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Utilization of fruit and vegetable pomace as functional ingredient in bakery products: A review

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ABSTRACT

Dietary fibre is an important component of diet conferring plethora of health benefits and helps in prevention of various diseases. Plant foods are particularly associated with high amounts of dietary fibre. Large amount of pomace produced from juice and wine industries presents cheap source of dietary fibre. Fruit and vegetable pomace represents a novel ingredient for fibre enrichment in bakery products owing to its better functionality due to balanced ratio of soluble/insoluble fibre, better hydration properties, better fermentability and presence of phytochemicals. Source of pomace and its processing to form powder by various pre-treatments, drying techniques and size reduction has influence on its functionality. Fruit and vegetable pomace can be used to improve the functionality of food by the virtue of its functional properties. Variety of fruit and vegetable pomaces are used in wide array of bakery products like biscuits, buns, cookies, crackers, cakes, muffins, wheat rolls and scones. Fruit pomaces tend to amalgamate well with bakery products and confer them better sensory properties. An important intervention of fruit and vegetable pomace is the improvment of the storage quality of baked products due to its associated antioxidants. Thus, fruit and vegetable pomace can be used as effective functional ingredient for development of fibre rich bakery products.

Key words: Bakery, Dietary fibre, Fruit and vegetable pomace, Functionality, Valorisation.

Plant foods like cereals, vegetables, fruits and nuts are associated with dietary fibre, though the amount and composition of dietary fibre may vary from food to food (Desmedt and Jacobs, 2001). Foods rich in non-starch polysaccharides have high amounts of dietary fibre ranging from 20–35 g of fibre per 100 g on dry weight basis in contrast to starchy foods that constitutes 10 g per 100 g of dry weight.

The content of fibre of fruits and vegetables is 1.5–2.5 per 100 g of dry weight (Selvendran and Robertson, 1994), however it is due to high moisture content of fruits and vegetables and pomace left after juice extraction contains high amount of it. Fruits and vegetables account for nearly 90% of the total horticulture production in the country. India is the second largest producer of fruits and vegetables in the world and is the leader in several horticultural crops (Ministry of Agriculture & Farmers Welfare, 2016). The surplus fruits and vegetables can be processed in a number of ways like canning, freezing, dehydration and processing into juice. Juice processing is an important sector of fruit processing and many fruits and vegetables are used for the extraction of their use. However, juice processing industries also produce significant amount of pomace as a by-product which is not finding any proper use except for the use as an animal feed or land filling (Sahni and Shere, 2017).

Fruit and vegetable wastes represents good source of dietary fibre due to high dietary fibre content, being inexpensive, and having high water binding capacity and relatively low enzyme digestibility (Serena and Kundsen, 2007). Many fruits and vegetables are used for the extraction of their juices and waste left after juice extraction can be used for recovering dietary fibre and phytochemicals for incorporation in food products. Dietary fibres are potent food ingredients owing to their physiological role in conferring good health as well as for imparting techno-functional properties in food matrix in order to allow their utilization as novel ingredient for the valorisation of food products (Sharoba *et al*., 2013; Schieber *et al*., 2001; Thebaudin *et al*., 1997). In order to take advantage of the dietary and functional properties of fibre, some high dietary fibre formulated foods are currently being developed (Sharoba *et al*., 2013; Grigelmo and Martin, 1999a; Herbafood. Herbacel AQ Plus, 2002; Tudorica, 2002). Thus, demand for a unique fibre ingredient will continue and fibres from fruit and vegetable waste represents good prospects as novel ingredient in market shelves and for the supplementation of food products (Sloan, 2001).

Currently, wide array of by-products are used for preparation of dietary fibre powders (Femenia *et al*., 1997). Commercialized dietary fibre powders should have total

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dietary fibre content above 50%, moisture lower than 9%, low content of lipids, a low caloric value and neutral flavour and taste and must perform in a satisfactory manner as a food ingredient when used for valorisation of food product (Larrauri *et al*., 1997; Larrauri, 1999; Jaime *et al*., 2002). Pomace is the residue remaining when fruits are processed for juice, wine, or other products. Many studies have reported that fruit pomaces contain abundant phenolic compounds (Lu and Foo, 1997; Ruberto *et al*., 2007). Hence, pomace obtained from the juice and wine industry might be useful raw materials for creating new value-added products. Thus, present review gives insights regarding the functionality of fruit and vegetable pomace and its utilization for valorisation of bakery products.

Health benefits of dietary fibres: Dietary fibre (DF) has become subject of marketing owing to increase in lifestyle diseases due to inadequate consumption of fibre in the diet. Dietary fibre confers beneficial effects on human health as they are resistant to hydrolysis by the alimentary enzymes of man; with complete or partial fermentation in the large intestine; and majorly constitutes hemicellulose, cellulose, lignin, oligosaccharides, pectins, gums and waxes (Trowell *et al*., 1985; AACC, 2000). A healthy individual should consume 20-35 g of dietary fibre per day. Lack of adequate dietary fibre in the diet is associated with constipation, diverticulosis, cardiovascular disease, and cancer (Trowell *et al*., 1985). Diets constituting high amount of dietary fibre have manifestation in prevention, reduction and treatment of diseases like coronary heart diseases, colon cancer and diabetes (Figuerola *et al*., 2005; Nawirska and Kwašniewska, 2005). Various studies have demonstrated the positive impact of dietary fibre in treating these diseases. Ferguson and Harris (1996) reported that dietary fibre may protect against colorectal cancer by providing good intestinal health by virtue of its functional property and by products of fermentation in large intestine by bacteria. High dietary fibre intake is manifested with decreased consumption of simple carbohydrates. Although, dietary fibre contributes to the total caloric content of a diet but is much more resistant to digestion by the small intestine and even somewhat resistant in the large intestine. Also, dietary fibre tends to decrease fat digestibility. These could be associated with decreased metabolizable energy of the diet high in fibre (Baer *et al*., 1997).

Diets high in saturated fat, low dietary fibre and high non structural carbohydrates significantly increase the risk of developing type two diabetes owing to high glycemic load of diet due to high amounts of easily digestible and rapidly absorbable carbohydrates (Hu *et al*., 2001). High DF consumption is associated with treating diabetes due to slower rise in the blood sugar level. Strong inverse relationship exists between dietary fibre intake and diabetes when adjusted for age and body mass index. Consumption of an average of 26 g per day of dietary fibre resulted in lowering risk of developing diabetes by 22% in comparison to women only consuming 13 g per day (Meyer *et al*., 2000).

DF consumption has been correlated with colon health and is known to prevent various diseases associated with colon. Consumption of DF alleviates constipation and facilitates regularity by adding bulk to stool and speeding up the passage of foods through the digestive system. Insoluble fibre tends to reduce transit time in colon whereas as soluble fibre increase bulk and soften texture of stool; and makes stool easy to pass. High fibre diets increase wet and dry fecal weights than low fibre diets. In high fibre diets, bran diets retain higher fecal moisture, cecum lengths and stomach weights as compared to cellulose diets; however, high cellulose diet has manifestation with increased colon weight (Kahlon *et al*., 2001). Also, the prebiotic effect of fibre has profound role in maintaining good colon health. Olano-Martin *et al.* (2002) observed that pectin stimulated the growth of certain strains of *Bifidobacteria* and *Lactobacillus in vitro*. These bacteria are considered to be directly related to the health of the large intestine and their concentrations depict a healthy microflora population. Manifestation of high fibre diets with weight reduction is owing to increased satiety. Koh-Banerjee *et al.* (2004) reported that for every 40 g/d increase in whole grain intake, weight gain decreased by 1.1 lbs.

High fibre diets are associated with prevention of cardiovascular diseases and this is particularly associated with high excretion of cholesterol in the faeces. High excretion of cholesterol is associated with *in vitro* binding of bile acids. Increasing proportions of oat bran, total and insoluble dietary fibre, as well as beta-glucan in pre-digested oat-based extrudates has been shown to increase the in vitro binding of bile acids (Drzikova *et al.*, 2005). Diet particularly high in water-soluble fibre protects against cardiovascular diseases. Theuwissen and Mensink (2008) reported that many well-controlled intervention studies have shown that water-soluble fibre (β-glucan, pectin and guar gum) effectively lower serum LDL cholesterol concentrations, without affecting HDL cholesterol or triacylglycerol concentrations.

Fibres having cation exchange capacity and phytic acid (e.g. cereal fibres) have been found to depress the absorption and retention of several minerals. However, certain highly fermentable fibres like pectin, gums, resistant starches, cellulose, fructo-oligosaccharides, inulin improves metabolic absorption of certain minerals like calcium, magnesium and iron, even when phytic acid is present at lower concentrations (Tungland and Meyer, 2006).

Fibre from fruit and vegetable waste: Fruits like grapes, apples, orange, pineapple and guava etc. which are mainly utilized for production of juice produce significant amount of peel and pomace. This waste represents significant losses and could lead to high cost of final processed products, if not recovered by appropriate means (Schieber *et al*., 2001).

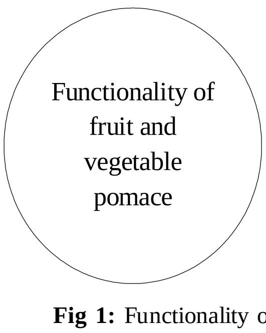
Larrauri (1999) reviewed methods for production of high dietary fibre powders from fruit by-products and the potential preparation of those fibres with associated bioactive compounds. It has been found that while milling and screening have been the main steps in obtaining high dietary fibre powders from cereals; wet milling, washing, drying and dry milling are very important in producing fibres from fruits.

Numbers of studies have been conducted for exploration of fruit and vegetable as source of fibre. Orange peel residues can be good source of dietary fibre. Fibre fraction can be obtained after pectin extraction of orange peels by nitric acid and ethanol. Fibre fraction obtained contains high amount of soluble (213 g/kg) and insoluble (626 g/kg) dietary fibre on a dry basis (Aravantinos-Zafiris *et al*., 1994). Larrauri *et al.* (1997a) prepared high dietary fibre powders from Valencia orange and Persa lime peels and found that fibres from both peels had high total dietary fibre content (61-69%) with an appreciable amount of soluble fibre (19-22%). Grigelmo-Miguel *et al.* (1999) characterised peach dietary fibre concentrate for food use. Total DF constituted 31% dry matter of the concentrate with 20% insoluble and 11% soluble dietary fibre on dry basis. Nawirska and Kwasniewska (2005) determined the amounts of particular dietary fibre fractions in samples containing apple, black currant, chokeberry, pear, cherry and carrot pomace. The results revealed that in each pomace sample, pectins occurred in the smallest amounts, and the content of lignin was very high in black currant and cherry pomace and comparatively high in pear, chokeberry, apple and carrot pomace. Ubando-Rivera *et al.* (2005) determined the dietary fibre composition and antioxidant capacities of Persian and Mexican lime peels. The total dietary fibre contents of both varieties were 70.4% and 66.7%, respectively. Both lime peel varieties had an appropriate ratio of soluble/insoluble fractions. The water-holding capacities of DF concentrates were 6.96–12.8 g/g and it was higher in the DF concentrate of Mexican lime due to high content of soluble DF.

Apple has been used in juice processing as well as cider production and can produce large amount of pomace. Industrial apple pomace resulting from a modern apple juice production plant can be considered as a raw material for direct preparation of dietary fibre, since it contains above 50% of total DF. Raw material that cannot be used for dietary fibre preparation due to its high polyphenol content can be used for production of phytochemical concentrates (Kołodziejczyk *et al.*, 2007). Also, apple skin is a rich source of dietary fibre and phenolics. The blanched, dehydrated, and ground apple skin powder contains approximately 41% total dietary fibre (Rupasinghe *et al*., 2008).

Dietary fibre concentrates extracted from date fleshes showed high contents ranging from 88% -92%, with 67% extractability (Elleuch *et al*., 2008). Asparagus by-products can be used for preparing high dietary fibre powders by various methods. Treatment in water for 90 min at 60 °C was found to contain highest dietary fibre content and lowest was found in fibres extracted in ethanol for 1 min at room temperature. Solubility and oil holding capacity of freeze-dried fibre was higher than oven-dried fibres (Fuentes-Alventosa *et al*., 2009). Pomace is rich source of dietary fibre and contains fewer amounts of other components in some fruits. Dietary fibre in the pomace of plum was five to nine times higher than that in the fruit (Kosmala *et al*., 2013) and pineapple pomace showed low fat and protein content and had dietary fibre as one of its major components with the insoluble fraction accounting for the majority of the fibre (Selani *et al.*, 2014).

Physicochemical and functional properties of pomace: ''Ideal dietary fibre'' should not have nutritionally objectionable components, should be in highly concentrated form possible, free from any taste, colour and odour; have a appropriate and balanced associated bioactive compounds; have a good shelf life; have congeniality with food processing operations; and exert physiological effects (Larrauri, 1999). It is very essential to understand that fibre enrichment has profound role on techno-functional properties and thus affects the overall sensory characteristics of the food by virtue of water binding and enhancement of viscosity (Kethireddipalli *et al*., 2002). Dietary fibres from fruits and vegetables have better quality in comparison to fibres from cereals. Fibres of fruits and vegetables have well balanced soluble and insoluble fibre content, better functional properties viz. hydration(Grigelmo-Miguel and Martin-Belloso, 1999) and oil absorption capacity and good colonic fermentability, low caloric value, lower amounts of anti-nutritional factors and association of bioactive compounds (Fig 1).



Low caloric value
Water holding capacity
Oil absorption capacity
Water retention property
Good colonic fermentability
Well balanced insoluble and soluble fibre content
Lower amounts of anti-nutritional factors
Association of bioactive compounds
Antioxidant property
Fat replacer

Fig 1: Functionality of fruit and vegetable pomace

Optimizing the process of development fruit fibres will allow lesser loss of bioactive compounds. However, such losses will also be less if whole pomace will be used instead of isolated fibres (Larrauri *et al*., 1997). Functional properties of fruit and vegetable fibres will be dictated by source of fibre, proportion of soluble and insoluble fibre, particle size, and extraction condition (Jaime *et al*., 2002). Sahni and Shere (2017) observed highest swelling capacity in carrot pomace powder followed by beetroot and apple pomace powder. Sharoba *et al.* (2013) also reported higher water holding and swelling capacity of carrot pomace as compared to orange waste, potato peels and green pea peels. However, as aforesaid in addition to source of fibre, other factors also comes into picture which dictates that functional properties of fruit and vegetable pomace powders.

Particle size of fibre is an important factor that has profound role in dictating functional properties as well as important digestive processes like transit time, fermentation and fecal excretion. Particle size of the fibre depends on the nature of cell wall polysaccharides, and on degree of processing it has undergone (Dhingra *et al*., 2012). Studies have shown that particle size affect the hydration properties (Auffret *et al*., 1994; Raghavendra *et al*., 2006). Sahni and Shere (2017) studied particle size distribution of apple, carrot and beetroot pomace powder and found that pomace powders majorly consisted of particles sized less than 150 μm and lowest percentage was of particles sized 150 μm. High water retention capacity was also manifested with the high percentage of large particle size which maintains the fibre structure. Particle size has major role in swelling capacity was observed owing to porosity of fibre. Increase in swelling capacity as the particle size was decrease from 1127 to 550 μm. Further reduction in size up to 390 μm resulted in a decreasing swelling capacity. Increase in particle size beyond 550 μm resulted in a decrease in water holding and retention capacities (Auffret *et al*., 1994).

The hydration properties of fibre are important for its physiological role as well as for its interventions in techno-functional properties of the food. Hydration property of fibre governs its efficacy in stool bulking. Water holding capacity, water retention capacity and swelling capacity provide information regarding the hydration capacity of fibre and give insights regarding its behaviour during gut transit and food processing (Dhingra *et al*., 2012). Good hydration properties of pomace powders will allow its use as functional ingredient in food products as high water holding capacity tend to exert their physiological effect by absorbing water in the gut and resulting in stool bulking (Sahni and Shere, 2017). However, studies have shown that high affinity to water could have detrimental effect on the texture of the processed food (Chen *et al*., 1988; Sharoba *et al*., 2013; Sahni and Shere, 2016). Washing during the preparation of dietary fibre powder enhance the water holding capacity along with reduction of browning during the drying of pomace (Lario *et al*., 2004). Chen *et al.* (1988) documented high water holding capacity of apple fibre and its use as dietary fibre source and humectant in some food products. Kohajdova *et al.* (2012) observed that carrot pomace powder has good hydration properties and tend to influence water absorption, dough development time and dough stability; and mixing tolerance index of dough. Sudha *et al.* (2007) documented increased water absorption from 60.1% to 70.6% and decrease in peak viscosity from 950 to 730 BU and cold paste viscosity from 1760 to 970 BU with increase in apple pomace from 0% to 15%.

Oil absorption capacity of fibre depends on structure and chemistry of the plant polysaccharide, its surface properties, overall charge density, thickness, hydrophobic nature of the fibre particle, particle size and drying (Carme *et al*., 2007; Fernandez-Lopez *et al*., 2009; Figuerola *et al*., 2005; Sharoba *et al*., 2013). Oil absorption capacity of fibre increases with decrease in particle size and Sahni and Shere (2017) observed highest oil absorption capacity in carrot pomace powder as compared to apple and beetroot pomace due to small particle size of carrot pomace powder. Raghavendra *et al.* (2006) observed increased hydration properties by reduction in the particle size from 1127–550 μm, and the hydration properties were found to decrease with decrease in particle size beyond 550 μm. The oil absorption capacity was also reported to increase with decrease in particle size.

Fruit and vegetable pomace have high amount of crude fibre content which justify their use for fibre enrichment in the food products. Sahni and Shere (2017) observed high crude fibre content of 21.51%, 17.94% and 11.12% in apple, carrot and beetroot pomace powder respectively. In some cases fruit and vegetable pomaces can have fair amounts of lipids and high ash content; and thus their supplementation in food will also increase mineral content along with enrichment of fibre (Shyamala and Jamuna, 2010; Sahni and Shere; 2017). Figuerola *et al.* (2005) evaluated some functional properties of fibre concentrates from apple and citrus fruit residues and found that all fibre concentrates had a high content of dietary fibre, with a high proportion of insoluble dietary fibre. Protein and lipid contents ranged between 3.12 and 8.42 and between 0.89 and 4.46 g/100 g dry matter respectively. Shyamala and Jamuna (2010) reported that moisture content of pulp waste from carrot and beetroot ranged from 79 - 84% whereas protein content was 6.21mg/100g and 13.23 mg/100g respectively. The antioxidant activity was 40% and 78% for carrot and beetroot pulp waste respectively. Antioxidant activity of beet root pomace is owing to phenolics, flavanoid, anthocyanin, and betaxanthins in beetroot pomace (Čanadanovic-Brunet *et al*., 2011).

Drying of pomace: Drying of pomace is an effective method to reduce its bulk and to ensure better shelf life. Low moisture content of pomace powders is important for maintaining good storage stability by preventing deteriorative reactions because of high water activity (Sahni and Shere, 2017). Singh *et al.* (2006) osmotically dried the carrot pomace by dipping in 65°Brix sucrose syrup and by adding 35% sucrose dry powder to the pomace followed by convective dehydration at 60°C temperature up to 4-5% moisture content and packaging under vacuum in aluminum laminated package. Wang *et al.* (2007) evaluated the characteristics of thin layer microwave drying of apple pomace with and without hot air pre-drying in a laboratory scale microwave dryer and observed that nearly 70% of total drying time was spent to remove the latter half of moisture (wb) in the microwave drying with or without pre-drying.

Interventions of pre-treatment of pomace on its functionality have been documented by some studies. Chantaro *et al.* (2008) reported that blanching has a significant effect on the fibre content and composition, water retention and swelling capacity of the fibre powder whereas drying temperature in the selected range did not affect the hydration properties. Alam *et al.* (2013) studied the effect of pre-treatments and methods of drying on quality of dried carrot pomace powder and found that citric acid blanching pretreatment followed by convective drying at 65°C was best combination for retaining the quality attributes of carrot pomace.

Method of drying has been documented to influence the final quality and characteristics of dried pomace powder. Mechanical drying was found superior to the sun drying for drying of carrot pomace and resulted in better retention of β-carotene (9.86 to 11.57 mg/100g) whereas increasing temperature from 60 to 75ºC resulted in decreased retention (22.95 to 13.53 mg/100g) of ascorbic acid (Upadhyay *et al*., 2008). Optimal drying was observed at 65ºC on the basis of β-carotene and ascorbic acid retention. Lavelli and Corti (2011) reported that air-drying at 60ºC was better than vacuum-drying at 40 ºC in terms of anthocyanin and flavanol retention with no adverse effect of drying on flavonols, dihydrochalcones and hydroxycinnamic acids.

Functionality of fruit and vegetable pomace in bakery products: Fruit and vegetable pomace powders can be used as inexpensive, non-caloric bulking agents in food for partial replacement of flour, fat or sugar, as they tend to improve the functionality of food by enhancement of water and oil retention and improved emulsion stability (Elleuch *et al*., 2011). Recent trend in development novel fibre sources due increased importance of fibre in diet has lead to exploration of new sources of fibre and its incorporation in food (Chau and Huang 2003). Supplementation has been focused on cookies, crackers and other cereal-based products, enhancement of fibre content in snack foods, beverages, spices, imitation cheeses, sauces, frozen foods, canned meats, meat analogues and other foods has also been investigated (Hesser, 1994).

Baked products are often employed for incorporating new sources of functional compounds such as dietary fibre and bioactive compounds (Ktenioudaki, 2013).Variety of plant fibres are added to various baked products to increase their fibre content (Masoodi *et al*., 2001). Bran of various cereals, hulls of legumes and pomace of fruit and vegetables is commonly used to improve the fibre content of baked products (McKee and Latner, 2000). Baked products, particularly biscuits and cookies are good carrier for fibre enrichment, since they have become indispensible part of our life and are ideal for supplementation due to palatability, compactness, convenience and long shelf life of the product and being widely consumed by every individual irrespective of age (Sahni, 2017; Wade, 1988). Utilization of various fruit and vegetable pomaces in bakery products has been highlighted in Table 1.

Colour and appearance is an important parameter for the likeability of the consumer and helps consumer in judging quality of baked products. Some fruits tend to be rich in polyyphenols which might act as substrate for enzymatic browning in baked products and tend to product dark product. Sahni (2015) reported that incorporation of apple pomace powder had marked negative effect on colour of the cookies with the increase in the level of supplementation and resulted in the darkening of the cookies. Mir *et al.* (2017) observed same trend for colour of crackers incorporated with apple pomace. Fruit pomaces tend to improve taste and aroma of bakery product by amalgamation of fruity and baked taste and aroma of the baked product. Apple pomace has been found to impart its typical flavour to bakery products and tend to improve its acceptability. Increase in taste and flavour score of cakes and cookies with apple pomace powder is attributed to peculiar fruity taste and flavour of apple. However, further supplementation decreased the taste score due to slightly bitter after taste due to high polyphenol content of apple pomace powder (Sudha *et al*., 2007; Sahni, 2015). Ajila *et al*. (2008) also reported slight bitter taste in biscuits with 20% mango peel powder in the biscuits due to high polyphenol content.

As aforesaid, good hydration properties also tend to affect the final characteristics of the products incorporated with pomace powders. Numerous studies have been carried out that documented the effect of incorporation of fruit and vegetable pomace on bakery products. Huge quantities of apples are being processed by juice processing and thus number of studies reported utilization of apple pomace in bakery products. Chen *et al.* (1988) observed that addition of apple fibre decreased the loaf volume of bread, and spreading in the cookies and increased the density of muffin.

Table 1: Juice processing waste as functional ingredient in bakery products.

Source	Bakery Product	Reference
Apple pomace	Cookies	Sahni, 2015; Sahni and Shere, 2017b
	Crackers	Mir *et al.*, 2017
	Baked scones	Reis *et al.*, 2014
	Cake	Sudha *et al.*,2007
Apple fibre powder	Cookies	Chen *et al.*, 1988;
		Kohajdová *et al.*, 2011
Apple skin	Muffins	Rupasinghe *et al.* (2008)
		Kumar and Kumar, 2011;
Carrot pomace	Cookies	Hernández-Ortega *et al.*, 2013;
		Sahni and Shere, 2017a; Sahni and
		Shere; 2017b
		Gayas *et al.*, 2012; Baljeet *et*
	Biscuits	*al.*,2014
		Kohajdova *et al.*, 2012
	Wheat rolls	Kumar and Kumar. 2012
	Buns	Sharoba *et al.*, 2013
	Cake	
Orange pomace	Muffins	Romero-Lopez *et al.*, 2011
	Cake	Sharoba *et al.*, 2013
Beetroot pomace	Cookies	Sahni and Shere, 2016; Sahni and
		Shere, 2017b
Mango peel	Soft dough biscuits	Ajila *et al.*, 2008; Bandyopadhyay
	Cookies	*et al.*, 2014

Sudha *et al.* (2007) noticed the decrease in volume and increased density of the cake incorporated with apple pomace. Sensory evaluation of the cakes showed that the scores for crust decreased only at 30% level of addition of apple pomace as crumb colour changed from creamish yellow to brown colour and due to more compact and dense cells. Rupasinghe *et al.* (2008) found that the total dietary fibre content, total phenolic content, and total antioxidant capacity of muffins were positively correlated to the amount of apple skin powder incorporated into muffins. The mean percent recovery of quercetin glycosides, catechins, chlorogenic acid, phloridzin, and cyanidin galactoside after baking were 61%, 57%, 53%, 44%, and 20%.

Apple fibre powder incorporation in cookies has negative effect on specific volume and volume index of cookies with reduced thickness and width of products; and decrease lightness and increased redness (Kohajdová *et al.*, 2011). Reis *et al.* (2014) developed functional extruded snacks and baked scones using apple pomace and it was successfully added up to 20% in extruded snacks and 30% in baked scones. The incorporation in baked products increased the fibre content with no effect on the chemical composition of the products when compared to the control.

Studies have reported that addition of carrot pomace tend to improve the colour of bakery products in contrast to darkening with apple pomace. Hernández-Ortega *et al.* (2013) utilized microwave dried carrot pomace as a source of fibre and carotenoids in cookies and repoted profound increase in dietary fibre content (3.7 fold) with 30% level of incorporation and improved sensory properties of the cookies. Like any other pomace powder, carrot pomace powder also tend to harden bakery products owing to its water binding capacity. Kohajdova *et al.* (2012) reported that wheat rolls with 5 and 10% carrot pomace powder were significantly harder than wheat rolls prepared only from fine wheat flour. Incorporation at level of 10 % negatively affected loaf volume. Increase in the supplementation resulted in appreciable darker crust colour of wheat rolls and incorporation up to 3% was acceptable. However, Sahni and Shere (2017a) reported that carrot pomace powder was acceptable in cookies upto 10 % level of incorporation owing to attractive colour and better taste and flavour. Incorporation of carrot pomace tend to increase the L* and a* values with the increase in proportion of carrot pomace in cookies, whereas no pattern of change was observed in b* value with change in proportion of carrot pomace (Kumar and Kumar, 2011). Kumar and Kumar (2012) found that incorporation of carrot pomace decreased the lateral expansion and surface expansion and increased the bulk density of bun.

Studies have been conducted for utilization of carrot pomace along with other ingredients in the cookie formulation. Gayas *et al.* (2012) prepared carrot pomace powder enriched defatted soy flour fortified biscuits and reported increase in moisture, ash and beta carotene and decrease in protein content in biscuit with increase in the level of carrot pomace powder. Baljeet *et al.* (2014) utilized of carrot pomace powder and germinated chickpea flour in biscuits and observed increase in the spread ratio and protein content of the biscuits with the increase in carrot pomace powder and germinated chickpea flour in the blends. It is important to note that in contrast to aforesaid studies, the protein content and spread ratio increased by increased in level of incorporation and thus it gives insights for utilization of blends with multiple ingredients to fine tune the required nutritional and sensorial properties.

Mango processing also produces significant amount of waste in the form of peels that can be used for fibre enrichment. Mango dietary fibre concentrate can be used as effective bakery ingredient. Bakery products prepared with mango dietary fibre have well balanced soluble and insoluble dietary fibre, anti-radical efficiency and low glycemic index (Vergara-Valencia *et al.*, 2007). Incorporation of 20 % mango peel powder decreased spreading, increased hardness and soluble dietary fibre in soft dough biscuits whereas mango peels and kernel powder could be utilized up to 30% in cookie formulation to enhance its nutritional quality without affecting the textural and sensory properties (Ajila *et al*., 2008; Bandyopadhyay *et al*., 2014).

Orange baggase has high amount of insoluble DF and its addition in muffins upto 15 % resulted in increased total dietary fibre with a higher content of insoluble dietary fibre, increased ash content, decreased protein content and no change in moisture and fat content (Romero-Lopez *et al*., 2011). Orange waste and carrot pomace can be used for valorization of cakes at 5 and 10% without affecting the quality attributes. However, water absorption, dough stability and dough development and resistance to extension values increased and extensibility values decreased significantly by increasing the level of incorporation from 0 to 20% (Sharoba *et al*., 2013). Beetroot pomace can be excellent source of phytochemicals along with dietary fibre. However, beetroot pomace powder rendered the cookies dark and thus can be used only upto 10 % level where it improved the acceptability of cookies due to better taste and flavour. The incorporation of beetroot pomace resulted in poor spreading of cookies except for 5 % where it resulted in higher spreading. The moisture, crude fibre, protein and ash increased whereas carbohydrate content decreased with the increase in the level of incorporation (Sahni and Shere, 2016).

Fruit and vegetable pomace contains bountiful of bioactive compounds including antioxidants that confer added health benefit. However, the effect of pomace powders on the storage quality of cookies has been documented by Sahni and Shere (2017b) in a study where fruit and vegetable pomace powders were found to exert strong influence on the sensory attributes of cookies during storage. Predominantly the detrimental effect was only observed in the colour of cookies which were incorporated with pomace powders; otherwise cookies maintained better sensory attributes as compared to control. Cookies incorporated with pomace powder demonstrated better storage stability and need of comparatively simple packaging requirements as compared to control cookies.

CONCLUSION

Present scenario of low fibre in diet is driving force for exploration of dietary fibre as novel ingredient in food products. The interest in the utilization of fruit and vegetable pomace powder for fibre enrichment is due to its better functionality owing to the presence of balanced amount of soluble and insoluble dietary fibre and association of bioactive compounds with them. Fruit and vegetable pomaces can be incorporated in bakery products where their optimum level does not affect the quality attributes and also tend to improve the sensory attributes of the product. Being a cheap source of dietary fibre it will help is the valorisation of the food products and can be used for designing new 'functional foods'. Thus, opens up a doorway of efficient waste management for juice manufacturing industry to earn profit.

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