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Fortification of fruit products – A review

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Abstract: Fortification is one of the most important processes for the improvement of nutrients in food. This process can be a very cost-effective public health intervention. Due to the high consumption rate of fruit products, fortification of these products will effectively reduce and prevent diseases associated with nutritional deficiencies. This paper offers an overview of the fortification of fruit products with minerals (calcium, iron), vitamins, and dietary fibre. Fortification is defined, and the main reasons behind carrying out this process are discussed. This review studied the different types of products and their fortification model.

Keywords: beverage; bioavailability; biofortification; fortified; nutrition

Considering the importance of food safety and quality, more attention is being paid to the health of consumers (Grunert 2005). However, due to nutrient deficiencies in human societies, especially during certain periods of life, importing and consumption of fortified foods are increasing (Preedy et al. 2013). Subpopulations most at risk for nutrient deficiencies include pregnant women and children five years and younger. Primarily affecting the developing world, nutrient deficiencies are rare, but not absent, in populations residing in industrialised nations (Bailey et al. 2015).

Generally, the addition of one or more essential nutrients to food and increasing the concentration in that food product to levels higher than normal is known as a fortification. This process is targeted at averting and rectifying an identified deficiency in nutrients in a particular population (Bonner et al. 1999). Nutrition scientists have mentioned that fortification of food products using natural resources (fruit) is one of the best ways to improve the overall nutrient intake of food with minimal side effects (Bouis et al. 2011). Fortification is achieved by the addition of fortificants to the selected food product, which serves as the vehicle for carrying the nutrients.

Per the general principle of fortification, nutrient fortification should not only harm the sensory attributes of the final product but should also not reduce the consumer demand for the consumption of unfortified food. The process should effectively increase nutrient absorption and bioavailability and should have a positive effect on the consumer's health (EFSA 2006; Bouis et al. 2011).

As per World Health Organization (WHO), food fortification occurs in three major approaches: mass, targeted, and market-driven. Foods such as wheat, milled cereals, salt, oils and fats, and sugar that are widely consumed are involved in mass fortification to eradicate

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the unacceptable health risk of deficiency in a particular micronutrient (Allen et al. 2006). Foods consumed by specific populations, such as infants, are identified as a target fortification. Complementary foods for young children are approached as a targeted fortification. For market-driven fortification, the food product is fortified as value-added products and complies with the specifications for acceptable nutrients and quantities. The mass and targeted fortification have focused on micronutrients that are required by most of the population (Venkatesh and Wesley 2008).

Biofortification is the process of increasing the nutrient (vitamins, iodine, iron, zinc, etc.) content in plants by selective breeding or genetically engineering a nutrient targeted at a specific agronomic technique to enhance the content of specific health-effective compounds in widespread crops (Cashman 2015; Govindaraj 2015; Mozaffarian et al. 2018). Biofortified staple foods help to increase the daily sufficiency of micronutrient intakes (Bouis et al. 2011). Although traditional fortification practices in which vitamin D is exogenously added to foodstuffs continue to be an important strategy for increasing vitamin D intake, the introduction of novel vitamin D fortification approaches, including the use of biofortification, attracts attention (Meenakshi et al. 2010). Fruits can accumulate iodine if it is either present or exogenously administered to the soil. The biofortification of tomato crops with iodine has been proposed as a strategy for improving human nutrition. A greenhouse experiment was carried out to evaluate the possibility of biofortifying tomato fruits with iodine (Kiferle et al. 2013). The results showed that the increasing concentrations of iodine supplied as KI or KIO_3 and the use of both the iodised salts induced a significant increase in the fruit's iodine content. For crops with the capability of selenium accumulation, broccoli can be discussed, and it is classified as a secondary accumulator of selenium (Bachiega et al. 2016; Hegedűsová et al. 2017). This is also confirmed by other experimental results, such as various research studies. Ghasemi et al. (2016) found that increasing the selenium dose resulted in a gradual, multifold increase of the selenium content in broccoli. Again, the enrichment of broccoli and carrot with selenium was achieved by the combination of different types of selenium phytotechnologies (Banuelos et al. 2015).

This review describes the fortification of fruit products regarding some mineral elements (calcium, iron), vitamins, and dietary fibre often lacking or not adequately present in human diets.

GENERAL CASES FOR THE ADDITION OF NUTRIENTS TO FOOD

There are opportunities to improve the nutritional profile and sustainability of the diet throughout the food chain, from farm production, through retail to households. These include crop diversification, food enrichment, improved transport efficiency, waste minimisation and, finally, food reformulation (FAO/WHO 2004; Buttriss 2013).

Within the FAO/WHO Food Standards Programme, the Codex Alimentarius Commission adopted general principles for fortification (FAO/WHO 1995). According to these general principles, essential nutrients may be added to food to achieve any of the following: restoration of nutrients lost during processing, the nutritional equivalence of substitute foods, fortification, and ensuring the right nutrient composition. Also, Regulation (EC) No. 1925/2006 (The European Parliament and of the Council of 20 December 2006 on the addition of vitamins and minerals and of certain other substances to foods) stipulates which vitamins and minerals may be added to foods, sets out the safety assessment processes for certain other substances, and outlines how substances may be considered for inclusion.

FORTIFICATION OF PROCESSED FRUIT PRODUCTS WITH MINERALS, VITAMINS, AND DIETARY FIBRE

Food fortification involves a broader concept and is done for many reasons. The first reason is to restore nutrient loss during processing, a process known as enrichment. For nutrient restoration, the amount of nutrients added is approximately equal to the natural content in the food before processing. The second reason is to add nutrients that may not be available naturally in food, a process known as a fortification. In this concept, the amount of nutrients added may be more than that present before processing (Mejia 1994; Bhagwat et al. 2014).

Processing of food may result in loss of nutrients. To counter such losses, foods are enriched with nutrients. One of the most important global public health problems is mineral deficiencies of iron, zinc, calcium, and iodine. Of the several approaches to reducing deficiency of minerals, fortification is the advanced technique to correct the intake of minerals without causing a change in the existing dietary patterns (Hurrell 1997; Weaver et al. 2014). Nevertheless, the development of a fortification technology that makes the mineral

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Table 1. Recommended dietary allowances and adequate intakes

Life stage group	Vitamin A	Vitamin B_9	Vitamin B_{12}	Vitamin C	Vitamin D	Vitamin E	Calcium	Iron
	(µg per day)			(mg per day)	(µg per day)	(mg per day)		
Infants (months)								
0–6	375	80	0.4	25	10	4	300	–
7–12	400	80	0.7	30	10	5	400	9.3
Children (years)								
1–3	400	150	0.9	30	10	6	500	5.8
4–8	450	200	1.2	30	10	7	650	6.3
Males (years)								
9–13	600	400	2.4	40	5	11	1 300	14.6
14–18	600	400	2.4	40	5	15	1 300	18.8
19–30	600	400	2.4	45	5	15	1 000	13.7
31–50	600	400	2.4	45	5	15	1 000	13.7
51–70	600	400	2.4	45	10	15	1 000	13.7
70+	600	400	2.4	45	15	15	1 300	13.7
Females (years)								
9–13	600	400	2.4	40	5	11	1 300	14.0
14–18	600	400	2.4	40	5	15	1 300	32.7
19–30	500	400	2.4	45	5	15	1 000	29.4
31–50	500	400	2.4	45	5	15	1 000	29.4
51–70	500	400	2.4	45	10	15	1 300	11.3
70+	600	400	2.4	45	15	15	1 300	11.3
Pregnancy	800	600	2.6	55	5	15	1 200	29.4
Lactation	850	500	2.8	70	5	19	1 000	15.0

Source: FAO/WHO (2004)

bioavailable in the food vehicle has remained an issue (Barclay and Haschke 2015). Recommendations for the intake of calcium, iron, and vitamins are indicated in Table 1.

MINERAL FORTIFICATION

The issue of osteoporosis and anaemia are two major health concerns that could be alleviated or even eliminated by modifications in dietary intake, notably by mineral fortification to increase the consumption of relevant metal ions. However, several issues regarding fortification are still being actively debated. The metal ions most often referenced are calcium and iron (FAO/WHO 2004).

Calcium fortification. Calcium provides strength to the bones and teeth and is used in the developmental phases of human growth (Nascimento de Paulo et al. 2014). The deal of interest today is the creation of awareness to prevent osteoporosis. Many bioavailable forms of calcium exist, and food producers make use of these forms for the fortification of several food products (Nemati et al. 2016). Mostly used forms are calcium carbonate, calcium citrate, calcium malate, calcium lactate, and calcium glycerol phosphate. Other forms, such as calcium lysinate and tricalcium phosphate, are preferred for fortification because they have greater bioavailability (Nascimento de Paula et al. 2014; Trailokya et al. 2017). For the addition of calcium salt targeted at fortification, the choice of the salt is guided by its organoleptic properties (Allen et al. 2006). Some authors confirmed that calcium impregnation improves the nutritional value of processed fruits and increases concentration and bioavailability (Xie and Zhao 2004; Anino et al. 2006). Clear beverages (e.g. apple juice) and cloudy beverages (e.g. nectars, orange, grapefruit, cranberry juices) are also commonly fortified with calcium (Gerstner 2003). Table 2 shows some calcium-fortified products and their fortification models.

Iron fortification. Iron-fortified foods and beverages can help fight the issue of anaemia and its effects (Mehansho 2002). The deficiency is a common nutri-

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Table 2. Commonly fortified food products with calcium

Food source	Fortification model (mineral doses)	Available calcium after fortification (mg L^{-1})	Reference	Maximum fortification level
Apricot nectar	calcium lactate (162 mg L^{-1})	29.8	Flynn et al. (1999)	800 mg L^{-1} (EFSA 2006)
Grapefruit juice	tricalcium citrate (240 mg L^{-1})	57.9	Anderson and Garner (1995)	
Fruit juice	calcium lactate gluconate (240 mg L^{-1})	29.7	Reddy et. al. (1999)	
Tangerine juice	tricalcium phosphate (240 mg L^{-1})	93.0		
Pineapple snack	calcium chloride [3.675 g (100 mL)$^{-1}$]	1.3	Lima et al. (2016)	
Orange juice	tricalcium citrate (414 mg L^{-1})	99.9	Gerstner (2003)	
Tropical nectar	tricalcium citrate (200 mg L^{-1})	48.2		
Cranberry juice	calcium lactate gluconate (240 mg L^{-1})	57.9		
Mixed fruit juice	calcium citrate malate (1 000 mg L^{-1})	110.0	Franklin et al. (2014)	

Table 3. Commonly fortified food products with iron

Food source	Fortification model (mineral doses)	Available iron after fortification (mg L^{-1})	Reference	Maximum fortification level
Apricot jam	ferrous sulphate [4 mg (100 g)$^{-1}$]	1.4	Catana et al. (2009)	14 mg mL^{-1} (EFSA 2006)
Plum jam	ferrous sulphate [6.5 mg (100 g)$^{-1}$]	2.4		
Botanical or fruit flavoured beverage	ferrous sulphate (6.3 mg)	2.3	Davidsson et al. (2000)	
Apple-based meal	EDTA-iron sodium (13.5 mg kg^{-1})	2.1	MacPhail et al. (1994)	
Apple slices	ferrous gluconate [3.2 mg (100 g)$^{-1}$]	0.4	Barrera et al. (2004)	
Carioca kidney beans	ferrous sulphate [34.4 mg (100 g)$^{-1}$]	12.6	Miano et al. (2018)	
Pumpkin jam	ferrous sulphate [11 mg (100 g)$^{-1}$]	4.0	De Escalada Pla et al. (2009)	
Passion fruit juice	ferrous sulphate (49.2 mg L^{-1})	18.1	Haro-Vicente et al. (2006)	
Mixed fruits beverage	ferric pyrophosphate [3.2 mg (200 mL)$^{-1}$]	1.0	Fleige et al. (2018)	
Apricot puree	ferrous sulphate [3 mg (100 mL)$^{-1}$]	1.1		
Orange juice	ferrous sulphate heptahydrate [0.2 mg (100 g)$^{-1}$]	0.1	De Almeida et al. (2003)	
Fortified iron solid beverage	ferrous sulphate [16 mg (100 g)$^{-1}$]	5.9	Chunling and Yu (2013)	

EDTA – ethylenediaminetetraacetic acid

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tional disorder worldwide, and an imbalance in the long term may cause anaemia (Walker 1988). In healthy people, taking high doses of iron supplements (especially on an empty stomach) can cause stomach upset, constipation, nausea, vomiting, and diarrhoea. Large amounts of iron may also cause more serious effects, including inflammation of the stomach lining and ulcers (Boccio and Iyengar 2003).

Mohammadi et al. (2016) reported that various iron salts are used; among these salts, $FeSO_4$ is more beneficial for fortification because it is rapidly absorbed, low in price, and has a high bioavailability characteristic. In water-based beverages, ferrous gluconate is used due to its good solubility. Other important salts that may be used are ferrous fumarate, ferrous tartrate, ferrous succinate, and ferrous citrate (Baltussen et al. 2004). Furthermore, ferrous amino acid chelates, along with the earlier mentioned salts, can be used together to obtain higher bioavailability during the fortification process (Mohammadi et al. 2016). Iron is a challenging micronutrient to add to food and beverages due to its bioavailability characteristics that interact with food constituents to produce undesirable changes. When foods fortified with iron-containing high levels of unsaturated fatty acid are stored for long, it can cause rancidity (Davidsson et al. 2000). This happens due to the pro-oxidant properties of iron that speed up the oxidation process in unsaturated fat-containing liquid beverages. To reduce these problems, the level of iron salt is either increased, or some organic acid like ascorbic acid is added together with iron salt in the beverage product (Walczyk et al. 2014). In the case of apricot and plum jams fortified with iron, Catana et al. (2009) reported 4 mg Fe $(100\ g)^{-1}$ and 6.5 mg Fe $(100\ g)^{-1}$, respectively, as shown in Table 3. Sensorial analysis of the product 'apricot and plum jams fortified with iron' proved that in the case of all the experimental variants, the used fortification agents (ferrous sulphate) do not determine modification of sensorial characteristics (appearance, colour, taste, and smell) in comparison with the control sample (jams unfortified with iron).

VITAMIN FORTIFICATION

Vitamin A. Vitamin A is an essential vitamin for the normal functioning of the visual system, immune functions, maintenance function of the cell, reproduction, and growth of epithelial cells (Whited et al. 2002). Vitamin A is found in a wide range of foods, usually of fruit origins. Deterioration in eyesight, specifically night blindness and xerophthalmia, is directly associated with its deficiency (Zayed et al. 2015). Fortification with β-carotene not only serves as a precursor of vitamin A but also provides colour to beverages and jams. Fortification of vitamin A in beverages having high moisture levels tends to have adverse effects on the stability of vitamin A. To overcome this problem, an encapsulated fortification method with an additional moisture barrier was evaluated, with carotenoid being used as a source of vitamin A (Whited et al. 2002).

Vitamin B_{12}. Vitamin B_{12} plays an important role in the brain and nervous system functioning. It is rarely added during fortification. In beverage products, vitamin B_{12} addition has a good interaction with vitamin D, folates, and riboflavin (Abdollahi et al. 2008). Some of the signs and symptoms of deficiencies resulting from less intake of vitamin B_{12} are low energy, depression, cognitive decline, bleeding gum, and numbness (Oliva et al. 2016). A different strategy for the addition of vitamin B_{12} was reported by some researchers. The researchers coated the ready-to-blend fruit salad with vitamin B_{12} and chitosan at the rate of 0.25 mg L^{-1} and 10 g L^{-1}, respectively. Fortified beverage products had good levels (8.6 μg kg^{-1}) of vitamin B_{12} (Artés-Hernández et al. 2017).

Vitamin B_9. Fortification of folic acid plays an important role in the development of nucleic acid that intervenes in tissue growth and cell multiplication (Abdollahi et al. 2008; Dary 2008). Green leafy fruits are the main source of folate. Folic acid is water-soluble, with good stability in an aqueous medium, and is therefore effectively used in beverage fortification. Apart from beverages, a variety of other products such as fruit bars, jams, and jellies can be fortified using folic acid (Yang et al. 2010).

Vitamin C. Its metabolic role is to maintain collagen formation. The best sources of vitamin C are found in fresh edible fruits. However, since vitamin C is unstable when exposed to an alkaline environment, oxygen, light, and or heat, losses can be substantial during storage (Lindsay et al. 2006). Foods fortified with vitamin C include baby food (Reidy et al. 2018), juices (Thakur et al. 2018), jelly, and candies (Mohammadi et al. 2018). Acute vitamin C deficiency leads to scurvy. Scurvy evolution time varies with vitamin C levels, but signs may occur within 1 month after the decrease or absence of vitamin C consumption is below 10 mg per day (Wang and Still 2007). The degradation reactions of total lycopene or ascorbic acid in tomato ketchup are dependent on the factors; the initial content, presence of other compounds affecting or taking part in the oxidation and nonenzymatic reaction conditions of the tomato paste

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processing. Total lycopene degradation kinetic is very complex, and therefore, data is not usable for the general shelf-life estimation (Rajchl et al. 2010).

Vitamin C is often added to fruit juices, fruit-flavoured candies, dried fruit, and frozen fruits to fortify or add a citrus flavour. Again, vitamin C acts as an antioxidant, which provides multiple benefits to food products, that is, slowing the oxidation and preserving colour and freshness. The low pH of vitamin C can help prevent microbial growth, thereby preventing spoilage and preserving the freshness of food such as jam and jellies (Lindsay et al. 2006). The range of total antioxidant capacity is large among different fruit flavours, as reported by Čížková et al. (2009). Of all the samples, berries and plums have the highest content, which agrees with high anthocyanin concentration. Also, the single antioxidant composition of samples is rather variable. The concentration of total polyphenols varied from 414 mg kg^{-1} to 1 452 mg kg^{-1}. Content of ascorbic acid, which is in the majority artificially added and declared as an antioxidant, ranges from 186 mg kg^{-1} to 550 mg kg^{-1} (Čížková et al. 2009).

Vitamin D. Although required in very low amounts, vitamin D is important for many physiological functions (Tangpricha et al. 2002). Fortification of vitamin D requires a media containing fats in it since vitamin D is soluble in fat-based systems. Most foods are low in vitamin D, so to achieve the desired intake, other strategies for fortification of vitamin D are used (Harris et al. 2001). To assess whether vitamin D was bioavailable in orange juice, Tangpricha et al. (2003) obtained weekly measurements of serum 25(OH) D concentrations, the most accurate marker of vitamin D status, in a daily glass of orange juice fortified with vitamin D_3 as shown in Table 4. The functional beverages are fortified with vitamin D ergocalciferol (D_2) and cholecalciferol (D_3). When the beverages are fortified with these vitamins, the types of vitamins used must be listed in the ingredient statements of the product (Chowdhury et al. 2014). It can be noted that fortification of fruit products with vitamin C is more common than with vitamin A, B_9, B_{12}, and D.

The intake of most vitamins and minerals is generally adequate though the cited fortified products did not meet the recommended fortification levels. However, the risk of a low intake of some nutrients (e.g. vitamin D, iron) is likely to appear in specific population subgroups, such as children and adolescents (Harris

Table 4. Commonly fortified food products with vitamins

Food source	Fortification model (doses)	Reference	Maximum fortification level
Apple jam	β-carotene yield (biomass) (55 µg g^{-1})	Yashneeil et al. (2015)	3.5 mg (100 mL)$^{-1}$ (EFSA 2006)
Fresh-cut mixed fruit salad	vitamin B_{12} (0.25 mg L^{-1})	Artés-Hernández et al. (2017)	1.6 µg (100 mL)$^{-1}$ (EFSA 2006)
Apple juice	vitamin B_9 (200 mg L^{-1})	Moreno et al. (2016)	200 µg (100 mL)$^{-1}$ (EFSA 2006)
Tomato juice	vitamin C [34.7 mg (100 mL)$^{-1}$]	Sánchez-Moreno et al. (2006)	16 mg (100 mL)$^{-1}$ (EFSA 2006)
Cashew juice	vitamin C [203.5 mg (100 mL)$^{-1}$]	Akinwale (2000)	
Mango juice	vitamin C [30.9 mg (100 mL)$^{-1}$]		
Pineapple juice	vitamin C [14.7 mg (100 mL)$^{-1}$]		
Cranberry juice	vitamin C [80 mg (100 mL)$^{-1}$]	Roidoung et al. (2017)	
Gooseberry juice	vitamin C [478.56 mg (100 mL)$^{-1}$]	Jain and Khurdiya (2004)	
Date syrup	vitamin C [50 mg (100 mL)$^{-1}$]	Riaz et al. (1993)	
Pear juice	vitamin D_3 [0.187 mg (100 mL)$^{-1}$]	Dima et al. (2020)	
Orange juice	fortification with 1 000 IU (25 µg) vitamin D_3	Tangpricha et al. (2003)	
	1 000 IU (25 µg) vitamin D_3 or vitamin D_2 in orange juice	Biancuzzo et al. (2010)	
Pink guava juice	vitamin E (225 mg L^{-1})	Bujang et al. (2012)	2 mg (100 mL)$^{-1}$ (EFSA 2006)

IU – international unit

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et al. 2001; Mehansho 2002). Food fortification and dietary supplementation are adequate approaches for tackling nutritional deficiencies; however, an acceptable approach to using these products is to support, but not replace, a well-balanced diet (Klopotek et al. 2005).

Vitamin E. Vitamin E is a fat-soluble antioxidant in the body. It protects cellular membranes and other lipids against oxidative damage (Atkinson et al. 2008). It curtails the formation of hydroperoxides and delays the initial phase of the oxidative process (Li et al. 2008). However, it is difficult to add these vitamins to aqueous foods while retaining their activity. Again, vitamin E is liposoluble and freely oxidised in the air. With respect to vitamin E, it was demonstrated that its absorption and bioavailability are increased when it is encapsulated in liposomes (Wang and Quinn 2000). Experimental work for the addition of vitamin E was reported by Bujang et al. (2012). The researchers fortified pink guava juice with 225 mg L^{-1} vitamin E. Fortified beverage products were much preferred due to emulsion stability, colour stability and vitamin E content.

DIETARY FIBRE FORTIFICATION

Dietary fibre includes huge masses of oligosaccharides, polysaccharides, and prebiotics. The chemical substance of oligosaccharides is sialic acids, fucose, glucose, and galactose. The chemical substance of polysaccharides is d-glucose, d-fructose, d-galactose, l-galactose, d-mannose, l-arabinose, and d-xylose. The chemical substance of prebiotics are fructooligosaccharides, galacto-oligosaccharides, and trans-galacto-oligosaccharides (Gupta and Sharma 2016). Dietary fibre addition has several usages both from technological and nutraceutical perspectives. Their addition can act as a thickening, gelling, dispersing, and carrying agent. It also improves glucose intolerance, lowers blood cholesterol, and decreases the risk of colon cancer (Cassidy et al. 1994; Bingham et al. 2003; Hassanpour 2016). Fortification by fibre is given in Table 4 with the fibre material used. Souad et al. (2012) also reported that albedo and flavedo from orange fruits were used in the watermelon-based candy to improve the nutritional value. Contrastingly, chia seeds contain 42.1% carbohydrates (of which 83% is fibre) and this was attributed to the increased fibre content of the chia seed-fortified jams (Nduko et al. 2018). The results obtained indicated that fortification of pineapple jam with chia seeds improved the nutritional value (protein from 0.53% to 8.60% and fibre from 4.83% to 21.02%) without affecting texture. Nonetheless, the addition of chia seeds at lower amounts (e.g. 6.25%) is shown in Table 5.

A beverage comprising soluble dietary fibre supplement (gum and pectin) with a fibre level of at least 2 g per 8 mL fluid (237 mL) has been successfully prepared without alteration in sensory characteristics (Akad et al. 1991). Sáyago-Ayerdi et al. (2007) reported that a beverage of *Hibiscus sabdariffa* flowers contained dietary fibre as the largest component (33.9%) and soluble dietary fibre of 0.66 g L^{-1}. The addition of fibre in probi-

Table 5. Commonly fortified food products with dietary fibre

Food source	Fortification model (added concentration)	Reference	Specific maximum fortification level (%)
Pineapple jam	chia seeds (6.25%)	Nduko et al. (2018)	
Carrot and apple blended jam	flaxseed (10%)	Ujjwali et al. (2019)	
Pineapple jam	baobab pulp (40%)	Osei-Agyeman et al. (2021)	
Guava jam	sapota fibre (40%)	Patil et al. (2013)	
Cherry, redcurrants, and apricot jam	bamboo fibre (1%)	Dordevic et al. (2020)	
Pedada jam	red dragon fruit peel extract (50%)	Nizori and Lamtiar (2020)	
Tomato sauce	bael pulp (30%)	Pingale and Dighe (2015)	30 to 40 (Lambo et al. 2005)
Apple fruit leather Fig fruit leather	*Moringa oleifera* (25%)	Thiruvengadam et al. (2020)	
Tomato puree	grape skin fibre (3%)	Marinoni et al. (2015)	
Amla juice	amla fruit fibre (0.5%)	Surya et al. (2020)	
Pineapple jam	hibiscus extract (15%)	De Silva et al. (2019)	
Pineapple juice	drumstick leave extract (*Moringa oleifera*) (10%)	Pandhare et al. (2018)	

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otics-based food enhances the viability of beverages containing such hydrocolloids (Gupta and Sharma 2016). Fibre-based hydrocolloids are typically used at a level of 0.05% and 0.03% in 250 mL – this counts for about 0.125 g and 0.75 g in the beverage. Acacia gum is good when used in non-dairy beverages since it can tolerate low pH. However, it does not lead to enhanced viscosity even at high concentrations, but it imparts mouthfeel impact without changing the flavour (Viscione 2013).

There is overwhelming evidence that dietary fibre is a necessary component in the human diet. In acknowledging the physicochemical properties, dietary fibre is sub-classified as soluble viscous fermentable, insoluble nonviscous unfermentable, or mixed type (Bingham et al. 2003). Fibre is not absorbed by the body (Palafox-Carlos et al. 2011). Dietary fibres belonging to the soluble-viscous-fermentable may delay gastric emptying or reduce glucose absorption, thereby improving glucose tolerance tests; inulin and oligofructose are soluble and highly fermentable but of low viscosity. They can be classified as dietary fibre that regulates both gastrointestinal and systemic functions. The main physiological roles of indigestible but fermentable saccharides overwhelm the otherwise important question of their quantitative analysis. This has become necessary for the consumer to be informed clearly and specifically on the nature and the beneficial effects of such dietary fibres when they are present in or added to a particular food (Roberfroid 1993).

BIOAVAILABILITY OF MINERALS (CALCIUM AND IRON) AND VITAMINS

Calcium. Calcium is absorbable in the soluble form or bound to soluble organic molecules. Notwithstanding, undissociated low-molecular-weight salts of calcium can also be absorbed independent of vitamin D by paracellular routes or pinocytosis. Depending on solubility, chemical form, and other factors of the food, humans absorb about 30% of dietary calcium (Weaver and Heaney 2006). The bulk of unabsorbed calcium is complexed into bile acids, free fatty acids, and oxalic acid and excreted with the faeces (Heaney 2002). Absorption is increased by lactose, vitamin D, inulin, fructooligosaccharides, and some casein phosphopeptides; the latter by preventing precipitation of calcium by phosphates. Most calcium salts used in fortified foods are absorbed to a similar extent as calcium from dairy foods. The absorbability of calcium citrate malate is higher, and especially oxalate inhibits calcium absorption (Weaver 2001).

Iron. Hurrell (2018) reported the relative bioavailability of different iron fortification compounds in detail. Iron from ferrous sulphate, which is added to food, is absorbed to the same extent as native iron because it is influenced in the same way by inhibitory and boosting food components and by the physiological state of the consumer. The relative absorption of other iron compounds is controlled by the extent to which they dissolve in the gastric fluid during digestion. Ferrous sulphate and ferrous gluconate dissolve readily in the gastric fluid because they are water-soluble. Ferrous fumarate is poorly water-soluble but dissolves completely in the dilute acid of the gastric fluid during digestion and is considered to have the same bioavailability as ferrous sulphate. Sodium ferric ethylenediaminetetraacetate (NaFeEDTA) also has the same bioavailability as ferrous sulphate in the absence of iron absorption inhibitors but a 2–4-fold higher absorption in their presence (Heimbach et al. 2000).

Iron absorption is also regulated for an individual's iron status to ensure sufficient iron absorption to meet the needs while avoiding excess iron absorption that could result in negative health consequences (Hurrell 2018). Thus, an individual with low iron status markedly increases iron absorption to cover the additional needs, whereas an individual with adequate iron status decreases absorption as necessary to cover the lower requirements. Iron absorption from soluble iron compounds (such as ferrous sulphate) is more efficiently upregulated with low iron status than absorption from more insoluble compounds (Zimmermann et al. 2005).

Vitamins. Carotenoids are absorbed from the small intestine into enterocytes by passive diffusion and then through the chylomicrons to lymph. Less than one-sixth of carotene is absorbed intact in humans (Hollander and Ruble 1978). Studies indicate that about 50% to 75% of carotene may be utilised (Lala and Reddy 1970), but breakdown may also occur. The initial increase in carotene level on feeding is in the chylomicrons fraction (Lala and Reddy 1970).

At low levels of intake of vitamin C, it is efficiently absorbed and retained by humans. Divided doses are absorbed more efficiently than a single bolus at intakes up to 100 mg per day to 180 mg per day, and about 80% to 95% is absorbed (Hornig 1981). At higher intakes, the absorption mechanism becomes overloaded so that for a single 1.5 g dose, only 50% is absorbed, and for 12 g, 16% is absorbed (Rivers 1987). At high intakes, provided the subject is initially near saturation, the absorption efficiency can be estimated by the fraction of the dose that is recovered in the urine within 24 h.

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Although gram doses are not efficiently absorbed, the total amount that can be absorbed increases steadily across a wide range of increasing intakes up to a maximum of 1.2 g at high single doses (Rivers 1987). Since the amount absorbed also determines the concentration achieved in the tissues, it is possible to increase tissue ascorbate levels progressively by increasing the intakes to high levels.

Vitamin D is, with the other fat-soluble vitamins, absorbed by emulsification into mixed micelles, uptake in the enterocyte, followed by incorporation in the chylomicrons and transport into the circulation via the lymphatic pathway (Hollander 1981). Vitamin D esters, if present, are hydrolysed during solubilisation in the mixed micelles. Vitamin D is efficiently absorbed in the proximal small intestine in the presence of fat which is dependent on bile acid secretion. Long-chain fatty acids promote the absorption of vitamin D (Holmberg et al. 1990). α-tocopherol is absorbed unchanged from the intestinal lumen, whereas tocopheryl esters are first hydrolysed by pancreatic esterase. The greatest capacity for absorption appears to be in the region between the upper and middle thirds of the small intestine (Gallo-Torres 1980). It is generally examined that the absorption of α-tocopherol and its esters are inadequate. In human studies, estimates of 24-hour absorption efficiencies for α-tocopherol and α-tocopheryl acetate range from 21% to 86% (Gallo-Torres 1980).

The absorption and distribution of vitamin E within the body are linked to dietary fat. Absorption in the intestine requires the presence of bile, pancreatic enzymes and adequate fat (Kayden and Traber 1993; Herrero-Barbudo et al. 2006). The process is similar to all the fat-soluble vitamins in that there is a prerequisite for the formation of micelles containing dietary lipids emulsified in the presence of bile (Traber et al. 1985). Once internalised into the enterocyte, vitamin E is packaged into chylomicrons and enters the circulation via lymph (Traber et al. 1985). Excess chylomicrons are consequently produced, and cholesterol, along with vitamin E, is transferred to high-density lipoproteins. The resultant chylomicrons remnants are taken up into the liver by way of the receptors (Hoppe and Krennrich 2000). Vitamin E is metabolised in the liver by cytochrome P450 induced ω-oxidation followed by consecutive β-oxidation yielding carboxyethyl-hydroxy chroman, which is present in both plasma and urine (Galli et al. 2003). Vitamin E has a high bioavailability between 50% to 80% and follows the general absorptive route of dietary fats. Vitamin E is absorbed even in the absence of dietary lipids, but its uptake in the small intestine can be enhanced by simultaneous fat consumption (Flory et al. 2019).

CONCLUSION

Fortification of fruit products is an accepted approach for improving the nutrient status of a target population. Fortified food can be obtained not only by the addition of minerals, vitamins, or fibre to food but also by the biofortification of crops. The setback for the fortified product manufacturers is to provide products with the highest nutrient content, good taste, and appealing properties. Again, special attention should be paid to the form of the fortified nutrients (organic or inorganic). The consumption of fortified products helps to fight nutrient deficiencies which are the cause of many diseases. To have health-promoting effects, these minerals, vitamins, and fibre must be released during digestion (bioaccessibility) and then absorbed in the human gut to reach systemic circulation (bioavailability). Combined efforts of various stakeholders are required to make viable measures for the use of the fortified product for a specified market and geographical area.

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