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Review

A review: Modified agricultural by-products for the development and fortification of food products and nutraceuticals

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ABSTRACT

Producing more food for a growing population in the coming decades, while at the same time combating environmental issues, is a huge challenge faced by the worldwide population. The risks that come with climate change make the mission more daunting. Billion tons of agriculture by-products are produced each year along the agricultural and food processing processes. There is a need to take further actions on exploring the inner potential of agro-waste to stand out as food ingredient to partially or fully substitute the foods in orthodox list. Some of the agro-waste contains the most valuable nutrients in the plant and it is truly a "waste" to dispose any of them. Furthermore, the paper aims at discussing the possible methods of modification to improve the safety and feasibility of the agro-waste either through physical, chemical or microbiological ways. The safety issues and bioactivity contains in the agro-waste also been discussed to present the better overall ideas about the employing of agro-waste in food applications.

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1. Introduction

The United Nations Food and Agriculture Organization estimates that about 805 million people of the 7.3 billion people in the world, or one in nine, were suffering from chronic undernourishment in 2012–2014, mostly in developing regions of Asia/Pacific, Sub-Saharan Africa, South/Central America, and the Caribbeam (Fao, 2014link). Sustainable agriculture has an important role in eliminating hunger and malnutrition. Over the past few years, urbanization, biofuels and food scarcity have led to higher global food prices and price volatility. Rapidly increasing consumer prices limit food access. Increased price volatility reduces the benefit that small scale farmers derive from higher producer prices. Biofuels create competition between poor people in the developing countries and energy consumers in the developed countries. All these factors further worsen the world hunger problem and more actions need to be taken to combat hunger and malnutrition problem.

Ironically, disposal of solid waste generated from agricultural activity is another serious problem in developing countries like India. The major quantities of wastes generated from agricultural sources are defatted rice bran, defatted corn germ, fruit waste and etc. Modification and extraction of phytochemicals from the agricultural waste must be implemented as an idea of "food for food". The waste from the food and agricultural industries need to be lowered and eventually pull more people out from the situation of hunger.

The disposal of agro-waste induced growing problem since most of them are very prone to microbial spoilage, thus limiting further exploitation. On the other hand, costs of drying, storage and shipment of by-products are economically limiting factors. Therefore, agro-waste is often used as feed or as fertilizer. The problem of disposing by-products is further aggravated by legal restrictions. Thus, efficient, practical and environmentally sound utilization of these materials is becoming more important especially since profitability and j obs may suffer.

In recent years, there has been a growing interest to maximize the uses of the agricultural by-products for different purposes encompassing from material as bioabsorbent (Sud, Mahajan, & Kaur, 2008), rhizobial inoculant production (Ben Rebah, Prévost, Yezza, & Tyagi, 2007),food additive (J. F. Ayala-Zavala, et al., 2011) and other applications. The objective of this paper is to target on the

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agro-waste that was abundantly disposed or used for non- food applications and suggest the potential of it to become warrior to fight for world hunger.

2. Existing products and current researches

Many efforts have been done by researchers and organizations in order to cope with the agro-industrial waste produced by the industries. Indeed, many by-products that were previously underutilized have been transformed into useful ingredients. Some of these ingredients were commercialized and widely used by the industries as food products or as nutraceutical ingredients in food products.

2.1. Isolated soy protein (ISP)

The most established usage of by-products from soybean oil mill was the production of soy protein isolate from the defatted soybean meal (Berk & FAO, 1992). There has no official standard on the composition of ISP, but it was defined by the Association of American Feed Control Officials (AAFCO) as "*the major proteinaceous fraction of soybeans prepared from dehulled soybeans by removing the majority of non-protein components and must contain not less than 90% protein on a moisture-free basis*" (*'90 Soya Bluebook*, 1990).

Current food trends are transforming from meat-based diet to plant-based diet, and producing plant-based protein is actually of enormous interest. Soybean proteins has all of the essential amino acids required by the human body, which includes methionine, lysine, isoleucine, lysine, histidine, phenylanaline, threonine, tryptophan and valine (Friedman & Brandon, 2001; Friedman, 1996). This full coverage of essential amino acid by soybean protein makes ISP a very important ingredient in food industry as ISP can be added into various food products in order to increase the protein content as well as to overcome the lack of essential amino acids in other food products. The examples of food products contain ISP listed by the Soyfoods Association of North America ("Soy Protein Isolate | Soyfoods Association of North America, 2013|) which are available in the market are as below:

- dairy based product including infant formula
- beverages including liquid soy milk and fruit drinks
- soups and sauces
- energy bar
- meat analogs including vegetarian food products
- breads and pastries
- breakfast cereals and other nutritional food products
- protein drink for muscle building and weight gaining purpose

2.2. Textured soy protein (TSP)

The defeated soybean meal has also always been used in producing texturized soy protein. This ingredient is very famous in vegetarian food products as meat analog which it mimics the texture of meat products. Textured soy protein has been an important food ingredient since 1960s(P. Singh, Kumar, Sabapathy, & Bawa, 2008), with the first textured vegetable protein produced by Boyer in 1947 (Wilding, 1971). Codex Alimentarius (2007) has recorded the standard for vegetable protein products (Codex Standard 174–1989) and the standard for utilizing vegetable protein products in foods (CAC/GL 4–1989) as functional ingredients, protein increasing ingredients, partial or complete substitution of animal protein as well as sole protein source of a product.

Berk and FAO (1992) reported the utilization of TSP where TSP are used as either meat extenders, meat analogs, imitating bacon bits as well as pasta with texturized soy protein granules. The advantages of incorporating textured soy protein discussed by Gordon-Davis and Van Rensburg (2004) were:

- lower cost compared to meat
- can act as meat extender
- shelf stable
- almost zero fat which is suitable for low fat diet
- zero cholesterol as it is vegetable based

2.3. Rice bran oil

Rice bran was previously being considered as a waste as the rice kernel (white rice) is the important product where the major income from rice comes from this part. Rice germ and bran are usually being considered as by-products previously, until researchers found that rice bran oil has good composition of monounsaturated and polyunsaturated fatty acids which turns to be health beneficial to humans(Kochhar & Gunstone, 2002).

Rice bran oil has been commercialized now in India, United States of America, Thailand and many more. The benefits of rice bran oil were being discussed by many researchers and it is being showed as below, which has been summarized by Friedman (2013):

- anti-allergic activities
- anti-cholesterol activities
- anti-diabetic activities
- producing liquid-solid or semisolid form of product from rice bran oil (e.g. shortening or spreads)
- regulation of immune system

2.4. Possible utilization of agro wastes into food and nutraceutical ingredients

Other than those established, commercialized and widely used ingredients as mentioned above, there are as well many researches that valorized agricultural wastes and agro-industrial wastes into useful food ingredients as well as nutraceutical or functional ingredients. These wastes from either agricultural practices or agro-industry processes can be divided into several groups according to their sources (Table 1)

3. Modification (by-products to food product)

Agro-industrial wastes are often under-utilized and pose a major disposal problem to the concerned parties. Food processing wastes are promising sources of valuable compounds such as dietary fiber, antioxidants, essential fatty acids, antimicrobials, minerals because of their favorable technological, nutritional and functional properties (Schieber, Stintzing, & Carle, 2001). The higher-value products may be developed through various modification methods.

3.1. Extraction

3.1.1. Solvent extraction

In solvent extraction, the solvent acts as a physical carrier to transfer the target molecules between different phases of solid, liquid or vapour (Galanakis, 2012). Various compounds can be isolated using solvent extraction, which are tocopherols, flavonoids and related compounds such as coumarins, cinnamic acid derivatives, and chalcones; phenolic diterpenes; and phenolic acids (Oreopoulou & Tzia, 2007, pp. 209–232). Non-polar solvents

Table 1
Summary of types of agro wastes.

Types of agro wastes	Value added products	Source
Plant parts, wastes		
Cassava bagasse	Gluten-free noodle	Fiorda, Soares, da Silva, Grosmann, and Souto (2013)
	Lactic acid	John, Madhavan Nampoothiri, et al. (2006) and John, Nampoothiri, et al. (2006)
Sugarcane bagasse	Lactic acid	Laopaiboon, Thani, Leelavatcharamas, and Laopaiboon (2010)
	Ethanol	de Moraes Rocha et al. (2011)
	Inulinase	Mazutti, Bender, Treichel, and Di Luccio (2006)
	Xylitol	Santos, Sarrouh, Rivaldi, Converti, and Silva (2008), Rao, Jyothi, Prakasham, Sarma, and Rao (2006)
Coffee husk	Anthocyanin	Prata and Oliveira (2007)
Corncobs	Vanillin	Torres et al. (2009)
	Xylitol	Li et al. (2012)
	Anthocyanin	Yang and Zhai (2010)
	Prebiotic (oligosaccharide)	Vázquez et al. (2006)
Palm empty fruit bunch	Xylose	Tan, Dykes, Wu, and Siow (2013)
Rice hull	Antioxidant and phenolic compounds	Wang, Chen, and Lü (2014)
	Rice hull smoke extract	Kim et al. (2011); Yang et al. (2011)
Wheat bran	Antioxidant and phenolic compounds	Kim, Tsao, Yang, and Cui (2006)
	Flour	Hemery et al. (2011)
	Arabinoxylooligosaccharides	Swennen, Courtin, Lindemans, and Delcour (2006)
	Bread	Hemery et al. (2010)
	Meat patties	Talukder and Sharma (2010)
	Noodle	Chen et al. (2011b)
Pressed cakes		
Defatted corn germ	Wheat flour	Siddiq, Nasir, Ravi, Dolan, and Butt (2009b)
	Wheat bread	Siddiq et al. (2009a)
	Cookies	Nasir et al. (2010)
Defatted rice bran	D-lactic acid	Tanaka et al. (2006)
	Bakery products (bread)	Sairam, Krishna, and Urooj (2011)
	Pan bread	Ajmal, Butt, Sharif, Nasir, and Nadeem (2006)
	Vitamins B	Chen et al. (2011a)
	Rice bran protein	Zhang, Zhang, Wang, and Guo (2012)
	Phenolic acids	Fabian, Tran-Thi, Kasim, and Ju (2010); Wataniyakul, Pavasant, Goto, and Shotipruk (2012)
	Phenolic-saponins rich fraction	Chan, Khong, Iqbal, and Ismail (2013)
Palm mesocarp fiber	B-carotene	Mustapa, Manan, Azizi, Setianto, and Omar (2011)
Palm pericarp fiber	Bread	Zaman (2008)
Sunflower seed	Oil	Gunstone (2011)
	Wheat bread	Škrbić and Filipčev (2008)
	Sunflower seed protein	González-Pérez and Vereijken (2007)
Fruit rinds, skins, wastes		
Apple pomace	Cake	Sudha et al. (2007)
	Pectin	Wang et al. (2007)
	Fat replacer	Min, Bae, Lee, Yoo, and Lee (2010)
	Phenolic and antioxidant compounds	García, Valles, and Lobo (2009); Wijngaard and Brunton (2010); Wijngaard and Brunton (2009)
	Xyloglucan	Fu, Tian, Li, Cai, and Du (2006)
Citrus wastes	Pectin	Lim, Yoo, Ko, and Lee (2012); Wang et al. (2014)
Grape pomace	Polyphenol and antioxidant compounds	Ruberto et al. (2007)
	Xylanase and pectinase	Botella, Diaz, De Ory, Webb, and Blandino (2007)
	Procyanidin	Khanal, Howard, and Prior (2010); Khanal, Howard, and Prior (2009); Monrad, Howard, King, Srinivas, and Mauromoustakos (2009)
	Fiber source for cookies	Górecka, Pachołek, Dziedzic, and Górecka (2010)
	Anthocyanin	Monrad, Howard, King, Srinivas, and Mauromoustakos (2010)
Jackfruit seed	Monascus pigments	Babitha, Soccol, and Pandey (2007)
	Starch as thickener and stabilizer in chili sauce	Rengsutthi and Charoenrein (2011)
	Starch	Kittipongpatana and Kittipongpatana (2011)
	Flour	Ocloo, Bansa, Boatin, Adom, and Agbemavor (2010); Chowdhury, Bhattacharyya, and Chattopadhyay (2012)
Kiwi fruit peel	Pectin	Kulkarni and Vijayanand (2010)
	Polyphenol	Sun-Waterhouse, Wen, Wibisono, Melton, and Wadhwa (2009)
Pineapple wastes	Bromelain	Ketnawa, Chaiwut, and Rawdkuen (2012)
	Citric acid	Kuforiji, Kuboye, and Odunfa (2010)
	Vinegar	Gu et al. (2010)
	Bioprotein	Jamal, Tompang, and Alam (2009)

(hexane, petroleum ether) can be used for the recovery of tocopherols and certain phenolic terpenes. Ethyl ether and ethyl acetate are very efficient for the recovery of flavonoid aglycons, low-molecular-weight phenolics, and phenolic acids. Solvents of higher polarity (ethanol or ethanol–water mixtures) additionally can extract flavonoid glycosides and higher molecular weight phenolics, resulting in higher yields of total extracted polyphenols (Oreopoulou & Tzia, 2007, pp. 209–232). Organic solvents, such as acetone and ethyl acetate, are used for the extraction of carotenoids, and acetone results in the highest yield compared to ethanol, petroleum ether, and hexane (Calvo, 2005). Solvent permitted for use in the preparation of food ingredients in the European Union are ethanol, ethyl acetate and acetone (Marriott, 2010). Pectin extraction is accomplished by the use of mineral acids, usually hydrochloric or nitric acid (Oreopoulou & Tzia, 2007, pp. 209–232). The extract is separated from the solid residue and pectin is precipitated by the addition of ethanol or AlCl solution. Purification of the precipitated pectin involves washing with acidified, alkaline, and finally neutral alcohol (J. Ayala-Zavala, et al., 2011). Extraction of defatted soy flake with aqueous alcohol improves the flavor and color of soy protein isolate as well as markedly improved its foaming and gelling properties by removing phospholipids and other alcohol-soluble materials. Soy protein isolate as a highly purified commercial soy protein product has been used in meat and dairy foods where emulsifying, thickening and gelling properties are of prime importance (Hua, Huang, Qiu, & Liu, 2005).

However, health, security, and regulatory problems are always associated with the use of organic solvents such as hexane and chloroform. Additionally, efficient solvent recovery processes are needed to commercialize these processes. Therefore, alternative methods such as supercritical CO2, solid states fermentation, and subcritical water extraction are used to replace toxic organic solvents to extract valuable compounds from agricultural by-products.

3.1.2. Supercritical fluid extraction (SFE)

Supercritical fluid extraction involves the use of gas above its critical temperature and pressure (Galanakis, 2012). Supercritical fluid is defined as a state where the liquid and gas are indistinguishable from each other above its critical point, or a state where the fluid is compressible, has a similar density and solvating power to liquid. Supercritical fluid extraction has several advantages over the conventional methods, including faster processing times, high selectivities (i.e., high quality extract) and high extraction yields (Farias-Campomanes, Rostagno, & Meireles, 2013; Herrero, Cifuentes, & Ibanez, 2006). Carbon dioxide is the most commonly used fluid in SFE due to its low critical point (304.2 K/7.4 MPa), favorable environmental characteristics and low costs. CO_2 can be easily separated by depressurization and thus, can be recovered and reused (Farias-Campomanes, et al., 2013).

Numerous vegetable matrices have been used as natural sources for compressed fluid extraction. Legumes, spices, aromatic plants and even fruit beverages, such as natural orange juice (Señoráns, et al., 2001), have been processed to obtain natural antioxidant compounds. Mira, Blasco, Berna, and Subirats (1999) extracted orange essential oil from dehydrated orange peel using SFE. Several applications have been developed using SFE in the recovery of value-added components from grape residues, including oil from seeds, tannins from seeds and polyphenols from both skins and seeds (Farias-Campomanes, et al., 2013). The recovery of catechin and other phenolic compounds was found to be higher during isolation of phenolic compounds from grape seeds using supercritical carbon dioxide (Murga, Ruiz, Beltrán, & Cabezas, 2000; Palma & Taylor, 1999) (Louli, Ragoussis, & Magoulas, 2004). employed supercritical fluid extraction after ethyl acetate extraction of wine industry by-products caused higher antioxidant activity, allowing odourless and clearer extracts.

A single-step supercritical fluid extraction can be effectively used to recover residual oil from palm pressed fiber, a palm oil by-product, researched by the Malaysian Palm Oil Board (MPOB). Separation techniques are then used to isolate valuable phytochemicals from the oil, while the combination of supercritical fluid extraction and separation techniques are able to extract about 0.1–0.2% of phenolics (Y. A. Tan, Sambanthamurthi, Sundram, & Wahid, 2007).

3.1.3. Subcritical water extraction (SWE)

Subcritical water extraction (SWE), an extraction which uses hot water under pressure, has recently emerged as a useful and environmentally friendly tool to replace the traditional extraction methods. Basically, the instrumentation consists of a water reservoir coupled to a high pressure pump to introduce the solvent into the system, where the extraction cell is placed and extraction takes place and a restrictor or valve to maintain the pressure. Extracts are collected in a vial at the end of the extraction system. Subcritical water extraction has been widely used to extract different compounds from several vegetable matrices such as rosemary (Arvanitoyannis & Kassaveti, 2008; Herrero, et al., 2006).

3.1.4. Thermal processing (steaming/microwave/sterilization)

Thermal processing has also been found to enhance the recovery of phenolic compounds, as described by Garrote, Cruz, Domínguez, and Parajó (2003) for autohydrolysis of corn cobs, where increased phenolics yields, but with lower specific activity, were obtained with increased reaction temperatures in higher phenolics yields. Jeong, et al. (2004) also reported that there is a significant increase in the total phenolic content after heating citrus peel at 150 °C for 40 min. Sterilizing onion by-products was also found to improve the soluble:insoluble fiber ratio with less oil holding capacity, cation exchange capacity and swelling capacity, although their physicochemical properties were generally higher than those of cellulose. Therefore, sterilization might be a good method to stabilise onion by-products to use as a potential dietary fibre ingredient (Benítez, et al., 2011).

Microwave-assisted extraction has been applied for the extraction of pectin and phenols from apple pomace and potato by-products, respectively (Oreopoulou & Tzia, 2007, pp. 209–232) Microwave energy is able to heat solvents rapidly and thus accelerating transfer of analytes from the sample matrix into the solvent. This technique is easy to handle, requires moderate solvent and was reported to increase substantially recovery of total phenols from berries pomace compared to the conventional solid-liquid extraction (Galanakis, 2012).

3.1.5. Solid-state fermentation (SSF)

Solid-state fermentation (SSF) also known as koji fermentation is gaining wide interest these days for the production of organic acids, enzymes and other biotechnological products (Dhillon, Kaur, & Brar, 2013). Agro-industrial residues are generally considered the best substrates for koji fermentation processes, especially for enzyme production (Dhillon et al., 2013) The presence of lignin and cellulose/hemicellulose acts as natural inducers, and most of these residues are rich in sugar, promoting better fungal growth and thus making the process more economical especially for the cellulo- and ligninolytic-enzymes.

Apple pomace undergone koji fermentation to produce of organic acids, heteropolysaccharide (i.e. xanthan, chitosan) aroma compounds, bioethanol, enzymes, edible mushroom (*Pleurotus ostreatus*), antioxidants, nutritional enrichment among others. Several factors making apple pomace suitable as a raw material for biotechnological products are the high content of polysaccharides (mainly cellulose, starch and hemicelluloses); presence of mono-, di- and oligosaccharides, citric acid and malic acid, which can be metabolized by microorganisms; and richness in vitamins and other mineral ions which could limit the cost of nutrient supplementation for fermentation media (Dhillon, et al., 2013). Apple pomace extract was also found able to produce baker's yeast, *Saccharomyces cerevisiae* with higher cellular yield coefficient and lower ethanol production as compared to jaggery and molasses. During fermentation of apple pomace using *P. chrysosporium*, the polyphenolic compounds was increased significantly and the nutraceutical properties was improved.

Correia, McCue, Magalhães, Macêdo, and Shetty (2004) also described the use of the fungus *Rhizopus oligosporus* to produce phenolic compounds from a pineapple waste (residual pulp, peels and skin)-soybean flour mixture and a twofold increase in total phenolics content was observed. There is great potential for the use coffee pulp and coffee husk as substrates to microbial aroma production by solid state fermentation using two different strains of *C. fimbriata* (Murthy & Naidu, 2012).

3.1.6. Extrusion

Extrusion combines a number of unit operations i.e. mixing, cooking, shearing, puffing, final shaping and drying in one energy efficient rapid continues process (Harper, Linko, & Mercier, 1989) and can be used to produce a wide variety of starchy foods including snacks, ready to eat (RTE) cereals, confectioneries and extruded crisp breads (Suknark, Phillips, & Chinnan, 1997). This process of high temperature short time extrusion bring gelatinization of starch, denaturation of protein, modification of lipid and inactivation of enzymes, microbes and many antinutritional factors (Bhattacharya & Prakash, 1994). Extruded foods have been proven to provide nutritious products and combine quality ingredients and nutrients to produce processed foods that contain precise levels of each required nutrient (Cheftel, 1986). The fruit wastes, defatted hazelnut flour and durum clear flour can be used in combination with cereal flours for production of nutritionally-balanced convenient extruded snack foods due to their valuable characteristics (Yağcı & Göğüş, 2008).

3.1.7. Enzymatic hydrolysis

Animal by-products are rich sources of protein even though they are often discarded due to aesthetic reasons (Lasekan, Bakar, & Hashim, 2013). Most of the protein fractions can be easily extracted and thus be used extensively in the production of hydrolysates as food ingredients. Enzymatic hydrolysis has been used mainly for converting these wastes to hydrolysates with a high degree of hydrolysis and yield. Most researches on the utilization of animal by-products as sources of hydrolysates have focused on the fish processing by-products (Harnedy & FitzGerald, 2012) and this might be due to the ease of isolation and hydrolysis of the fish proteins. Large amount of proteinaceous wastes in form of heads, scales, bones and viscera from fish processing are generated and used for the production of protein concentrate and hydrolysate. However, chicken by-products (viscera, head, skin, and feet) can also as a source of hydrolysates as well as source of peptone in microbiological media (Jayathilakan, Sultana, Radhakrishna, & Bawa, 2012)

4. Safety

Lately, food safety has become a more conspicuous issue for global trade in agricultural and food products (Henson & Jaffee, 2008; Josling, Roberts, & Orden, 2004). The potential impact of the food safety standards, whether promulgated by governments or private sector, are not merely on the safety and health concerns of consumers, but also on the ability of developing countries to gain and maintain access to markets for high value agricultural and food products, especially in industrialised countries. However, impacts are greatest for low-income countries due to their weaker food safety and quality management capabilities which can then impede their efforts towards export-led agricultural diversification and rural development.

This section highlights the food safety challenges and constraints that need to be addressed in regard to products related to agricultural by products. The food safety hazard has been outlined as below (Table 2):

Mycotoxins are secondary metabolites produced by fungal species that are known to be widely distributed worldwide in many foods and feedstuff (Pfohl-Leszkowicz, Petkova-Bocharova, Chernozemsky, & Castegnaro, 2002), including oil seed cakes (e.g. peanut, soybean, sunflower, palm kernels, cotton, corn and etc.). Among all mycotoxins, aflatoxins (AFs), ochratoxin A (OTA), deoxynivalenol (DON) and zearalenone (ZEN) have garnered much attention due to their high frequency and severe health effects in humans and animals (Bhat, Sridhar, & Karim, 2010). They can enter into human body in many ways such as inhaled, consumed, or absorbed through the skin. The ingestion of products from animals (milk or meat) exposed to contaminated feed is also one of the indirect ways. However, regardless of how they entered, they will eventually cause sickness in both animals and humans (Bankole & Adebanjo, 2004), and can even be lethal in severe cases. The adverse effect that caused by the consumption of the mycotoxins are either acute or chronic, for examples, carcinogenic, teratogenic, immunosuppressive or estrogenic effects (Binder, Tan, Chin, Handl, & Richard, 2007).

The reasons why mycotoxins are thriving without fallen for centuries are that the fungi and fungal spores are able to colonize and penetrate deep into the matrices of agricultural crops and produce mycotoxins during preharvest and postharvest practices, and processing and storage stages (Bhat, et al., 2010) and their production is very much dependent on the ecological and environmental factors such as temperature, type of substrate, moisture content, relative humidity, water activity (aw), occurrence with other fungi, physical damage by insects, use of fungicides, as well as storage conditions (Zöllner & Mayer-Helm, 2006). In terms of bacterial contamination, foodborne pathogen e.g. *Salmonella* spp. and *E coli O157:H7* are normally associated with the contamination of agricultural products or by-products due to the application of contaminated manure especially from animal source (Maciorowski,

Table 2
Summary of food safety hazards associated with agricultural byproducts.

Food safety Hazard	Types	Occurrence	References
Mycotoxins	- Aflatoxins - Ochratoxin A (OTA) - Deoxynivalenol (DON) - Zearalenone (ZEN)	Oil seed cake (e.g. peanut, soybean, sunflower, palm kernels, cotton, corn and etc.) and corn by-products.	Afsah-Hejri, Jinap, Hajeb, Radu and Shakibazaeh (2013)
Antinutritional constituents	-Tannin -Phytate -Saponins -Protease inhibitor -Lectins -Goitrogens -Cyanogens -Glucosinolates	Legumes related products including defatted soybean meal; Jatropha oil seed cake; coffee pulp and husks.	Murthy, P. S. and M. Madhava Naidu, 2012; Abou-Arab and Abu-Salem (2010); Chen, Li, Vadlani, Madl, and Wang (2013)
Bacterial contamination	-*Salmonella spp.* -*E coli O157:H7*	Agricultural products or by-products	Nahashon and Kilonzo-Nthenge (2011)
Heavy metals	-Arsenic	Rice bran and its related product	Sun et al. (2008)

Herrera, Jones, Pillai, & Ricke, 2007). Thus, the most effective safety measure is to implement and constantly practice Good Agricultural Practices (GAP) in the farms, for examples, food safety plans on the growing, harvesting, storage and packing, and Good Manufacturing Practice (GMP) throughout the processing. These safety plans can compromise with the heat treatment or ionizing radiation that might be applied for the purpose of elimination of bacterial and mycotoxins contaminations in addition to the later detection stage which can be sometimes difficult due to their low levels or the limitation of the traditional culturing methods itself. In other words, monitoring and prevention at the earlier stage of processing or at the raw material itself is the most crucial and promising mitigation efforts in the prevention of entering the food processing.

Anti-nutritional factors are compounds that interfere with the utilization of dietary nutrients in various paths, for examples the factors which impart depressive effect on protein digestion and utilization (trypsin and chymotrypsin inhibitors, lectins or haemagglutinins, polyphenolic compounds, NSP-s and saponins); negative effect on the digestion of carbohydrates (amylase inhibitors, polyphenolic compounds, NSP-s, flatulence factors) and minerals (glucosinolates, oxalic acid, phytic acid, gossypol); inactivate vitamins or cause an increase in the animal's vitamin requirements (anti-vitamins). Consequently, there are many oil seed meals, legumes and related products rich in major nutrients and balanced amino acids remain unutilized or under-utilized due to the presence of these antinutritional constituents. Heat processing is the most typical treatment used to reduce them to a reasonably safe level. Apart from that, fermentation is also an effective means in detoxification. For instances, studies on detoxification of coffee husk in solid state fermentation using three different strains of Rhizopus, Phanerochaete, and Aspergillus spp. showed great detoxification effect, most notably Aspergillus spp.(Brand, Pandey, Roussos, & Soccol, 2000; Pandey, et al., 2000). In the case of soybean or soy meal, besides the degradation of anti-nutritional factors (including oligosaccharides, trypsin inhibitor and phytic acid), fermentation could also degrade large soy protein into peptides and amino acids which subsequently remove the allergenic effect of soy protein. Additionally, it helps to enhance the nutritional profiles of soybean and soymeal along with removal of undesirable factors (Chen et al., 2013).

Besides, it is also worth noting about the Jatropha oil seed cake where many studies have been focus on its transformation to be one of the potential source of livestock feed owing to its rich protein content (Aderibigbe, Johnson, Makkar, Becker, & Foidl, 1997; Makkar, Becker, Sporer, & Wink, 1997; Martinez-Herrera, Siddhuraju, Francis, Davila-Ortiz, & Becker, 2006) At this moment, Jatropha cake is still yet to be used as a feed due to the presence of high levels of toxic and antinutritional constituents such as trypsin inhibitor, phytic acid, saponins and glucosinolates. Phorbol esters which present at high levels in the kernels are the most toxic compounds found in the cake. These diterpene esters of Euphorbiaceae, such as phorbol, deoxyphorbol and ingenol esters, are known to be strong tumour-promoting agents. Various methods, water leaching, autoclaving, and acid and alkali treatments, were adopted to detoxify Jatropha curcas meal, and the detoxified meal was used to feed animals. Shu, Yin, Zhang, and Wang (2012) has studied on various methods, especially enzyme treatment, to obtain a method that cannot only efficiently degrade the toxin and antinutritional components but also improve the nutritional quality of the detoxified meal. They concluded that no single method can remove or eliminate all of the antinutrients and toxic factors. A combination of hydrolysis of enzymes (cellulase plus pectinase) and washing with ethanol (65%) brought about all of the desirable changes in J. curcas meal. This treatment significantly reduced PEs and antinutritional components, such as phytates, tannins, the flatulence-causing factors, saponins, protease inhibitor, and lectin activities. Among all of the varieties studied, the detoxified meal by this treatment had better nutritional indices (protein quality) than the other treatments. In addition, the 65% ethanol treatment is more economic and toxicologically feasible than the methanol treatment.

Arsenic in rice or rice product has recently become a popular controversial topic among consumers after FDA issued a reassuring update on levels of arsenic in rice and rice products in the year 2013. In fact, this issue has been elevated few years back where rice bran were reported to have levels of inorganic arsenic, a non-threshold, class 1 carcinogen, reaching concentrations of ~1 mg/kg dry weight, around 10–20 fold higher than concentrations found in bulk grain (Sun, et al., 2008). Studies were also shown that total arsenic levels were much higher in bran than in endosperm (white rice) obtained from the same whole grain rice (Rahman, Hasegawa, Rahman, Rahman, & Miah, 2007; Ren, Liu, Wu, & Shu, 2006) whereas Meharg, et al. (2009).showed that whole grain (brown) rice had a higher inorganic arsenic and total arsenic content than polished (white) rice. This emerging issue should not be treated lightly because rice bran is widely used as a traditional ingredient in Japanese cooking such as rice bran pickling and its stabilized rice bran extract was promoted as a superfood in several food aid programs where malnourished children are given a daily ration of the product due to their high level content in antioxidants, vitamins, mineral nutrients, and soluble fiber. In view of this critical matter, it is at best that food standards should be set for arsenic levels, while industry and government should work hand in hand to reduce arsenic levels in rice. Agricultural practices that may lead to increases in arsenic in rice for examples: The use of pesticides containing arsenic, and arsenic-laden manure as fertilizer should be restricted or banned as soon as possible.

5. Fortification

Protein-calorie malnutrition is one of the nutritional problems in most of the developing countries. Food fortification serves as an crucial strategy to fight malnutrition. Numerous of food fortification programs have been implemented to combat malnutrition especially among children and mothers. Global Alliance for Improved Nutrition (GAIN) has implemented GAIN's National Food Fortification Program since 2003 and has expanded to support 19 countries with high levels of vitamin and mineral deficiencies. Foods and condiments including wheat and maize flour, sugar, vegetable oil, milk, soy sauce and fish sauce are being fortified with Vitamin A, Vitamin D, Vitamin B complex, iron and zinc. GAIN implemented Multinutrient Supplements Program to reduce micronutrient deficiencies among children where they introduced two home fortification products, including multi-nutrient powders and lipid-based nutrient supplements that are readily added onto foods for consumption (GAIN, 2012 http://www.gainhealth.org/programs). In Indonesia, a community-based nutrition program (2010–2014) has been executed by Ministry of Health, including universal salt iodization, flour fortification and fortification of cooking oil with Vitamin A (http://scalingupnutrition.org/sun-countries/indonesia/progress-impact/implementing-aligning-programs/nutrition-direct-programs). World Health Organization plays an essential role in combating malnutrition by setting the guidelines and recommendations on food fortification. WHO and Food and Agriculture Organization (FAO) published the Guidelines on Food Fortification with Micronutrients in 2006 that acts as a resource for any party when considering food fortification (WHO/FAO, 2006). Some of the common reports are guidelines for the use of iron supplements to prevent and treat iron deficiency anemia, recommendations on wheat and maize flour fortification and salt as a vehicle for fortification (De-Regil, Finkelstein, Sæterdal, Gaitán, & Peña-Rosas, 2016; Pasricha et al., 2012)

Considerable interests in applying food and agricultural processing wastes as functional food ingredients has been evinced as the waste are rich in protein, dietary fibre and beneficial bioactive compounds (Table 3). By-products that have health benefits have been extensively used in food fortification.

There is increasing demand of using inexpensive high protein resources to improve the nutritional status of many people. Defatted seed meal from oil seeds is high in good quality protein and serves as good protein supplements in human dietary. It has been widely used in fortification of cereal based products particularly baked goods. For instance, defatted soybean meal was incorporated to enhance protein quality in tortilla (Amaya-Guerra, Alanis-Guzman, & SaldíVar, 2004). Researches on cookies supplemented with defatted wheat germ, defatted maize germ four, and king palm flour have been reported (Arshad, Anjum, & Zahoor, 2007; De Simas, et al., 2009; Nasir, et al., 2008). High fiber bread and cookies were produced using palm pressed fiber, defatted palm kernel cake or oil palm trunks as fiber enrichment agent (C. Ofori-Boateng & K. Lee, 2013).

Apart from being applied in cereal based products, the incorporation of defatted seed meal has been extended to edible films. An antimicrobial film effective against *Salmonella* was developed using defatted soybean meal as film base material and lactoperoxidase as an antimicrobial system (H. Lee & Min, 2013). The composition of defatted soybean meal affected the color and tensile properties of the film and the diffusion of the antimicrobial in the film.

However, the presence of coating did not significantly influence the sensory properties of the sliced ham, indicating the potential for the application to commercial ham products and other meat products. Besides that, sunflower protein concentrates with different phenolics content were used as base material for film preparation (Salgado, López-Caballero, Gómez-Guillén, Mauri, & Montero, 2012). Moreover, sunflower protein extracted from defatted sunflower flour was used as wall material in the microencapsulation of α-tocopherol by spray drying (Nesterenko, Alric, Violleau, Silvestre, & Durrieu, 2013).

Tonnes of fruit pomace were generated as a result of juice extraction. Fruits pomace has been incorporated with flour for making high dietary fibre bakery goods and to increase the antioxidant properties of the products. For instance, apple pomace which is a rich source of fibre and polyphenols was incorporated with wheat flour to improve the rheological properties of flour in cake making (Sudha, Baskaran, & Leelavathi, 2007). Apple skin powder was used to partially substitute wheat flour in muffin baking (Vasantha Rupasinghe, Wang, Pitts, & Astatkie, 2009). Grape pomace rich in antioxidant polyphenols compounds was added in bread (Hayta, Özuğur, Etgü, & Şeker, 2014), wheat biscuits (Mildner-Szkudlarz, Bajerska, Zawirska-Wojtasiak, & Górecka, 2013)and sourdough mixed rye bread (Mildner-Szkudlarz, Zawirska-Wojtasiak, Szwengiel, & Pacyński, 2011). In all the studies, grape pomace was incorporated at different level and its influence on physical and sensory properties was investigated. They found that grape pomace had positively contributed to the dietary fiber and total phenolic content of the products. The antioxidant properties of the bakery goods were greatly increased. The products were readily accepted by consumers at certain level of addition of grape pomace. In another study, grape seed flour produced from pomace was used in the production of noodles, pancakes and cereals bars (Rosales Soto, Brown & Ross, 2012). Protective effect of two different forms of grape by-products, namely dried powdered skins and freeze-dried extract therefrom, fortified bread against hypercholesterolemia in Wistar rat was reported (Mildner-Szkudlarz & Bajerska, 2013). They found that fortified bread had the ability to reduce the negative impact of a high-cholesterol/cholic acid diet. Furthermore, mango peel was incorporated in the production of macaroni at three different levels where 5% level had yielded an acceptable product with improved antioxidant properties (Ajila, Aalami, Leelavathi, & Rao, 2010). Asides from bakery goods, fruit fibers have been included in the production of dairy products as well. Yogurt was enriched with passion fruit fiber (Espírito-Santo, et al., 2013), passion fruit peel powder (do Espírito Santo, Perego, Converti, & Oliveira, 2012), and orange fiber (Sendra, et al., 2010). White grape pomace as antioxidant dietary fiber to enhance the nutritional value and improve the storability of yogurt and salad

Table 3
Agricultural wastes as fortificants in lists of products.

Agricultural wastes	Food products fortified	Nutrients being fortified	References
Defatted soybean meal	Tortilla	Increased protein content	(Amaya-Guerra et al., 2004)
Defatted soy flour	Pretzel products	Protein enrichment, increased calcium, potassium, magnesium, phosphorus and sulphur content	(Naik & Sekhon, 2011)
Toasted or partially defatted soy flour	Pasta	Increased protein content	(Baiano, Lamacchia, Fares, Terracone, & La Notte, 2011)
Defatted soy flour	Spaghetti	Increased protein content, increased lysine, threonine and amino acids content	(Shogren, Hareland, & Wu, 2006)
Defatted soy flour	Biscuits	Increased mineral, oil, crude fiber, protein and lysine content	(Serrem, de Kock, & Taylor, 2011)
Defatted soy flour	Wheat bread	Increased protein content	(Mashayekh, Mahmoodi, & Entezari, 2008)
Brown rice flour	Wheat-based dough, wheat-based flat bread	Increase ash content, decreased gluten content	(Khoshgozaran-Abras, Azizi, Bagheripoor-Fallah, & Khodamoradi, 2012)
Defatted wheat germ	cookies	Increased protein, fiber, calcium, potassium, iron and casein content	(Arshad et al., 2007)
King palm flour	Gluten-free cookies	Increased dietary fiber, calcium, magnesium, potassium, iron, zinc and manganese content	(De Simas et al., 2009)
King palm flour, sieved king palm flour	Cookies	Increased total dietary fiber content	(Vieira et al., 2008)
Defatted maize germ flour	Cookies	Increased protein and fiber content	(Nasir et al., 2008)
Defatted rice bran	Chapatti	Increased total dietary fiber content	(Yadav, Singh, & Rehal, 2012)
Defatted wheat germ flour	Noodle	Increased mineral, fiber and protein content	(Ge, Sun, Ni, & Cai, 2001)
Extruded flaxseed meal, partially defatted soy meal, wheat bran, wheat germ	Cereal bars	Enhanced quality and quantity of proteins, dietary fiber and ω6:ω3 ratio.	(Giacomino et al., 2013)
Defatted soybean and defatted melon flour	Fried cassava balls	Increased protein, ash and energy content	(Chinma, Ingbian, & Akpapunam, 2007)

dressing (Tseng & Zhao, 2013). In addition, orange pulp was incorporated in dressing-type oil in water emulsion to enhance its rheological properties and improve its stability against creaming (Chatsisvili, Amvrosiadis, & Kiosseoglou, 2012).

6. Bioactivity

The protective effects that are contributed by the agro-industrial by products to the diseases or processed food, in large part, due to the antioxidants present including the antioxidants nutrients vitamin C and β-carotene, but also the minor carotenoids, and plant phenolics such as flavonoids and phenylpropanoids may also have a significant role (Table 4). The polyphenolic components of higher plants byproducts may act as antioxidant or agents of other mechanisms for examples anticarcinogenic or cardioprotective action.

The flavonoids constitute a large class of compounds, ubiquinous in plants, containing a number of phenolic hydroxyl groups attached to ring structure, conferring the antioxidant activity (Harborne, 1986). Besides exhibiting a wide range of physiological properties like cardioprotective, anti-cancer, and neuroprotective activities; phenolic compounds are effective natural food preservatives against oxidative deterioration and microbial contamination (Burton-Freeman, 2010; Crozier, Jaganath, & Clifford, 2009) They often occur in the glycosidic form, cleavage of the free polyphenol taking place possibly in the gastro-intestinal tract. Plant polyphenols are multifunctional and can act as reducing agents, hydrogen donating antioxidants, and singlet oxygen quenchers. In some cases metal chelation properties have been proposed. Estimates of daily intake range from about 20 mg to 1 g (Hertog, Feskens, Kromhout, Hollman, & Katan, 1993), 1. The flavanols, particularly the catechin and catechin gallate ester family, and the flavonols quercetin, kaempferol, and their glycosides are constituents of the beverages green and black teas and red wine. Quercetin is also a predominant component of onions and apples, and myricetin and quercetin of berries. The flavanones are mainly found in citrus fruits.

The biological, pharmacological, and medicinal properties of the flavonoids have been extensively reviewed. Flavonoids and other plant phenolics are reported, in addition to their free radical

Table 4
Biological activity associated with fruit waste.

Common name	Scientific name	Origin	Biological activity	References
Red dragon fruit	*Hylocereus polyrhizus*	Peel	Anti-diabetic and antioxidant	Okonogi et al. (2007)
Pomegranate	*Punica granatum*	Peel	Anti-hyperglycemic and patoprotective	Singh, Chidambara Murthy, and Jayaprakasha (2002)
Apple	*Malus domestica*	Peel	Hypocholesterolemic and antioxidant	(Leontowicz et al., 2002)
Apple	*Malus domestica*	Waste	Anti-cancer	(McCann et al., 2007)
Peach	*Prunus persica*	Peel	Hypocholesterolemic and antioxidant	(Leontowicz et al., 2002)
Pear	*Pyrus*	Peel	Hypocholesterolemic and antioxidant	(Leontowicz et al., 2002)
Mango	*Mangifera indica*	Peel	Antioxidant	(Ajila, Naidu, Bhat, & Rao, 2007)
Banana	Musa paradisiaca	Peel	Antioxidant	(González-Montelongo, Gloria Lobo, & González, 2010)
Persimmon	Diospyros virginiana	Peel	Anti-diabetic	(Lee, Chung, & Lee, 2006)
Quince	*Cydonia oblonga*	Seed and peel	Antioxidant	(Silva et al., 2004)
Citrus		Peel	Antioxidant	(Guimarães et al., 2010)
Avocado	*Persea americana Mill*	Peel and seed	Anti-oxidant	(Rodríguez-Carpena, Morcuende, & Estévez, 2011)
Avocado	*Persea americana Mill*	Peel and seed	Anti-bacterial	(Rodríguez-Carpena et al., 2011)
Oil palm	Elaeis guineensis	Mesocarp fibre/palm kernel cake/empty fruit bunches/fronds/trunks/shells/leaves/roots/mill effluent	Anticarcinogenic, antioxidant, ani-diabetic, anti-microbial and anti-fungitoxicity activities, antihypertensive effects and cardiovascular protection, skin protection	(Ofori-Boateng & Lee, 2013)
Pineapple	*Ananas comosus*	Peel and residual pulp	Ani-diabetic	(Riya et al., 2014)
Grape	Vitis vinifera	cane	Hepaprotective/anti-oxidant	(Rayne, Karacabey, & Mazza, 2008)
Rapeseed	*Brassica rapa* L.	Meal	Antioxidant	(Salminen, Estévez, Kivikari, & Heinonen, 2006)
Camelina	*Camelina sativa*	Meal	Antioxidant	(Salminen et al., 2006)
Soy	*Glycine max*	Meal	Scavenging activity and anti-fatigue activity	(Yu, Lu, Bie, Lu, & Huang, 2008)
Peanut	*Arachis hypogaea*	Meal	ACE inhibition	(Quist, Phillips, & Saalia, 2009)
Sunflower	*Helianthus annuus*	Meal	ACE inhibition	(Megías et al., 2004)
Sunflower	*Helianthus annuus*	Meal	Copper chelating properties	(Megías et al., 2008)
Sunflower	*Helianthus annuus*	Meal	Hypocholesterolemic activity	(Megías et al., 2009)
Rice	*Oryza sativa*	Bran	Anti-proliferative	(Kannan, Hettiarachchy, Johnson, & Nannapaneni, 2008)
Rice	*Oryza sativa*	Bran	Hypocholesterolemic activity	(Ha et al., 2005)
Sesame	*Sesamum indicum*	Meal	Anti-bacterial	(Das, Dutta, & Bhattacharjee, 2012)
Sesame	*Sesamum indicum*	Meal	Anti-oxidant	(Suja, Jayalekshmy, & Arumughan, 2005)
Sesame	*Sesamum indicum*	Meal (fermented by lactic acid bacteria)	Anti-inflammatory and antioxidative activities	(Jan, Fan, & Chu, 2010)
kenaf	*Hibiscus cannabinus*	Seed meal	Antioxidant	(Chan, Khong, Iqbal, Mansor, & Ismail, 2013)
Olive	*Olea europaea*	Mill waste	Anti-diabetic	(Hamden et al., 2010)
Olive	*Olea europaea*	Mill waste	Nueroprotective	(Schaffer et al., 2007)
Olive	*Olea europaea*	Leave	Anti-diabetic	(Jemai, El Feki, & Sayadi, 2009)
Mushroom	*Agaricus bisporus*	Stalks and mushroom waste (irregular dimensions and shapes)	Antimicrobial	(Wu, Zivanovic, Draughon, Conway, & Sams, 2005)
Algae	*Chlorella vulgaris*	Protein waste	ACE inhibition and antioxidant	(Sheih, Fang, Wu, & Lin, 2009)

scavenging activity, to have multiple biological activities including vasodilatory (Burns, et al., 2000), anticarcinogenic(Galati & O'Brien, 2004), antiinflammatory(Azuma, Ozasa, Ueda, & Takagi, 1986), antibacterial (Perez, Dela Rubia, Moreno, & Martinez, 1992; Vaquero, Alberto, & de Nadra, 2007), immune-stimulating (Zheng, et al., 2008), antiallergic (Yamamoto, et al., 2004), antiviral (Suárez, et al., 2010), and estrogenic (Miller, Wheals, Beresford, & Sumpter, 2001)effect, as well as being inhibitors of phospholipase (Lindahl & Tagesson, 1997) A_2, clycooxygenase (Kelm, Nair, Strasburg, & DeWitt, 2000), lipoxygenase (Laughton, Evans, Moroney, Hoult, & Halliwell, 1991), glutathione reductase (Zhang, Yang, Tang, Wong, & Mack, 1997), and xanthine oxidase (Lin, Chen, Chen, Liang, & Lin, 2002). The increased generation of reactive oxygen species such as superoxide anion (O^2) and hydroxyl (OH^{-1}) radicals, in conjunction with the overpowering of endogenous antioxidant defense mechanisms (enzymatic and non-enzymatic) is another causative factor for the initiation of chronic diseases. These diseases include heart disease, stroke, arteriosclerosis, diabetes and cancer (Davalos, Miguel, Bartolome, & Lopez-Fandino, 2004). Therefore, agri-byproducts with the high rate of production every year are potentially being the source for the extraction of valuable compounds with different bioactivities.

The natural antioxidants from residual sources may be also used to improve the stability of the food by preventing lipid peroxidation and protecting from oxidative damage. In the past, many synthetic antioxidants have been popularly used in food and pharmaceutical formulations. In industry application wise, increasing the oxidation stability of vegetable oils is the main topic to be concerned. The oxidative deterioration of fats and oils in foods is responsible for rancid odours and flavours, with a consequent decreases in nutritional quality and safety caused by the formation of secondary, potentially toxic compounds. The addition of antioxidants is required to preserve flavor and color and to avoid vitamin destruction. Among the synthetic types, the most frequently used to preserved food are butylated hydroxyanisole (BHA), butylated hydroxytoulene (BHT), prophyl gallate (PG) and tert-butyl hydroquinone (TBHQ). Recently, the demand for natural antioxidants has increased, due to consumer concerns about the safety of synthetic antioxidants (Okonogi, Duangrat, Anuchpreeda, Tachakittirungrod, & Chowwanapoonpohn, 2007).

7. Conclusion

Accumulation of unmanaged agro-waste especially from the developing countries has an increased environmental concern. To reduce the waste by turning them into food to feed the population that under the great pressure to get more food is a viable solution for both major global issues. There are some existing products eg. soy meal and rice bran which have showed promising results to provide phytonutrients and values to the current industries. These industries eventually generate incomes and created job opportunity to the residents. Therefore, there is a need to explore further their potential to be incorporated into different food products or employ different methods of modification for new sources of agro-waste. The modification process is required to minimize the anti-nutritional factors of the materials and increase the feasibility and safety of them to become food. The application of agro-wastes and its by-product as a raw material is of practical significance for developing material components as substitutes for traditional food materials and are consumer friendly.

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