32] used apple fruit peel as a good source of dietary fiber and phenolic content in the preparation of muffins and incorporated up to 16% without affecting the overall acceptability of the cakes.

Pomace

Apple pomace in cake formulation improved the volume, symmetry index and increased the batter viscosity [33] whereas in another study, apple pomace has been found to be used as a source of dietary fiber, polyphenol which has good antioxidants property and also served as a flavoring ingredient in cake making [34]. Masoodi et al. [33] incorporated the apple pomace in the preparation of wheat bread as a source of dietary fiber and found that the firmness value, baking time, water absorption increased whereas loaf volume and sensory parameters decreased. Bread with 5% pomace was found to be better in terms of odor and taste. Dehydrated apple pomace incorporated buns, muffins and cookies exhibited better free radical scavenging as well as cyto/DNA protective properties suggesting the retention of bioactivity after baking. It also potentially enhanced the bioactivity of the products [35]. Carrot pomace being a rich source of carotene and other vitamins was used in cookie preparation at different proportions and also studied for rheological characteristics. [22] found that there was an increase in hardness and color of the cookies with the increase in pomace level. Incorporation of carrot pomace increased the redness values (a*) signifying the increase in redness, which was evident from the red/orange carrot pomace color. Results showed that carrot pomace used at 6%. [36] reported that with an increase in pomace proportion in the bun formulation the lateral expansion and surface expansion of the buns decreased from 147.65% to 115.93% and 513.33% to 366.25% respectively. The bulk density and moisture content increased. The increase in bulk density was due to the incorporation of carrot pomace thereby decreasing the starch proportion, which is mainly responsible for the expansion. Hence the reduction in expansion resulted in an increase in bulk density. The Water Solubility Index (WSI) and Water Absorption Index (WAI) decreased from 3.62 to 2.19%, and 4.07 to 1.67g/g respectively. The decrease in values was attributed to the reduction in the amount of the starch available for gelatinization for degradation due to increase in the pomace proportion [37]. To investigate the influence of White Grape Pomace (WGP) on rheological, neutraceutical, physical and sensory properties, WGP was used at levels 10, 20 and 30% (w/w) in the biscuit formulation. It was found that the addition of 10% WGP caused an approximately 88% increase in total dietary fiber content and antioxidant properties. The brightness and yellowness of cookies all enriched samples was disturbed as WGP favoured browning reaction due to the presence of more sugars [38]. The DPPH scavenging activity of biscuits with white grape pomace showed a six-fold increase when compared to control biscuits. This was mainly attributed to the presence of gallic acid and catechin which have shown to possess high antioxidant activity. The IDF/SDF ratio which is considered to be nutritionally significant increased from 3.71 to 4.8. Turksoy & Ozkaya used Pumpkin Pomace Powder (PPP) and Carrot Pomace Powders (CPP) at 10, 15, 20, 25% levels in cookies preparation as a source of dietary fiber and enriched cookies had 1.5-2 times higher breaking strength values than control, whereas the spread ratio decreased (Table 3). Incorporation of the pumpkin pomace powders increased the yellowness (b value) and decreased with the addition of carrot pomace powder. Nutraceutical properties of cookies has been shown to be improved when supplemented with pumpkin and carrot pomace powder. Antimicrobial properties of Carambola fruit pomace were used in bread formulation in order to inactivate Bacillus species (potential rope spore causing bacteria). Carambola pomace at 5% was used instead of chemical preservatives and it was found that rope spore count owed a count of 0.7log10/g in carambola pomace while the bread with no preservatives had a count of 8.76log10/g. Bread prepared were safe for longer with added high dietary fiber [39].

Table 3: Antioxidant and phenolic content in wastes. db-dry basis; wb-wet basis; TE: Trolox Equivalent; GAE-Gallic Acid Equivalent.

Wastes	Antioxidant Activity	Phenolic Content	References
Mango Peel	10.13mmol/100gwb	--	Guo et al. [60]
Ridge guard peel	--	6830mg/kg	Padmashree et al. [64]
Apple peels	312.2μmol of vitamin C equivalents/g of peels & 1701mg TE/100g	588.9mgGAE/100g of peels & 1144mgGAE/100g	Wolfe et al. [72] & Wijngaard et al. [71]
Passion Fruit Peel	41.98mg ascorbic acid/ 100gdb	461.81mgGAE/100g	Hernandez-Santos et al. [61]
Date Peel	16.69mmol/100gwb	--	Guo et al. [60]
White pomegranate peel	82.11mmol/100gwb	--	Guo et al. [60]
Orange Peel	5.69mmol/100gwb	--	Guo et al. [60]
Plum Peel	8.09mmol/100gwb	--	Guo et al. [60]
Mango peel	93.89%	19.06mgGAE/g	Ashoush et al. [54]
Banana peel	3.16mmol/100g	158mg/100g	Guo et al. [60] & Someya et al. [67] & Wadhwa & Bakshi [70]

Muskmelon peels		0.7%	Wadhwa & Bakshi [70]
Watermelon peels	0.62mmol/100g	1.4% & 2.4mgGAE/g	Guo et al. [60], Wadhwa & Bakshi [70], Al-Sayed & Ahmed [25]
Kiwifruit peel	1803mgTE/100g	820mg GAE/100g	Wijngaard et al. [71]
Guava peel	10.24mmol/100g	827mgGAE/100g	Guo et al. [60] & Bertagnolli et al. [55]
White cabbage cut-offs	449mgTE/100g	341mgGAE/100g	Wijngaard et al. [71]
Cauliflower cut-offs	535mgTE/100g	402mg GAE/100g	
Broccoli stems	761mgTE/100g	494mg GAE/100g	
Grapefruit peel	1389mgTE/100g	2335mg GAE/100g	
Carrot pomace		4.3%	Wadhwa & Bakshi [70]
Carambola pomace	328.9(µmolTE g-1db)	5.6(gGAE 100gdb)	Pantaleon-Velasco et al. 2014
Apple pomace	1435mgTE/100g	10.16mg/g & 870mg GAE/100g	Sudha et al. [34] & Wijngaard et al. [71]
Grape pomace	250.56mmol TE/gdb	31.22mgGAE/gdb	Mildner-Szkudlarz et al. [38]
Grape seed	55.54mmol/100g	9109.22mg/100g	Guo et al. [60] & Hussein, & Abdrabba, S. [62]
Mango seed	14.59mmol/100g	23.90mgGAE/100g	Guo et al. [6] & Ashoush et al. [54]
Date seed	37.42mmol/100g	3650mg GAE/100g	Shams Ardekani et al. [66]

Seeds

Guava seed meal is high in fiber, iron and essential fatty acid linoleic acid was used in cookie preparation [40]. Farinograph characteristics of GSM-wheat flour blends showed the GSM decreased the water absorption, dough development time and stability and increased the dough weakening. Also, post baking, improvement was observed in the volume, specific volume, diameter and thickness of the cookies. 6% guava seed meal gave an acceptable cookie (Table 4). In another study, Grape Seed Extract (GSE) as a supplement increased the antioxidant activity of the bread when compared to control. However, 30-40% less was observed due to thermal processing. GSE-fortified bread is promising to be developed as a functional food with relatively lower Carboxymethyl-Lysine (CML) [41] whereas [42] studied Grape Seed Flour (GSF) in a cereal bar, noodles, and pancakes for DPPH free radical scavenging activity. The highest radical scavenging activity was observed in pancakes containing GSF (25 & 30%), noodles with GSF (20%) and cereal bars having GSF (5%) with consumer acceptance. Muffins were prepared by using Date Seed flour Hydrolysate (DSFH) (2.5%) or Date Seed flour (DSF) (2% and 5%) as a functional ingredient. Muffins with DSFH were highly acceptable with respect to texture and flavour. However, muffins enriched with DSF had lower sensory acceptance but were found to be a good source of dietary fiber and ash content [43]. Both date seed flour and hydrolysate showed radical scavenging activity, also muffins had 60% angiotensin converting enzyme (ACE) inhibition with the IC_{50} value at 16.7mg. Biscuits fortified with Jamun seed powder at 0, 2.5, 5, 7.5, 10% levels resulted in an increase in moisture content gradually during storage. Biscuits prepared were high in content of ash, protein, fat and dietary fiber and also recommended to Diabetic patients [44]. Cookies fortified with Jamun seed powder resulted in enhanced total phenolic content and antioxidant activity. Cookies had scored high in sensory such as colour, appearance, flavour, crispness, taste and overall acceptability [45]. Resistant Starch (RS) and Apricot Kernel Flour (AKF) has been used as a fat replacer in cookies and further effects of fruit powders like apple or apricot as wheat flour replacer on the quality of low-fat cookies were investigated (Ibrahim et al, 2010). Replacement of fat mainly affected the textural characteristics of cookies. Also, substitution resulted in increase in total dietary fiber content. Apricot powder was more suitable flour replacer than apple powder in low-fat cookies. In one of study, Cake margarine prepared by blending Mango Kernel Fat (MKF) with palm oil and vegetable fat was used in muffin preparation. 50% replacement of commercial margarine with experimental margarine was acceptable. The fatty acid composition of MKF incorporated muffin showed a decrease in palmitic acid and trans fatty acid and increase in stearic acid content [46]. Wheat flour substituted with pumpkin seed flour (15%), full fat and defatted ground cantaloupe seeds increased the crude protein, potassium and phosphorus contents of composite cookies, thus leading to therapeutic functional food products [25,47]. Bread made with various pumpkin seed products (raw, roasted, germinated, fermented, autoclaved, pumpkin protein concentrates and isolates) resulted in bread with increased level of lysine, sulphur containing amino acids, crude protein, protein digestibility and therefore found this study as good source of proteins and nutrients for fortification of bread. [48] substituted jackfruit seeds in noodles and found noodles to be low in fat and moisture content whereas the protein, ash, and crude fiber content increased and thus improved the overall nutritional value of the noodles. However, substitution of jackfruit seed flour to the wheat flour in bread increased the fiber content. Bread prepared using composite flour consist of refined Wheat Flour (WF), Soy Flour (SF) and sprouted Mungbean Flour (MF) as a source of protein and Mango Kernel Flour (MK) at different levels and found that composite flour in lower proportions yielded bread with similar physical and organoleptic properties as refined wheat flour bread [49].

Table 4: Utilisation of wastes in bakery products. DM-Dry Matter; TE: Trolox Equivalent; GAE-Gallic Acid Equivalent; MPeF-Mango Peel Flour; MPP-Mango Peel Powder.

Fruit/ Vegetable Waste	Baked Product and Level (%)	Parameters		References
Peels				
Mango	Cake (30% MPeF)	Total Dietary fiber (%)	2.82 to 26.46	Vergara-Valencia et al. [52] Ajila et al. [9], Noor Aziah et al. [2]
		Soluble dietary fiber (%)	0.52 to 9.26	
		Insoluble dietary fiber (%)	2.30 to 17.20	
		HI	34.26±0.45 to 17.86±0.43	
		pGI	58.52±0.25 to 49.51±0.24	
	Biscuit (20% MPP)	Total phenolic content (mgGAE/g)	1.59±0.05 to 9.45±0.70	Ajila et al. [57,9], Ribeiro et al. [65] Ashoush et al. [54]
		Scavenging activity %	26.13±0.05 to 88.84±0.31	
	Biscuit (20% MPP)	Polyphenolics (µg GAE/g)	540±2 to 4500±50	Ajila et al. [9]
		Carotenoid (µg/g peel)	17±3 to 247±14	
		Scavenging activity (IC_{50} in mg)	250±32 to 4.3±0.3	
		Total Dietary fiber (%)	6.5±0.2 to 20.7±0.8	
		Soluble dietary fiber (%)	3.67±0.3 to 12.50±0.2	
		Insoluble dietary fiber (%)	2.80±0.1 to 8.20±0.4	
Banana Peel Flour (BPF)	Wholemeal bread (7% BPF)	Total dietary fiber (%)	11.3-14.4	Nasution et al. [26]
		Total phenolic content (mg GAE/g)	29.50±2.06 to 36.06±1.90	
Banana and Pomegranate Peel Powder (BPP, PPP)	Bread (5%)	Ascorbic acid (mg/100g)	0.886 to 1.05	Suresh et al. [27]
		Fiber (g)	0.97 to 9.8	
		Total phenol content (micro-GAE/g)	0.118 to 0.201	
Pomace				
Apple pomace	Cake (25%)	Total dietary fiber (%)	0.47±0.14 to 14.20±1.04	Sudha et al. [34]
		Soluble fiber (%)	0.3±1 0.02 to 8.40±0.79	
		Insoluble fiber (%)	0.16±0.06 to 5.80±0.68	
		Total phenol content (mg/g)	2.07 to 3.15	
	Bun (15%), muffins (30%) and cookies (20%)	RBC protectively IC_{50}µg/mL	2.1-4.9	Sudha et al. [68]
		IC_{50} (µg/mL)	6.9-20.2	
Grape pomace	Biscuit (30%)	Total dietary fiber (g/ kgDM)	34.44±1.07 to 110.30±2.11	Mildner-Szkudlarz et al. [38]
		Soluble fiber (g/kgDM)	27.12±1.36 to 91.30±1.75	
		Insoluble fiber (g/kgDM)	7.33±0.39 to 19.00±0.36	
		Total phenol content (mgGAE /gDM)	0.85±0.02 to 4.45±0.04	
		DPPH (mmolTE /gDM)	1.27±0.03 to 7.55±0.05	
Seeds/Kernels				
Mango kernel powder (MKP)	Biscuit (50%)	Total phenolic content (mg GAE/g)	1.59±0.05 to 24.37±0.35	Ashoush et al. [54]
		Scavenging activity (%)	26.13±0.05 to 91.57±0.11	
Guava seed meal	Cookies (9%)	Crude fiber (%)	0.52 to 3.90	Shams El-Din et al. [40]
		Iron (mg/100g)	0.62 to 1.15	
Date seed	Muffins (2.5%)	Scavenging activity (IC_{50})	27.7±0.3 to 66.1±1.2	Priyatharini et al. [44]
		Dietary fiber (%)	10.1 to 12.5	

Fiber concentrate

Dietary fiber is defined as the sum of non-starch polysaccharides which includes lignin, hemicelluloses, pectin, β-glucans and gums [50]. The dietary fiber content of these wastes ranged between 54.2% and 98.8% dry matter [51]. Sudha ML et al. [35] studied Dehydrated Mango Pulp Fiber Waste (DMPFW) in muffin preparation as a source of dietary fiber, polyphenols and carotenoids. The muffins were nutritionally rich with the bioactive. Similarly, Mango Dietary Fiber (MDF) incorporated in bread and cookies and showed that these bakery products were low in hydrolysis index and predicted glycemic index as compared to control and also had higher total dietary fiber and good antioxidant capacity [52].

Waste in combination

The sponge cake prepared using Mango Peel Flour (MPeF) and Pulp Flour (MPuF) were found to be high in dietary fiber and low in fat, calories, hydrolysis and glycemic index predicted comparable to control. On increasing mango peel and pulp flour level showed an impact on the volume, firmness, and color. Addition of 10% MPuF and 10% MPeF found to be the most acceptable [2]. Nassar AG et al. [53] studied the biscuit preparation from blends containing the different proportion of (0, 15, 25%) orange peel and pulp and evaluated for chemical composition, rheological properties, physical and sensory characteristics. There was an increase in dietary fiber content (2.73 to 15.31%), and ash content, while protein and fat content decreased. 15% orange pulp and peel in the formulation of biscuits were found to be highly acceptable. Effect of Mango peel powder (MPP-5, 10, 15 & 20%) and Mango kernel powder (MKP-20, 30, 40 & 50%) on antioxidant properties of biscuits were evaluated (Table 1). In this study, it has been found that there was an increase in water absorption (60.4 to 67.6%) when incorporated by MPP while a decrease in case of MKP. At different levels of MPP & MKP in biscuits resulted in increased content in phenolics from 3.84 to 24.37mg/g of biscuits. Acceptable biscuits were prepared using 10% MPP & upto 40% MKP with mango flavour and improved antioxidant activity [54]. Similarly, [55] also studied the Mango Kernels Powder (MKP) and Mango Peels Powder (MPP) at 5, 10 & 15% replacing levels in preparation of biscuits and found there was increase in crude fiber content from 0.22 to 16.79% and also phenolic contents increased from 0.43 to 10.28mg/g. Biscuits with 10% MPP and 5% MKP were found highly acceptable [56-60].

Conclusion

Fruit-vegetable waste from the processing industry comprising of peel, seed, kernel, stones, pith, hulls, pomace is high in dietary fiber, phenolic content and mostly show the antioxidant property [61-65]. These wastes can be used as supplementation in wheat-based baked products such as bread, cakes, biscuits, muffins, noodles, pasta etc. for the enrichment of the nutritional profile of the products. They would be a source of natural flavor and color in place of synthetic ones. These wastes would hence provide the majority of nutrients of fruits, provide several health benefits, the functional property of foods and can also have a preservative effect [66-72].

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