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Food Waste and Byproducts: An Opportunity to Minimize Malnutrition and Hunger in Developing Countries

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Food production and processing in developing countries generate high levels of waste and byproducts, causing a negative environmental impact and significant expenses. However, these biomaterials have ample potential for generating food additives which in turn will minimize malnutrition and hunger in the developing countries where it is produced. Many of these biomaterials are a source of valuable compounds such as proteins, lipids, starch, micronutrients, bioactive compounds, and dietary fibers. Additionally, antinutritional factors present in some byproducts can be minimized through biotechnological processes for use as a food additive or in the formulation of balanced foods. In this context, the use of these biomaterials is a challenge and provides great opportunity to improve food security. The purpose of this review is to project the potential of food waste and byproducts as a sustainable alternative to reduce malnutrition and hunger in developing countries.

Keywords: food waste, byproducts, hunger, food security and nutrition, phenolic compounds, sustainability, sustainable food systems

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INTRODUCTION

Agricultural production and agro-industrial processing generate a high amount of byproducts and waste. Fruit byproducts such as bagasse, peels, trimmings, stems, shells, bran, and seeds account for more than 50% of fresh fruit and have at times a nutritional or functional content higher than the final product (Ayala et al., 2011). Fruit and food waste is also generated by damage during transportation, storage, and processing. The growing popularity of fruit juices, nectars, frozen and minimally processed products has also increased the production of byproducts and wastes in recent years.

Byproducts and waste generation are having an impact on environmental, economic, and social sectors. To the environment, these contribute to Green House Gas (GHG) emissions (Girotto et al., 2015). Many of these biomaterials are not utilized and end up in municipal landfills where they create serious environmental problems due to microbial decomposition and leachate production. In some cases, the byproducts are burned to remove fungi and parasites. From the economic point of view, the adverse impact is due to the costs related to the handling of solid waste in landfills. Moreover, the management of large amounts of different degradable materials poses a challenge (Novoa-Muñoz et al., 2008; Pateiro-Moure et al., 2009).

Social impacts may be attributed to an ethical and moral dimension within the general concept of global food security since 805 million people across the globe suffer from hunger (FAO, 2014).

To manage the nutritional problems of today's society; we require more composite nutritional sources. Food wastes and byproducts are of paramount importance here due to the presence of sufficient quantities of proteins, lipids, starch, micronutrients, bioactive compounds, and dietary fibers. Protein deficiency and associated malnutrition is one of the serious problems in most of the developing countries (Müller and Krawinkel, 2005). Food fortification serves as a crucial strategy to fight malnutrition and important initiatives have been undertaken to utilize residues and byproducts in Europe and USA (Schieber et al., 2002; Baiano, 2014; Mirabella et al., 2014; Girotto et al., 2015). Poorer nations where the problems of malnutrition and hunger exists at a higher level, there is a greater potential of exploitation of these biomaterials as they generate large quantities of byproducts. The main raw materials used in the industries in such countries are fruits, vegetables, dairy products and fish. Tropical and subtropical fruits like mango, pineapple, banana, grape, and citrus are important fruits used in processing in poor countries (Schieber et al., 2002).

The utilization of residues and byproducts generated in the poor regions of the world for the formulation of novel foods will directly benefit the local communities. In Nigeria, for example, the use of mango byproducts has been suggested as the main ingredient in the diet of infants and adults since it increases the content of protein and antioxidants (Abdalla et al., 2007). As shown in **Figure 1**, a strategy to reduce malnutrition and hunger in developing countries is the use of food wastes and byproducts as a source of food additives or as a raw material for the feeding of animals for human consumption. Value-added product generation can benefit infrastructure development, transportation, food processing, and packaging industries. This contributes to the reduction in waste accumulation and results in significant financial benefits. Tropical fruits, dairy, and fish are an important commercial food and crop enterprise, which plays an important role in the socio-economic development of rural and urban populations in countries in Africa, Asia, and America. For example in Kenya, the production chain of mango and mango derived products contributes significantly to the agricultural Gross Domestic Product (GDP) and foreign exchange earnings (Muriithi et al., 2016). Therefore, the diversification of the chain with the valorization of byproducts will generate income and create employment opportunities for residents which will directly benefit poor communities. To achieve the Millennium Development Goals related to hunger and malnutrition, we need to address poverty (Müller and Krawinkel, 2005).

The depletion of renewable resources, reduction in land for cultivation, continuous growth of the world population and the over accumulation of waste are factors that justify the utilization of waste and byproducts in the food sector. Despite the wide potential of byproducts as materials for the formulation of foods, some may present low digestibility absorption due to the presence of anti-nutritional compounds such as tannins, cyanogenic glycosides, oxalates, and trypsin inhibitory substances (Arogba, 1997). This highlights the need to develop novel processes to reduce these nutritional factors from food wastes.

The experience of Europe shows that although there is legislation aimed at the use of waste in the production of biofuels, many of the small merchants do not fulfill with the norms and dispose of the wastes in the environment (Novoa-Muñoz et al., 2008; Pateiro-Moure et al., 2009). Additionally, the Environmental Protection Agency (EPA, 2017) had set a priority to use the surplus to feed the hungry people first, then animals, and finally industrial uses, composting and incineration. The process of incineration of waste attracted attention because the combustion process releases highly toxic pollutants (Fernández-González et al., 2011).

Proper use of food waste and byproducts as raw materials or food additives, could generate economic gains for the industry, contribute to reducing nutritional problems, would produce beneficial health effects and would reduce the environmental implications that generate mismanagement of waste. Presently, the industries are interested in innovations so as to obtain zero waste, where the waste generated is used as raw material for new products and applications. These actions can directly impact the Millennium Development Goals, the upcoming Sustainable Development Goals, the Post 2015 Agenda and the Zero Hunger Challenge. In this context, the main goal of this review article is to present the potential of food waste and byproducts as a sustainable alternative to reduce malnutrition and hunger in developing countries. The following examples have been chosen as being a contrasting set of materials for which much information is available and for which clear improvements and opportunities are envisaged.

BYPRODUCTS AND WASTES OF FRUIT PROCESSING

Mango

Mango (*Mangifera indica L.*) which belongs to the family *Anacardiaceae*, is grown naturally or mainly cultivated in tropical and subtropical regions. Mango is one of the most important fruits in the world, thanks to its delicious flavor, attractive fragrance, beautiful color, and nutritional value (Ibarra et al., 2015), so it enjoys the status of "the king of fruits." They have a high content of bioactive compounds such as ascorbic acid, lupeol, β-carotene, and polyphenolic compounds (Robles-Sánchez et al., 2013). The production of mangos, mangosteen, and guavas for the year 2014 was 45,225,211 million tons. India, China, Thailand, Mexico, Indonesia, and Pakistan are the main producing countries at the world level. Asia is the main continent in mango production (75.6%), followed by America (13.3%) and Africa (11%) (FAOSTAT, 2017).

Mango is generally consumed as a dessert fruit, but there has been an increase in consumption of mango products such as canned, frozen, concentrates, juices, jams, mashed, dehydrated products, and minimally processed (Masibo and He, 2009; Dussan-Sarria et al., 2014a,b). Processing of mango fruits generates a significant amount of byproducts such as peels (13–16%) (Serna et al., 2015) and seeds (9.5–25%) (Solís and Durán, 2011; Torres-León et al., 2017). It is estimated that 60% by weight of the fruit is discarded after processing (O'Shea et al., 2012).

Recently our research group published a complete review article on the nutritional and functional potential of mango seed

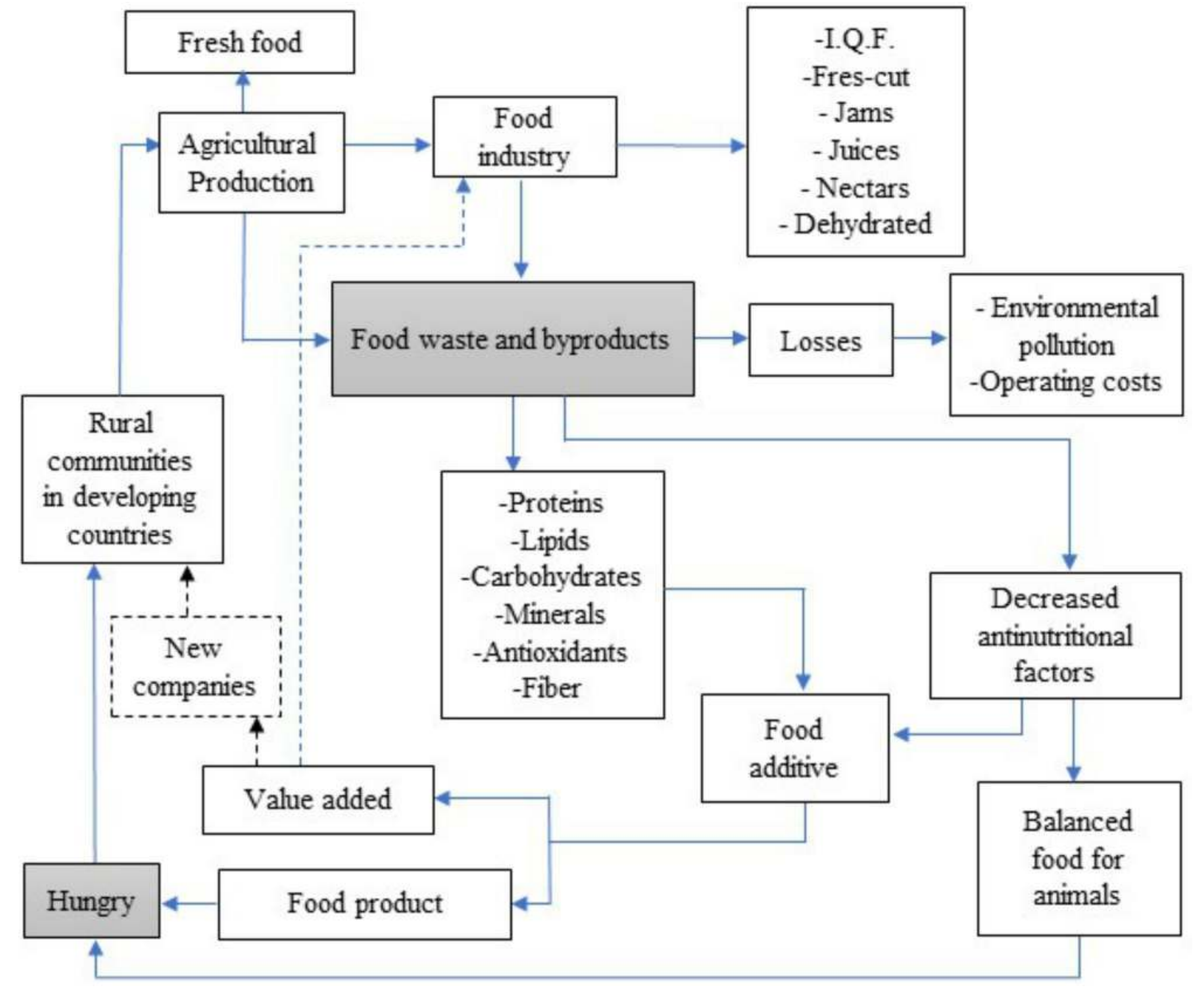

FIGURE 1 | Conceptual diagram of the use of food waste and byproducts in the minimization of hunger.

(Torres-León et al., 2016). This document highlights that the mango seed is a good source of carbohydrates (58–80%), protein (6–13%) with good profiles of essential amino acids and lipids (6–16%) rich in oleic and stearic acids (Siaka, 2014). Seed fat has attracted great interest as it has very similar physicochemical characteristics to those of commercial cocoa butter (Jahurul et al., 2015). **Table 1**, presents the nutritional content of mango seeds. The seed has a high protein content with the presence of all essential amino acids at higher levels than those referenced by the FAO as good quality protein. The seed also has high lipid content, these have typical characteristics of a vegetable butter (Muchiri et al., 2012). Mango seed kernel has a starch yield of 20%, with characteristics similar to commercial starch (tapioca) (Saadany et al., 1980). Although antinutritional characteristics are reported (Sandhu and Lim, 2008), these can be minimized to maximize the nutritional potential of the seed. Arogba (1997) reported that mango seed flour has a potential use in food preparation, for adults in households in Nigeria, and may also be suitable for infant formulas.

To know in detail about the chemical characterization of mango peel, it is advisable to read a complete review article written by Serna-Cock et al. (2016). This review document will present some basic aspects of the main nutritional components and their possible applications. The mango peels have high levels of soluble dietary fiber (Serna-Cock et al., 2016). Dietary fiber is an important additive for the formulation of functional foods. As also shown in **Table 1**, the dietary fiber composition of mango peel ranges from 51.2 to 78.4%. Dietary fibers are non-digestible carbohydrates present in plants and considered as an important component of the healthy human diet (Juarez Garcia et al., 2006).

Pineapple

Pineapple (*Ananas comosus*) is a tropical fruit (native of Central and South America) with attractive sensorial (mechanical

TABLE 1 | Nutritional properties of the main fruit byproducts grown in developing countries.

Byproduct	Moisture (%)	Ash (%)	Protein (%)	Fat (%)	Carbohydrate (%)	Fiber (%)	References
Mango seed kernel	44.4	2	6	12.8	32.8	2	Elegbede et al., 1995
Mango seed kernel	94	2.2	6.1	13.6	–	4.6	Odunsi, 2005
Mango seed kernel	45.2	3.2	6.36	13.3	32.2	2.02	Nzikou et al., 2010
Mango peel	72.25	1.3	1.76	–	–	78.4	Ajila et al., 2007
Mango peel	72.5	1.16	2.05	–	–	63.8	
Mango peel	–	3.0	3.6	–	–	51.2	Ajila et al., 2008, 2010
Pineapple pomace	3.77	2.24	4.71	0.61	43.46	45.22	Mabel et al., 2014
Banana peel	9.64	18.98	10.14	5.02	59	11.04	Anhwange, 2008; Memon et al., 2008
Grape pomace	8.2	3.50	7.31	5.50	60–70	76.37	Sánchez-Alonso et al., 2008
Pomegranate	5.5	3.59	1.26	3.57	17.75	16.08	Robledo et al., 2008
Tomato peel	5.71	3	13.3	–	–	86.15	Navarro-González et al., 2011

All results are presented on the dry basis.

properties, flavor, acidity/sweetness ratio, color) and nutritional (vitamin A, B, and C, minerals, fibers, and antioxidants) characteristics. Pineapples also contain a set of enzymes called bromelin commonly used in food production. Worldwide production of pineapple for the year 2014 was 25,439,366 million tons. Thailand, Brazil, Philippines, Costa Rica, and India are the main producers. Similar to mango, Asia is the main continent producing pineapple (48.2%), followed by America (34.5%) and Africa (16.4%) (FAOSTAT, 2017). During processing, large amounts of byproducts, consisting mainly of peel and pomace are generated, representing approximately 30–35% of the pineapple fruit, which is usually discarded as low-value byproducts (Varzakas et al., 2016).

Table 1, presents the nutritional composition of pineapple pomace, which has a high content of total dietary fiber values (45.22%) similar to those recorded in the mango peel. However, lower soluble dietary fiber contents are also reported. About 76% of pineapple byproduct (peel and heart) is fiber, of which 99.2% is the insoluble fraction and 0.8% is the soluble fraction (Martínez et al., 2012). Selani et al. (Mabel et al., 2014), found that pineapple bagasse has ample potential to enrich dietary fiber which is nutritionally poor. Pineapple stem is an agricultural waste with high potential as an alternative source of starch. The extracted starch has distinctly unique properties compared to commercial rice, corn and cassava starches (Nakthong et al., 2017).

Banana

Banana is a fruit that is widely grown around the world; which is mostly found in places with the tropical and subtropical weather. Bananas are native to Southeast Asia and are cultivated in over 130 countries (Mohapatra et al., 2010; Tock et al., 2010) including Brazil (Comim et al., 2010), México (Rodríguez-Ambriz et al., 2008), India (Bankar et al., 2010b), Thailand (Wilaipon, 2009), Uganda, Cameroon (Happi Emaga et al., 2007) as major producers. This fruit belongs to the *Musaceae* family, with nearly 300 species, of which only 20 varieties are used for consumption (Venkateshwaran and Elayaperumal, 2010).

Banana is consumed all over the world, mainly because of its low price and the fact that it can be harvested almost the entire year (Juarez Garcia et al., 2006; Bankar et al., 2010a; Comim et al., 2010). Bananas are considered one of the most important foods in the world, after rice, corn and milk and the second fruit with more production worldwide with a 16% just below citrus (Happi Emaga et al., 2008; Wilaipon, 2009). Also, bananas lead the market of fruit import around the world with 13.1%, which generates US$ 14,595.1 million per year (SIECA, 2016).

The edible part of the fruit represents only 12% of the plant's total weight, generating a large amount of agro-industrial waste such as peel which is mostly used for industrial processes for the production of new products (chips, dried pulps, jams, wine, beer, and sauces). Banana peels represent 30–40% of the total weight of the fruit (Boudhrioua et al., 2003; Zuluaga et al., 2007; Happi Emaga et al., 2008; Bankar et al., 2010b; Babbar et al., 2011). After the processing of bananas, a large amount of peel is collected and treated like garbage since it is considered as a fruit waste. These residues represent a serious pollution problem as it is dispersed in the planting area or burned. Due to the increase in the number of banana processing industries, there is a massive increase in the accumulation of banana wastes which necessitates the development of proper strategies to reuse these residues (Happi Emaga et al., 2007, 2008; Memon et al., 2008; Xu et al., 2015).

A large number of applications for these byproduct are reported in literature (Bankar et al., 2010b)—banana peels can be used to feed on cattle and poultry, as fertilizer, for the production of ethanol and biogas, for extraction of banana oil (Mohapatra et al., 2010), as adsorbent for heavy metal removal in water purification systems, for the production of proteins, for the production of biomass for conversion into energy (Bankar et al., 2010b; González Montelongo et al., 2010) and for developing neutraceuticals because if its antioxidant properties (Babbar et al., 2011).

The potential applications of banana peels depend principally on their chemical composition (Pelissari et al., 2014). Ripening in bananas is an important aspect, which influences the compounds present in the peel since it has been reported that when the fruit ripens, the starch and hemicellulose content is reduced. This is believed to be due to the activity of endogenous enzymes, increasing the number of soluble sugars such as glucose, fructose, and sucrose, as well as proteins and lipids (Happi Emaga et al., 2007, 2008; Mohapatra et al., 2010).

Banana peel contains a high concentration of phytochemicals with antioxidant properties; it contains pigments such as flavonoids (anthocyanins, delphinidines, cyanidines) and carotenoids (β-carotene, α-carotene, and xanthophylls), catecholamines such as dopamine and L-dopa (Happi Emaga et al., 2007; Babbar et al., 2011; Pelissari et al., 2014). Other compounds of interest in banana peel are minerals and micronutrients such as calcium, sodium, phosphorus, magnesium, iron, zinc, potassium, being the last one but the most important. In addition, banana peel contains all of the essential amino acids and vitamins (Happi Emaga et al., 2007; Mohapatra et al., 2010; Babbar et al., 2011).

It also contains saturated fatty acids, which represent between 40 and 50% of the fatty acids present in the banana peel including palmitic acid, stearic acid, arachidic acid and myristic acid and polyunsaturated fatty acids such as linoleic acid (omega-6) and α-linoleic acid (omega-3) (Happi Emaga et al., 2007; Mohapatra et al., 2010). Banana peels have also been reported to contain phytosterols (Venkateshwaran and Elayaperumal, 2010).

The peel contains high levels of dietary fiber, mainly insoluble dietary fiber (**Table 1**). The fiber content in the peel is approximately 50% dry matter basis, it contains pectin, which is widely used at industrial level, thanks to its properties to form gels so that it can be used as an emulsifier (Happi Emaga et al., 2007, 2008; Pelissari et al., 2014). It also contains sugars including glucose, galactose, Arabinose, rhamnose, and xylose (Mohapatra et al., 2010). Dietary fiber's composition consists of two fractions, the soluble fraction (pectins, gums) and the insoluble fraction (Cellulose, lignin, hemicelluloses, β-glucans) (Happi Emaga et al., 2008; Slavin, 2013). The importance of the Dietary fibers has increased in the recent years due to its health benefits an due to this the market is focused on the development of new products with high levels of fiber. It has been reported that Dietary fibers are related to the prevention and treatment of various diseases, mainly in the digestive tract, since this fiber provides an environment and conditions for the good growth of the beneficial intestinal flora (Juarez Garcia et al., 2006). The use of fibers from food wastes and byproducts gives added value to the final product and contributes to the reduction of the environmental pollution (Bilba et al., 2007; Venkateshwaran and Elayaperumal, 2010).

Grape

Grape is a fruit which is nutritious and having an impact on the economic status of the producing countries. These fruits are used as table grapes, raisins, juices and also used for wine production. The consumption of table grapes and wine has numerous nutritional and health benefits for humans because of the presence of antioxidant polyphenols such as resveratrol. The germplasm of the genus *Vitis* is variable and constitutes a valuable resource for obtaining desired traits, such as increased tolerance to pathogens and climate change through breeding programs (Fortes and Pais, 2016). Grape can be consumed fresh in the form of juicy clusters, but there is a powerful industry that has grown around this fruit (SIAP, 2017).

According to FAO (2013), annual global production of grapes is over 21.9 million tons. Derived from its diversified consumption, grape is characterized by its high economic value, and currently, 31% of the world production is destined for the fresh market; 67% to the elaboration of wine and other alcoholic beverages; and 2% is processed as dry fruit (FAO, 2013). Grapes are consumed as both fresh and processed products, such as wine, jam, juice, jelly, grape seed extract, dried grapes, vinegar, and grape seed oil. Out of the total production, a wastage of 45.53% is generated, equivalent to 51,801.0 tons (Borja-Bravo et al., 2016).

Grape is a fruit that has been extensively researched because of the health benefits in many respects. Grapes are an excellent source of manganese and a good source of vitamins B6, thiamine (vitamin B1), potassium, and vitamin C (Kammerer et al., 2004; Corrales et al., 2009). In addition, grapes are one of the richest sources of bioactive compounds such as phenolic acids, flavonoids, anthocyanins, and proanthocyanidins. These compounds are responsible for the color and smell of grapes and are found mainly in the skin of the grape. The U.S. Food and Drug Administration (FDA) approved the use of these pigments for the coloration of some beverages, also as additives that work as food preservatives (Piemontese, 2016). Several reports indicate that these phenolic compounds are of great interest for their biological and pharmacological activities including cardioprotective, neuroprotective, antimicrobial, and antioxidant properties (Lu and Yeap Foo, 1999; Iacopini et al., 2008; Sánchez-Alonso et al., 2008). Grape seed is another byproduct that is generated in most of the wine industries and it represents a maximum of 5 to 6% by weight with respect to the grape bunch. The oil obtained from grape seed is characterized by its richness in linoleic acid (60–70%), as well as in tocopherols, which hinder their oxidation. Grape seed oil also has important dietary properties which benefit human health, for preventing the formation of atheromatous lesions, and also for reducing cholesterol and lipidemia (Molero Gómez et al., 1996; Cao and Ito, 2003; Maier et al., 2009). It is being widely used for non-food sectors including cosmetic industry for the manufacture of soaps or even lipoquimia for the production of fatty acids. Seeds are also rich in proanthocyanidins (catechin polymers) or procyanidolic oligomers (OPC) which are having the property of assuring certain vascular protection and a partial cholesterol scavenging action (Cao and Ito, 2003; Maier et al., 2009; Da Porto et al., 2013). Kaur et al. (2008) and Iliodromiti et al. (2014) indicated that grape seed extract may be an effective chemopreventive agent against cancer. All these benefits make it possible to consider the skin of grape and the seeds as a good and easily accessible source for nutraceutical preparations.

Pomegranate

Punica granatum L. better known as a pomegranate is a shrub in the *Punicaceae family* that reaches between 2 and 6 m in height. This plant is having a very branched stem and sall elongated leaves, with vivid red flowers full of stamens (Jurenka, 2008; De la Cruz et al., 2015; Aguilar-Zárate et al., 2017). Although pomegranate is native to the Mediterranean region, Southeast

Asia and the Himalaya (Singh et al., 2002), it has been widely cultivated in countries in America, Asia, and Africa (Mertens-Talcott et al., 2006; Fischer et al., 2011; Aguilar-Zárate et al., 2017). Economically, pomegranate is very important since this fruit is either consumed fresh or used commercially for making juice, jam and also in wine industries. industries. Therefore, the world production of pomegranates reached up to 1,500,000 tons per year and it is increasing further due to the demand that exists in the global market. In addition to the fact that throughout history the consumption of this fruit has been promoted for its neutraceutical properties by many civilizations (Seeram et al., 2005; De la Cruz et al., 2015; Aguilar-Zárate et al., 2017) it is also found useful for specific medical applications. These properties can be attributed to a high concentration and a unique composition of polyphenolic compounds, in particular ETs (Seeram et al., 2005; Mertens-Talcott et al., 2006; Borochov-Neori et al., 2009). It has also been shown that extracts of any part of the plant including peel, bark of tree, root and leaves have therapeutic properties and they impart many health benefits (Jurenka, 2008).

Citrus Fruits

Citrus fruits are a family of widely consumed fruits worldwide. They have their origin in Southwest Asia and are currently distributed mainly in countries with warm and temperate climates, at temperatures ranging between 23 and 34°C (Amaro et al., 2015; Micheloud et al., 2016). Tropical and subtropical countries such as China (21%), Brazil (18%), India (6%), and Mexico (4.6%) are some of the main producers. It is estimated that about 69 thousand families depend on citrus cultivation (SAGARPA, 2012). This group of fruits belongs to the class *Angiospermae*, to the subclass *dicotyledonous*, to the rutae order, to the family Rutaceae and to the genus citrus. The most common varieties include orange (*Citrus sinensis*), mandarin (*Citrus reticulata*), lemon (*Citrus limon*), grapefruit (*Citrus paradisi*), and lime (*Citrus aurantifolia*). Citrus fruits are characterized by being fleshy fruits with high amounts of citric acid, an organic tricarboxylic acid, which gives them the characteristic acidic taste (Yáñez Rueda et al., 2007).

Vitamin C is another characteristic component of this fruit family. This is an abundant nutrient in citrus, which is a widely used antioxidant. In addition to these major compounds, we can also find a lot of fiber and minerals like potassium, calcium and magnesium (Rezzadori et al., 2012). Global production and consumption of citrus fruits have recorded strong growth since the mid-1980s. Approximately one-third of citrus fruits are used to produce fresh juice or drinks (Spreen, 2010). The yield of citrus juice represents half the weight of the fruit which is reflected in a large amount of waste (mainly peel) is produced each year globally. In traditional agriculture and product processing, these residues have very little or no value (de Moraes Crizel et al., 2013). A small percentage of this waste is being recycled to obtain essential oils which can be used in the cosmetic, food and pharmaceutical industries (Domínguez, 2016). In recent years citrus residues have been shown to contain a high amount of polyphenols such as phenolic acids and flavonoids, mainly polymethoxyflavones, flavanones, and glycosylated flavanones (Domínguez, 2016; Sormoli and Langrish, 2016). Although flavonoids are generally considered to be non-nutritive agents, the interest in flavonoids has been found to be associated with increased interest in drug research to combat multiple serious chronic diseases (Roussos, 2011; Chen et al., 2017).

Tomato

Tomato originally comes from South America in the Andean region particularly Peru, Ecuador, Bolivia, and Chile. However, its domestication was carried out in Mexico. This crop has a very important social importance, since a considerable part of the economically active population is directly or indirectly related to tomato cultivation. According to FAO (2013), annual global agricultural production of fresh tomatoes is over 163 million tons, making it one of the most important crops in the world. Mexico is in tenth place worldwide in tomato production (FAO, 2013). Agro-industrial waste accumulated from the production of tomato is of 473,989 tons (SIAP, 2017). Residues obtained from tomato processing are mainly seeds and skin. However, whole fruits may also be discarded because of damage. If these accumulated wastes are not properly processed, they would end up giving rise to environmental problems such as bad odors, water contamination or pest promotion. In addition, this type of waste is generated at a certain time just after the end of the tomato harvest, which means that in a short time large quantity of waste is accumulated.

Tomato is a species that is grouped within vegetables, which are herbaceous plants with edible fruits, for human consumption and are an important source of vitamins, minerals, and proteins. It has a low caloric value of 17 kcal/100 g and is characterized by a high-water content (90–94%), an important content of soluble sugars (fructose, glucose, and sucrose), lower proportion of proteins, fiber, and organic acids (citric and malic) and a significant contribution of vitamins (A and C), carotenoids and mineral elements. The fruit produced by this plant is an oval, round or peripheral berry. There are three ways to classify the tomato, according to its shape, maturity, and color. According to their shape, there are five types, from smallest to largest: cherry, saladette, pear type, standard ball, and large ball.

Tomato residues are a good source of bioactive molecules, especially carotenoids, such as β-carotene and lycopene, which confers not only high nutritional value but also beneficial health properties, due to their high antioxidant content. They also contain proteins, sugars, waxes, ois, lycopene, β-carotene fiber, and seed oil (Colle et al., 2010).

β-carotene is found in low proportion in tomato (Martí et al., 2016) and this carotenoid has some health-related properties such as disease prevention and it is also a precursor of vitamin A (Wang et al., 2014). Vitamin A is an essential micronutrient in the diet to boost immunity and healthy development (Verrijssen et al., 2015). Lack of vitamin A and some minerals such as zinc and iodine are associated with hidden hunger. According to the WHO, every year more than half a million children die due to this disease.

Lycopene is the primary pigment responsible for the red color in tomatoes (Borel et al., 2015). It comprises approximately 80–90% of the pigments present (Basuny, 2012). It is structurally different from carotene (Campos et al., 2017). Unlike β -carotene, lycopene is not a precursor of vitamin A (Zeng et al., 2015). Lycopene has a high antioxidant power against singlet oxygen ($^1O_2$) and high free radical scavenging ability (Boyacioglu et al., 2016).

OTHER WASTE

Buttermilk

In developing countries, milk production has been increasing in recent years, mainly due to the increase in number of animals destined for this purpose due to world population explosion. Currently, most dairy consumption is concentrated in industrialized countries, as a result of its higher purchasing power and its higher per capita consumption. World dairy production is close to 656 million tons per year (SIAP, 2017). Asia with 113,340 million tons of production generates amazing amounts of serum as waste every year. In America and Africa, whey is generated as byproduct of the dairy industry which has no added value although it is produced in large quantities. Nearly 1 million tons of whey containing 50 thousand tons of lactose and 5,000 tons of true protein are generated making it the main source of pollution in those countries and despite this potentially usable nutritional wealth, 47% of whey is discharged into the drainage and reaches rivers and soils, causing serious contamination problem (SIAP, 2017).

Whey is defined as a translucent green liquid substance obtained by removing the milk clot in the production of cheese after the precipitation of the protein (Hernández-Rojas and Vélez-Ruiz, 2014). Depending on the characteristics of the milk used to make the cheese, nutritional composition of whey can vary considerably; such characteristics will also depend on the type of cheese produced and the biotechnological process used. They can thus be classified in to two most common types sweet and acid (Bottomley et al., 1990). Sweet whey can be obtained from the processing of cheese by the use of proteolytic enzymes or rennet, which acts on milk caseins, causing them to destabilize and precipitate, under specific temperature conditions of approximately 15–20°C, with a slightly acidic pH and it contains among its components lactose (46–52 g/L), proteins (6–10 g/L), fats (5 g/L), calcium (0.4–0.6 g/L), and phosphorous (1.4–1.6 g/L), among others. It is called acid serum if the use of enzymes is replaced by organic acids. The acid whey is generated by the acid precipitation of casein, which is achieved by lowering the pH of the milk to a value of 4.5 or 4.6. At this pH the isoelectric point (5.2) of most caseins are reached, causing the casein micelle to destabilize and precipitate leaving only the serum proteins in solution (Parra Huertas, 2009). There is a third type of serum which is commonly produced in Egypt and it is a salt whey byproduct of the manufacture of Domiati cheese, the main fresh cheese of this region (Hernández-Rojas and Vélez-Ruiz, 2014). In 2016, Mexico was in the ninth place in global milk production, generating about 11,607,493 L of milk, leaving as residue an estimated of 5,874,905 L of buttermilk (SIAP, 2017).Within the dairy industry, cheese is a primary product, which uses about 25% of total world production in its preparation and the main byproduct of the dairy industry is the buttermilk used in the preparation of cheese, which retains about 55% of the components of milk.

Whey contains components of high nutritional value, containing 20% of whole milk proteins (lactalbumin and lactoglobulins) and approximately 4.5% lactose content (Hernández-Rojas and Vélez-Ruiz, 2014). However, these components are found considerably in small concentrations (Quintero et al., 2001). It also has group B vitamins [thiamine (0.38 mg/mL), pantothenic acid (3.4 mg/mL), riboflavin (1.2 mg/mL), pyridoxine (0.42 mg/mL), nicotinic acid (0.85 mg/mL), cobalamin] and ascorbic acid (2.2 mg/mL) (Parra Huertas, 2009), and is also rich in essential amino acids like leucine, tryptophan, and sulfur amino acids. The most abundant amino acids are lysine and leucine (Parra Huertas, 2009). Many people are unaware of the valuable biological value of the protein remnant that the whey contains. These proteins can be used for human consumption, like in the manufacture of whey-based beverages (Devi et al., 2017).

Biotechnological processing of whey generates products of interest to the agro-industrial sector, such as fermented beverages, organic acids (lactic and propionic acid) and microbial protein. To obtain these products, microorganisms which are able to consume the nutrients of the buttermilk are used, mainly the lactose, thus diminishing its pollution potential and at the same time useful products are obtained (Quintero et al., 2001).

Some Buttermilk Uses

Whey proteins have been used for many years as nutritional supplements of high value. The spectrum of confirmed benefits and the potential of whey protein for health ranges from infant nutrition using the purified α-La protein in infant formulas to the elderly nutrition (Hernández-Rojas and Vélez-Ruiz, 2014). Specifically, 20% of bovine serum milk proteins are present in whey and its main component is β-lactoglobulin (10%) and α-lactalbumin (4%). It also contains lactoferrin, lactoperoxidase, immunoglobulins and glycomacropeptides (**Table 2**) (Huertas, 2009). All whey proteins have different biological functions and among them, the main benefits are the prevention of cancer (breast, colon, and prostate), increase in glutathione levels, increased satiety response, antiviral and antimicrobial activities, prebiotic activity and immunomodulatory effects (Hernández-Rojas and Vélez-Ruiz, 2014).

There is a growing interest in improving the quality characteristics of milk (Drapala et al., 2016). The composition of the bovine milk differs in many aspects relating to human milk, such as to the content of casein, lactose, mineral salts and specifically in the proportion of proteins found (beta lactoglobulin is not present in breast milk). The byproduct from bovine milk is rich in raw materials and each of its components can be exploited in some way (Hernández-Rojas and Vélez-Ruiz, 2014. Some of the whey produced by dairy industry is used in animal feed (Restrepo Gallego, 2006), yogurt (Rodriguez et al., 2008), fermented beverages (Parra Huertas, 2010) and as a supplement in the production of the bakery (Visetnín et al., 2014) and confectionery products (Quintero et al., 2001; Posada et al., 2011).

TABLE 2 | Biological functions of whey proteins.

Protein	Biological function
Lactoferrin	Antibacterial, antiviral, antifungal activities. Prevents various microbial infections and various cancers Prebiotic activity
Lactoperoxidase	Biocides and biostatic activities, Prevention of colon cancer and skin cancer
Inmunoglobulins	Prevention and treatment of various microbial infections (upper respiratory infections, gastritis, dental caries, diarrhea, among others)
Glycomacropeptides	Interaction with toxins, viruses, and bacteria (mediated by the carbohydrate fraction) Control of acid formation in dental plaque Immunomodulatory activity
β-lactoglobulin	Carrier (retinol, palmitol, fatty acids, vitamin D and cholesterol) Increased pregastric esterase activity, Transfer of passive immunity Regulation of the mammary gland in phosphorus metabolism
α-lactalbumin	Cancer Prevention Lactose Synthesis Treatment of diseases induced by chronic stress

Adapted from Hernández-Rojas and Vélez-Ruiz (2014).

Fish

Being a product rich in protein, high quality amino acids, fatty acids, micronutrients like vitamin D, iodine and trace elements, people in developing countries depend of fish and finfish to meet their requirement for protein supplement (FAO, 2016; Lithgow et al., 2017). Due to aquaculture and other fisheries activities fishes and fishery products are an important source of food and thus a source of income in the developing countries. The world production of fish from capture and aquaculture in 2014 is approximately 167 million tons, (Villamil et al., 2017).

In 2014, countries like India, contributed 6.62%, Bangladesh 2.65%, Egypt 1.54%, and Latin America (Excluding Chile) 2.09% out of the total worldwide production through aquaculture (FAO, 2016). Along with the production of such high amount of fishery products huge quantities of fishery residues were also generated. Residues commonly consists of viscera, carcass, head, skin or bones and can represent from 50 to 70% depending on species and processing strategies and from this, only about 30% is destined to their re-utilization (Wong et al., 2016). For this reason, efforts are currently being made to the re-valorization of this class of byproducts to be used as a substitute for protein in animal feed and for the production of functional products.

Annual per capita consumption of fish rises constantly in developing regions with 18.8 Kg in 2013 (FAO, 2016); with the quantity of capture fishery remaining relatively static since 1980's. Fishes and fishery products helps in providing food security to many nations and techniques like aquaculture helps in meeting the targets. One of the principal expenses in aquaculture is in feeding formulations which comprises more than 50% of prices in the the total cost for fish culture industry (FAO, 2016) (Malaweera and Wijesundara, 2014). Fish meals from marine/fishery byproducts and residues can be incorporated to fish feeding formulations in a profitable manner (Olsen and Hasan, 2012). Fish meals are obtained from entire fish or their byproducts/residues with a high nutritional value composed of approximately 70% protein, 10% minerals, 9% fat, and 8% other components (**Table 3**); which forms an excellent combination of nutrients suitable for its inclusion in to a variety of animal feeds including fish feeds (Olsen and Hasan, 2012; Younis et al., 2017). In aquaculture fish meal is the primary choice for protein in animal diet, because of their amino and fatty acid balance, easy digestibility and good sensorial properties (Thuy and Ha, 2016). Because of this reason, production of fish feed from fishery wastes offers great potential and economic advantage for the aquaculture industry. De Silva and Turchini (2009) reported the use of different fish byproducts like trimmings, frames, milled dry wastes of smoked tilapia ad tuna cannery in African region for the production of fishmeal.

Utilization of fishery wastes and residues for production of fishmeal as protein source is a unique model process (Harnedy and FitzGerald, 2012), where it replaces the traditional fishmeal production from catfish processing wastes by enzymatic hydrolysis (Suprayudi et al., 2016). They claimed that almost 50% of fish meal can be replaced with a byproducts meal from smoked skipjack tuna without any negative effects on growth and performance of fish humpback grouper *Cromileptes altivelis* (Solà Oriol et al., 2011). Studies further revealed that piglets show greater preference for feed that includes fish meal as protein compared with others sources.

Applications of aquatic byproducts are not just restricted to aquaculture, but in swine, poultry and other animal feed formulations as well to promote food and nutritional security. This alternative programme helps developing countries in providing a nutritionally balanced feed for their live stock and also in managing their environment in a better manner (Malaweera and Wijesundara, 2014).

Aquatic byproducts are also suitable for the development of new products that ensures a better quality of life through the production of bio active substances including protein hydrolysates and other products for utilization as antihypertensive, antimicrobial, and antioxidants (Harnedy and FitzGerald, 2012). The properties of these products are due to the presence of peptide chains, from 2- 20 amino acids, encrypted into protein sequences and released through different methods as enzymatic hydrolysis and are termed as bioactive peptides (Korhonen and Pihlanto, 2006). Commercially available products derived from aquatic waste materials include Vasotensin® with antihypertensive effects, Seacure® to promote gastrointestinal health and Fortidium Liquamen® with anti-stress and antioxidant effects along with a lower glycemic index (Thorkelsson and Kristinsson, 2009; Harnedy and FitzGerald, 2012).

ANTINUTRITIONAL FACTORS

Food waste and byproducts are a good source of protein, carbohydrates, vitamins, and minerals. However, the use of these products is limited in the food industry mainly due to

TABLE 3 | Nutritional properties of different fish byproducts.

Byproduct	Fish	Humidity (%)	Ash (%)	Lipids (%)	Protein (%)	References
Head, frames and tail	Nile tilapia *Oreochromis niloticus*	66.5	8.9	5.5	14.6	Roslan et al., 2014
Muscle	Sardine *S. pilchardus*	78.1	1.5	1.2	18.8	Morales-Medina et al., 2016
Muscle	Horse merckel *T. mediterraneus*	77.5	1.5	1.0	21.4	Morales-Medina et al., 2016
Whole steamed fish	Dark muscle tuna –	70.5	1.35	2.4	26	Saidi et al., 2014
Whole fish	Lantern fish *Benthosema pterotum*	76.3	4.21	2.14	14.7	Chai et al., 2016
Ground muscle	Pacific whiting *Merluccius productus*	82.6	1.1	–	16.1	Pacheco-Aguilar et al., 2008

the content of antinutritional factors (ANF) such as condensed tannins, saponins, trypsin inhibitors, phytates, isoflavonoids, among others (Ee and Yates, 2013; Tresina et al., 2017). ANF are substances that are generated by the secondary metabolism of plants to protect themselves from predators. They can appear in any part of the plant, and their concentration varies according to the species, the crop, the conditions of growth, the seasons of the year and the post-harvest treatment (García, 2004; Savón and Scull, 2006). ANFs reduce the nutritional value of foods in which they are present by interfering with the digestibility and bio availability of proteins, carbohydrates, and minerals, with which they bind. In some cases, ANFs promote losses of endogenous protein, causing damage to the body that consumes them. Likewise, these may interfere with the palatability of food and inhibit digestion by affecting the catalytic activity of some enzymes (Elizalde et al., 2009).

ANF can be divided into two groups: thermolabile and thermostable. Among the thermolabile are protease inhibitors, amylases inhibitors, D, E and B12 antivitamins; and among the thermostable are the saponins, cyanogens, phytates, alkaloids, oligosaccharides, and tannins (Elizalde et al., 2009).

Due to the adverse effects that the consumption of these anti-nutritional compounds can bring, several studies have been conducted in the last few years to develop methods to decrease the level of ANFs to permissible levels. These treatments are divided into three groups: physical (husking, soaking), thermal (extrusion, cooking, toasting, frying), and biological (germination, enzymatic treatment, fermentation) (Etoa et al., 2005; Khattab and Arntfield, 2009; Djoulde Darman et al., 2011; Nidhina and Muthukumar, 2015; Rathod and Annapure, 2016). The choice of the type of treatment to be applied depends on several factors such as availability of equipment, facilities, costs (Jezierny et al., 2010) and mainly of the type of ANF that is to be eliminated.

Among the biological treatments, fermentation has been identified as one of the processes with greater efficiency because the ANF has been reduced and the digestibility of the protein has been increased substantially by this process. Microorganisms most used here are lactic acid bacteria (LAB) and filamentous fungi of the genus *Aspergillus* and *Rhizopus*. One of the special characteristics of these microorganisms is that they are recognized as safe (GRAS) since they are not producers of mycotoxins.

During fermentation, lactic acid bacteria play an important role in the reduction of ANFs due to its capacity to produce enzymes. It has been found that the bacterium *Lactobacillus plantarum* can reduce during fermentation, linamarin, a highly toxic compound found in cassava (Giraud et al., 1993; Djoulde Darman et al., 2011; Gunawan et al., 2015).

According to Adeymo and Onilude (Adeyemo and Onilude, 2013), soybean fermentation with lactic acid bacteria (*Lactobacillus plantarum*) reduces the levels of tannins, phytates and trypsin inhibitors by 75.51, 81.20, and 50%, respectively. There was also an increase in the amount of protein, thiamine, riboflavin, and niacin.

There are some experiments done using filamentous fungi under solid state fermentation processes (SSF). Londoño et al. (2016), used the strain *Rhizopus oryzae* (MUCL 28168) in an SSF process using sorghum as substrate an under optimized conditions of temperature 32.97° C, air velocity 84.11 mm 3 min-1, wheat bran 1.16% and particle size 0.82 mm, a reduction of about 86% of condensed tannins was achieved.

Among other works, Veerabhadrappa et al. (2014) optimized culture conditions in an SSF process with Jatropha seed cake as substrate and achieved reduction in some antinutritional compounds such as phytic acid, tannins, trypsin inhibitors, cyanogenic glucosides, and lectins at a level of 72, 38, 98, 19, and 89% respectively.

Soybean is a legume with highest protein value, however, its FAN content is very high. Many research studies have focused on reducing these compounds. Chen et al. (2014), used the strain *Aspergillus oryzae* (ATCC, 9362) in an SSF on soy meal to reduce phytic acid. At 50°C 41% moisture and inoculum size of 1.7 mL, 57% phytic acid was degraded. Likewise, the protein content was increased by 9.5%.

Improved Nutritional Content and Feed

When food is processed through fermentation technologies, some positive physicochemical and biochemical changes are achieved. These changes include increased levels of protein, essential amino acids, essential fatty acids, and vitamins; The increase in shelf life by producing antimicrobial compounds such as lactic acid, acetic acid and also the improvement in the digestibility and acceptability of food by the development of pleasant textures and aromas are also positive changes acquired by fermentation (Adeyemo and Onilude, 2013).

Fermentation is one of the processes that achieves a greater reduction of ANF, (Liang et al., 2008; Chelule et al., 2010; Elkhier and Abd-alraheem, 2011), due to the contribution of microbial enzymes or the activation of the endogenous enzymes of the materials, that cause degradation of the ANF content (Mahgoub and Elhag, 1998). With the reduction in ANF, fermentation causes an increase in the solubility of minerals in food, improving the bioavailability of the same in cereals and legumes (Liang et al., 2008). In animal production systems, the increase in the bioavailability of minerals leads to less environmental contamination due to the decrease in the excretion of the same. In addition, it can increase the profitability of the system, by reducing the expenses generated by the use of vitamins and minerals in food (Albelo Hernández et al., 2010).

Among the fermentation processes, SSF is one of the most interesting processes for utilizing alternative raw materials for animal food production. This is determined in the first instance by the large volumes of this waste produced annually in the world, and secondly, by the advantages that the SSF system has on conventional submerged fermentations (Castillo-Castillo and Ruiz Barrera, 2013). However, few studies have found the effect of the use of raw materials fermented by SSF processes in animal diets. Most studies focus on the inclusion of vegetable flours in diets in their original state, chemically ensiled, or fermented with bacteria and yeast, to reduce the amount of fishmeal used, or to substitute raw materials from imports, including those used in cereal formulations, roots and native tubers (Almaguel et al., 2010); although, the protein quality of unfermented vegetable flours does not generally meet all the nutritional specifications of the animals.

Among the feeding studies, Pedraza (2000) showed some results obtained when using cane bagasse fermented with a yeast strain for feeding chickens, rabbits, and dairy cows, indicating that in all cases the results were positive, without the presence of intoxications or low yields due to the use of this type of products. In the case of chickens, 11% of the traditional feed was replaced, 60% of substitution was fed to rabbits, and in the case of cows it was used as a supplement, increasing milk production by 1.8 L/cow/day, which indicates that it is possible to use this type of products in food substituting the raw materials traditionally used, without affecting the yields hitherto achieved.

Hassaan et al. (2015) reported the production of a commercial soybean meal fermented by a strain of *Saccharomyces cerevisiae* under SSF as a protein source in feed for Nile tilapia (*Oreochromis niloticus*). The studies showed that it is possible to replace approximately 37% of the traditional protein source (fishmeal), without disturbing development and animal health. These results may be due to the release of amino acids during the fermentation process, which makes protein and other nutrients more available. Alshelmani et al. (2016), manufactured a feed with palm kernel cake fermented by *Paenibacillus polymyxa* (ATCC 842) under SSF and evaluated their effect on the zootechnical parameters in broiler chickens. The results indicate that up to 15% of the palm kernel cake fermented in the rations without affecting the digestibility of the food and the development of the animals. Sharawy et al. (2016), evaluated the effect of substitution of dietary fishmeal with soybean meal fermented by a *Saccharomyces cerevisiae* strain under SSF on growth performance, feed utilization and palatability of white shrimp. The results showed that it is possible to replace up to 50% of the fish meal with soybean meal fermented without affecting the behavior and growth of the animals.

RESEARCH AND INNOVATION

Use of Food Wastes and Byproducts as Food Ingredients

The food demand all over the world is increasing and there is a need to develop new foods or make better some of the known (Ting Lai et al., 2017). Food development applying food wastes or byproducts from different agro-industries is a great alternative to make using some secondary food products. Many or almost all these products are always discarded, and they can be improved to make some foods like cookies or cereal bar as an example. Not all agro-industrial wastes can be used as an ingredient in a newly developed food and it can't be any kind of food, usually the foods developed using agro-industrial wastes are the ones made with flours.

There are some wastes which are used to fortify some foods. For example, tortilla added with defatted soybean meal increase the protein content (Amaya-Guerra et al., 2004), soy flour has been added to spaghetti too and it has increased the protein and amino acid content (Shogren et al., 2006). King palm flour was used in the production of cookies and gluten-free cookies for obtaining a higher yield of dietary fiber and some minerals like calcium, magnesium or potassium (Vieira et al., 2008; De Simas et al., 2009).

Paiva et al. (2012), used the core of the pineapple and merge it with another ingredient like soybean extracts and broken rice to produce a new cereal bar with high protein, dietary fiber and mineral content and low caloric value. Díaz Vela et al. (2015), applied pineapple peel flour to improve the physicochemical properties of cooked sausages and they got a great performance but compared with cactus pear peel flour, pineapple peel flour was not found better. It retains water in sausages and decreases oxidative rancidity. As presented in section Mango, mango rind is also a good source of dietary fiber; mango peel flour can be added in the formulation of pasta (macaroni), bakery products (bread, cakes, and cookies), dairy products (cheese, yogurt, and ice cream) and extruded foods. All these food products have a great relevance in the world food market (Serna-Cock et al., 2016).

Jabuticaba peel has been used in Brazil to develop cookies and cereal bars. Cardoso Zago et al. (2015), used jabuticaba peel to develop cookies without losing any sensorial properties of the traditional cookies. Appelt et al. (2015), combined jabuticaba peel with *Okara* instead of traditional flours and they created a new cereal bar with a high protein content and the sensorial characteristics have a great acceptability. Dischsen et al. (2013), reported that they can use cassava waste to develop a breakfast cereal in combination with corn grits as the main ingredients in preparation. The resultant product had a higher fiber content

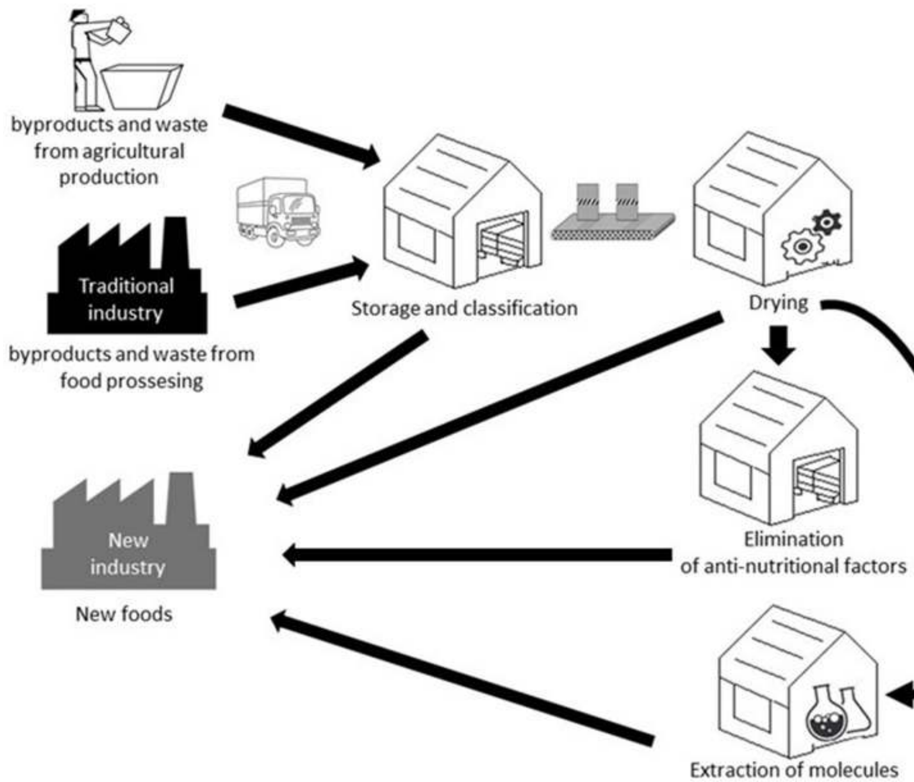

FIGURE 2 | Technological perspectives for the use of food waste and byproducts in the development of food.

and a crispy texture compared to the cereal made only with corn grits.

Ricce et al. (2013), used powders of asparagus and almond sugar powders, artichoke bracts, and wheat bran in different combinations and the quality characteristics of the products were evaluated. The sensorial acceptance of the bread, along with these materials were very good.

The extraction of different compounds from the accumulating food wastes and byproducts create new options to utilize these extracts into food industry to make better foods. Some of the wastes can give better nutritional characteristics to the existing food including higher antioxidant property, higher protein or fiber content and high concentrations of minerals very essentials to the human health (de Oliveira Sancho et al., 2015). Sun-Waterhouse et al. (2013), evaluated three different apple wastes. They reported that the three wastes from the three different apples had a considerable polypeptide concentration. The three different parts evaluated from the apples can be used in development of novel food products. There is a great opportunity for all food wastes and byproducts to be utilized for the production of diverse types of food with better nutritional characteristics. Food residues/wastes contain several compounds which are metabolized better in the human system than others. Proper utilization of these biomaterials can benefit human health, can bring advancements to the food industry and can solve many environmental problems created due to the discharge of these wastes.

TECHNOLOGICAL PERSPECTIVE

Due to the nutritional, nutraceutical, and functional properties of the food waste, it can be argued that this is a raw material with significant potential and numerous applications in food formulations, mainly in the developing countries where this waste is produced. Biomolecules like proteins, lipids, starch, vitamins, minerals, fibers, and antioxidants, present in the food wastes and byproducts can be separated individually from the biological matrix (using extraction techniques physical or chemical) or used directly as a food to make the most of the nutritional and functional components contained in them. However, microbiological risks should always be avoided, so that the unitary drying operation is a fundamental step to guarantee the microbiological and physicochemical stability of biomaterials. Therefore, new government actions must be implemented to install infrastructure and technology that allows taking advantage of waste and byproducts in its places of production and storage (**Figure 2**). The new developments in infrastructure should also contemplate the possibility of reduction of ANF. In this respect, as mentioned in section Antinutritional Factors, fermentation process is an effective method to eliminate ANF and fortify biomaterials.

With the appropriate preservation technology, food wastes and byproducts rich in dietary fiber can be used as food powders (Cuq et al., 2013). The powder can be directly used in drinks, taking advantage of its good solubility (Sogi et al., 2013). These biomaterials can also be used in the manufacture of bakery products (Odunsi, 2005) in developing countries where tropical fruit, buttermilk, and fish waste are mainly grown and processed. New research on the development of novel products based on byproducts is very much required. Technological innovation can contribute to the promotion of new business alternatives (**Figure 2**), which will contribute to the increase in the number of beneficial foods to reduce hunger and generate more employment, which directly benefits local communities.

In the evaluation of food waste as a source of food additives legal aspects should be considered, for evaluating food safety in potential consumers. The creation of a new product for marketing purposes must have an authorization from the state entity delegated to that function. The qualification of a certain substance as food has great implications since it means that generic and specific food legislation must be applied (Baiano, 2014). Finally, food products must comply with all the quality and safety requirements of the food regulations of the respective countries.

CONCLUSIONS

The development of sustainable solutions for the management of byproducts and food waste is one of the main challenges of our society. These solutions must be able to take full advantage of the biological potential of biomaterials and achieve economic, social and environmental benefits. With the nutritional problems facing society today (hunger indicators and the growing world population), the use of food waste for human food should be a priority. Wastes and byproducts produced in developing countries have a powerful nutritional and functional use in their formulation and a powerful tool in minimizing of hunger. In addition, the added value generated by the diversification of the productive chains can create job opportunities for the residents generating an additional social benefit.

AUTHOR CONTRIBUTIONS

CT-L defined the objective of the article, the topics to be discussed and coordinated the writing activities, the author also contributed with mango byproducts, and with CA also discussed the perspectives of the topic. NR-G, RD-H, and VN-M provided information on the byproducts and wastes of fruit processing. GM-M, OA-P, and MV contributed information about other waste. BP, JA-V, LL-H and CA carried out a wide-ranging discussion on the use of biomaterials and reduction of antinutritional factors.

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