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Scraps No More: Fruit Wastes for Benefits of Plants and Animals

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To meet the demands of increasing population and minimizing waste problems, researches are geared towards identifying and recovering bioactive compounds from fruit wastes for health purposes for both plants and animals. Tons of fruits wastes are continuously produced creating problems for solid and liquid wastes management in the community. Traditional products from fruit wastes are candied peel, oils. pectin, enzymes and wine and vinegar; however, recent efforts are harnessing bioactive compounds abundantly found in fruit scraps for food, pharmaceutical applications, source of natural fertilizers and animal feeds.

Literature search from scholastic articles in the past ten years revealed that fruits scraps are utilized as fertilizers to enhance soil fertility and enrich soil microbiota due to their minerals contents essential for the plant growth. Moreover, several studies showed active compounds from fruit peels and seeds have insecticidal and antifungal properties against some plant pathogens while some essential oils have potency in delaying senescence of fruits and thus extending shelf life.

Fruit scraps are also utilized as alternative to cereals as feedstocks for livestock. Several fruits wastes were found to have great amount of polyphenolic compounds, edible oils, dietary fibers, and pigments associated with the anti-cancer, anti-microbial, anti-oxidative, anti-inflammatory properties as well as immune-stimulating effects in vertebrates. Studies claimed that fruit scraps active components may be utilized to wound healing while some have acaricidal, insecticidal, and larvicidal effects against blood-feeding parasites. Researches pointed out that fruit wastes can be utilized to produce neutraceutical bioproducts

Keywords: fruit wastes, peels, bioactive compounds, neutraceutical, feedstocks, plant, animal

Introduction

World Bank estimates that between 2009 and 2030, food demands will increase by 50% as the population grows, and consequentlyt will require greater food production and and processing. Unfortunately, not all food produced in the fields end up in the tables to feed the population, but a great amount eventually will result to food waste (Menas *et al.,* 2011). It was further

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reported that 40 percent of the food produced is wasted, of which 44 percent are fruits and vegetables (Wadhwa and Bakshi, 2013)

Food waste does not only mean loss of caloric intake but also an environmental, economic and ethical concerns because it entails the complexity of the food system and the needless destruction of resources (Payne, 2014; Wadhwa and Bakshi, 2013). The great volume of food wasted may feed millions of hungry population from poor countries. Money is spent not only in producting the fruits but also in disposing of the unwanted food (Gunders, 2010). Moreover, food waste also means squandering oil, freshwater, soil fertility, land and human labor and the estimated the cost entailed in production of global food waste means utilization of approximately 675 trillion liters of water from wells, rivers and lakes (Stuart , 2009; Payne , 2014). It has been monitored that India, the Philippines, China and the United States of America can generate approximately 55 million tonnes of fruits and vegetable wastes destined in landfills or bodies of waters resulting to environmental hazards (Wadhwa and Bakshi, 2013).

In the premise of increasing demand for food production and staggering high percent of fruit wastes, an interest on how these fruit scraps can be diversified for use in agricultural systems was born. If fruit scraps can be utilized for agricultural plant crops and animal livestock, then they would not be considered wastes, but rather contributory to enhancing safe food production. Furthermore, efficient utilization of fruit wastes will enhance the quality but at lower cost of animal feeding, thereby increasing profits by generating an array of value-added products and help in waste management and reduction of environmental pollution. This review paper looks into the current researches on the utilization of fruit wastes that will benefit both plants and animals. It aimed to document the current trends on research, practices and potential uses of fruit wastes, more specifically for agricultural systems for sustainable development.

Materials and Methods

This status quo review paper looked into and evaluated the research studies and articles published in the past ten years to assess the state of the art of the fruit waste utlization for plants and animals. It is the objective of this review to establish the research trends in the efforts of harnessing the potentials for use of fruit wastes for plants and animal systems. It took into consideration also the phytochemical compositions and bioproducts produced from fruit wastes.

Discussions

There are many researches conducted on fruit wastes utilization for the benefits of plants and animals in the last decade. This could be probably due to the alarming increase in food wastes as well as concern on ethical responsibility for the environment and hunger. Furthermore, studies have shown that fruit parts that are discarded and considered as waste have as much if not more bioactive components as the pulps that could be harneseed for product development. Polyphenolic compounds commonly found greater in volume in peels and seeds of fruits (Paixao *et al.*, 2007; Wadhwa and Bakshi, 2013). For example, vitamin C content in peels of Dragon fruit has almost twice from the pulp (Sari and Hardiyanti, 2013),

Utilization of Fruit Scraps for Plant Benefits

Several studies reported that fruit wastes can benefit plants by promoting its growth and development by enhancing soil fertility and enriching soil microbiota, and protecting them from insects, nematodes,fungi and other plant pathogens.

It is a common practice to use fruit peels for composting for fertilizers and this practice if proven to be appropriate by many researches. Different formulations of organic fertilizers with fruit peels enhanced soil fertility and increase the volume and diversity of soil of microrganisms favouring good plant growth. Soil mineral content is increased because fruit peels and wastes contain potassium and minerals essential for plant growth. Pomegranates, orange, sweet lime, banana peels incorporation in soil enhance the number of micro organisms two folds and can be formulated into fertilizers (Tsay *et al.* 2004; Mercy, 2014).

The rampant use of chemical pesticides increased dramatically resistance among plant pathogens that campaign for green pesticides escalated. Researches have turned to many natural sources for pesticides and among them are fruit wastes. However, it was notable that there were fewer studies on use of fruit wastes for plants compared to animals, but more researches on this focus were done before. Some of the studies conducted within the decade are those of Siskos *et al.* (2008) that identified active components of bitter orange (*Citrus aurantium* L.) fruit peel petroleum ether extract causing 96% mortality to adults of the olive fruit fly *Bactrocera oleae;* Chutua *et al.* (2009) that found eessential oil (EO) isolated from the peel of *Citrus reticulata* Blanco had antifungal activity of t against five plant pathogenic fungi , namely *Alternaria alternata*, *Rhizoctonia solani*, *Curvularia lunata*, *Fusarium oxysporum* and

Helminthosporium oryzae. Kim *et al*. (2009) isolated flavonoids from *Citrus unshiu* that contains defensive substances.

Utilization of Fruit Scraps for Animal Benefits

Exploring the utilization of fruit wasted and by products from fruit proceeding industry is a worthwhile idea. According to Wadhwa and Bakshi (2013), aside from efficient production and waste reduction, diversification and enlarging the feed resources from novel food resources is the road to livestock development. The fruit scraps need not be wasted but could be recycled as feed resources for livestock or their bioactive components could be extracted and developed into value-added products. Fruit exocarps, seeds and pomace have abundance of bioactive compounds that could be extracted and added to food, feeds and other pharmaceutical applications (Wadhwa and Bakshi, 2013, Ayala-Zavala, 2011). Researches have revealed that fruits and their wastes represent are rich sources of sugars, minerals, organic acid, dietary fiber and phenolics that are reported to have strong potentials for antitumor, antibacterial, antiviral, cardioprotective and antimutagenic activities (Chandra , 2010) for potential utilization in production of beneficial feeds for livestock.

Antimicrobial Properties of Fruit Wastes. The search for new natural sources of anitibiotics for animals is very relevant specially with the issues of pathogenice microorganisms evolving resistant strains. Mutiple drug resistance in pathogenic microorganisms developed because of indiscriminate utilization of antibiotics to treat diseases..Since most fruits contain phytochemicals that can inhibit growth of microorganisms, fruit peel waste is an ideal source of low cost natural antimicrobials. Several researches have established antimicrobial activities of fruit wastes against important animal pathogens. Work of Jayaprakasha *et al.* (2003) on grape seeds and peels, Chandra *et al.* (2010) on mango peel, Prasad *et al.* (2010) on wampee peel revealed antimicrobial properties of fruit wastes. It was also noted that the appropriate solvent for extraction varies to obtain the best fraction with antimicrobial properties. Table 1 summarizes some of the fruit wastes and their antimicrobial properties against specific pathogens.

Table 1. Reported antimicrobial activities of some friuit peels against microorganisms causing infectious diseases

Fruit Wastes	Extract/Form	Pathogens	
***Citrus grandis* (Rutaceae)**	Hexane, ethyl acetate, butanol, methanol, benzene: acetone	*Bacillus subtilis, Bacillus cereus, Staphylococcus aureus, Escherichia coli, Salmonella enteritidis*	Mokbel et al, 2007
***Citrus reticulata* Blanco (Rutaceae**	Oil	*Alternaria alternata , Rhizoctonia solani, Curvularia lunata, Fusarium oxysporum, Helminthosporium oryzae*	Chutia et al, 2008
***Vitis vinifera* (Vitaceae)**	ethanol	*Staphylococcus aureus, Bacillus cereus Escherichia coli, Salmonella infantis, Campylobacter coli*	Mozina et al., 2010
***Citrus reticulata* Blanco(Rutaceae**	Flavonoid extract	*Escherichia coli, Staphylococcus aureus, Staphylococcus epidermidis, Enterococcus faecalis, Salmonella typhimurium, Enterobacter cloacae*	Yi et al., 2008
***Citrus acida* Roxb. (Rutaceae)**	Oil	*Bacillus subtilis, Bacillus cereus, Staphylococcus aureus, Escherichia coli, Enterobacter aerogenes, Salmonella typhimurium, Aspergillus ficuum, Aspergillus niger, Aspergillus fumigatus, Aspergillus flavus, Fusarium saloni, Fusarium oxysporum, Pencillium digitatum, Candida utilis*	Mahmod yet al., 2009
***Ficus carica* L. (Moraceae)**	Aqueous	*Bacillus cereus, Staphylococcus epidermidis, Staphylococcus aureus, Escherichia coli, Pseudomonas fluorescens*	Oliveira et al,. 2009
***Citrus bergamia* Risso (Rutaceae)**	Ethanolic fraction	*Escherichia coli, Pseudomonas putida, Salmonella enterica, Listeria innocua, Bacillus subtilis, Staphylococcus aureus, Lactobacillus lactis, Sacharomyces cerevisiae*	Mandalari et, 2007
***Nephelium lappaceum* L. (Sapindaceae)**	Ether, methanol, aqueous	*Escherichia coli, Klebsiella pneumoniae, Pseudomonas aeruginosa, Salmonella typhi, Vibrio cholerae, Enterococcus faecalis,*	Thitilertdecha et al., 2008

		Staphylococcus aureus, Staphylococcus epidermidis	
***Musa sapientum* (Musaceae)**	Chloroform, ethyl acetate, aqueous	*Staphylococcus aureus, Bacillus subtilis, Bacillus cereus, Salmonella enteritidis, Escherichia coli*	Mokbel and Hashinaga, 2005
***Trapa natans* L. (Trapaceae)**	Petroleum ether, 1,4-dioxan, chloroform, acetone, dimethylformamide, ethanol, aqueous	*Bacillus cereus, Micrococcus flavus, Staphylococcus aureus, Alcaligenes faecalis, Klebsiella aerogenes, Klebsiella pneumoniae, Proteus mirabilis, Proteus morganii, Pseudomonas putida, Pseudomonas testosteroni, Candida albicans, Candida albicans, Cryptococcus luteolus, Trichosporon eigelii, Aspergillus candidus, Aspergillus flavus*	Parekh and Chanda , 2007
***Mangifera indica* L. (Anacardiaceae)**	Hexane, chloroform, acetone	*Staphylococcus aureus, Staphylococcus subflora, Corynebacterium rubrum, Enterobacter aerogenes, Klebsiella pneumoniae, Proteus mirabilis, Candida albicans, Cryptococcus luteolus, Candida globate, Canadida tropicalis*	Chanda et al., 2010
Lagenaria icerania	Hexane, chloroform, acetone	*aureus, Staphylococcus subflora, Corynebacterium rubrum, Enterobacter aerogenes, Klebsiella pneumoniae, Proteus mirabilis, Candida albicans, Cryptococcus luteolus, Candida globate, Canadida tropicalis*	Chanda et al., 2010
Anona camosos	Hexane, chloroform, acetone	*aureus, Staphylococcus subflora, Corynebacterium rubrum, Enterobacter aerogenes, Klebsiella pneumoniae, Proteus mirabilis, Candida albicans, Cryptococcus luteolus, Candida globate, Canadida tropicalis*	Chanda et al., 2010
Punica granatum	methanolic	*Listeria monocytogenes, S. aureus, Escherichia coli* and *Yersinia enterocolitica.*	Al-Zoreky, 2009

Antioxidant Properties of Fruit Wastes. Antioxidants have been identified as part of healthy diet in animals and fruit peels are natural sources of antioxidants. Antioxidants are compounds considered as free radical scavengers that aid in preventing stress induced diseases such as melanoma, cardiac disorders, diabetes mellitus, inflammatory and neurodegenerative diseases, cancer (Prakash *et al.,* 2007; Jing *et al.*, 2008, Ajila, *et al.*, 2007). Free radicals released during the oxidation process have the potential to damage transient chemical species and the present antioxidant compounds in fruits are polyphenol that play the major role in contributing to the overall antioxidant activity, examples are carotenoids, phenolics and betalains (Ajila, *et al.*, 2007, Park *et al.,* 2008). Antioxidative compounds can prevent lipid peroxidation thus enhancing stability of foods (Wadhwa and Bakshi, 2013).

Studies found high content of phenolic compounds in peels and seeds of of some fruits. Since these phenolic compounds are greatly associated with antioxidant capacities, researches were conducted to evaluate their potential as sources of bioactive compounds (Kunradi -Vieira, 2008; Okonogie *et al*., 2007) . Interestingly, it was further established that the antioxidant capacity of peels and seeds were higher than the pulp (Deng *et al*., 2012). To cite some work proving the high antioxidant properties of fruit wastes are those of Kalpna et al. (2010) on *M. indica* peel; Singh (2014) and Okonogie *et al.* (2007) on pomegranate peels; Singh (2014) on lemon and orange peels; Wijngaard *et al.* (2014) on apple pomace; Okonogie et al. (2007) on peel *Nephelium lappaceum* (rambutan), and *Garcinia mangostana* (mangosteen); Deng et al. (2012) on peels and seeds of avocado, plantain, blueberry, Chinese olive, grape (USA), guava, hawthorn, longan, mango, starfruit, sweetsop, and ziziphus jujube; De Oliveira (2012) on residues of acerola and passion fruit; Rashad (2015) on wastes from pineapple; passion fruit seed oil (Malacrida, 2012) and Babbar (2011) on peels of kinnow, litchi and seeds of litchi and grapes. There are more studies on the antioxidant potentials of wastes from fruit canning and winery industries in the last decade.

Nutraceutical Properties of Fruit Wastes. Since fruit wastes have strong antioxidant properties, they also do possess many important capabilities related to animal health. They are also good potential sources of anticancer compounds. McCann *et al.* (2007) reported that crude apple extract from waste, rich in phenolic compounds beneficially influences key stages of arcinogenesis in colon cells. Okonogi *et al.* (2007) and Lansky and Newman (2007) stated that pomegranate fruits peels possess potent antioxidant, anticancer, and antiinflammatory activities. Rashad (2015) concluded that the extracts of pineapple wastes as such or fermented one is a good candidate for novel therapeutic strategies for cancer.

Bioproducts from Fruit Wastes. Bio-active compounds from peels, pomace and seeds can be tapped in the production of value-added bioproducts. Some of these bioproducts are essential oils, polyphenols, anti-carcinogenic compounds, edible oil, pigments, enzymes, bio-ethanol, bio-methane, bio-degradable plastic, and single cell proteins, reducing sugars, furfural, ethanol, carbohydrates, lipids, organic acids, phenols, activated carbon, degradable plastic composites, cosmetics, biosorbent, resins, medicines, foods and feeds, methane, biopesticides, biopromoters, secondary metabolites (Wadhwa and Bakshi, 2013; Kandari and Gupta, 2012).

Just to cite a few examples, edible oils may come from mango seed kernel as its fatty acide and triglyceride content is comparable to cocoa butter (Wadhwa and Bakshi, 2013) and passion fruit seed oil (Malacrida, 2012). These oil maybe of value to the food, chemical and pharmaceutical industries. The enzymes isolated from fruit wastes are bromelain from pineapple; papain from papaya, α-amylase, hemicellulase; cellulase from banana waste and kinnow pulp; lignin, manganese peroxidase and laccase from apple pomace; and pectinase from citrus peels that have potential use for various applications (Wadhwa and Bakshi, 2013). Barkat (2016) evaluated α-amylase and α-glucosidase inhibitors from honeydew skin, banana peel, and pineapple skin and concluded that these wasted could be alternatives sources for antidiabetic agent .

The review of the state of the art on the utilization of fruit wastes for plant and benefits reveal that there is much awareness, concern and action among researchers on the essence of harnessing important biocompounds from fruit wastes. As evidenced by the bulk of researches and developments on the field on isolating, identifying important biomolecules from fruit wasted and developing them into important bioproducts for industrial, agriculture and pharmaceutical applications. Nutraceuticals from fruit wastes is one of the concern and convertiong them into functional feeds and food. These scientific activities imply that there is more conscious effort to divert fruit wastes into products of value that further contributes to the safety of plants and animals, man and the environment.

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