Review Article

A review paper on agro-food waste and food by-product valorization into value added products for application in the food industry: Opportunities and challenges for Cameroon bioeconomy.

ABSTRACT

Agricultural production, agro-industrial food processing, distribution and consumption generate high amount of varied food by-products and waste which place a heavy burden on the environment and cause losses to the food industry. Food waste is commonly disposed of in landfills or incinerated, causing many environmental, social, and economic issues. However, many of these by-products and wastes have been reported to have at times a nutritional or functional properties higher than the final product, making them potential raw materials for application in the agro-food industry. This along with the recent sustainable development goals of food security, environmental protection, and energy efficiency are the key drivers for food waste valorization. Valorization of food waste within the bio-economy approach offers an economical and environmental opportunity, which can reduce the problems of its conventional disposal. Traditionally, in Africa, especially in Cameroon, food by-products and waste have been valorized into a range of product for application in food and food preparation, including, food additives and spices, food emulsifiers and stabilizers, food salts and nutraceuticals. Traditional Waste valorization methods could achieve sustainable development in technologically underdeveloped countries, methods that could not only improve agro-food waste management but could also lead to the production of industrially important biochemical, food ingredients and food products, in essence, valuable added products from waste. In addition, the processing and conversion of these agro-food by-products and waste generated in the poor regions of the world for the production and formulation of novel foods and biochemicals will directly benefit the local communities by reducing environmental pollution and increasing income in the food industry. The aim of this review is to provide an insight on the latest trends in food waste valorization using traditional methods in an Africa country such as Cameroon. This paper presents the variety and volume of food waste within the food chain and types of food waste feedstock's that valorized into various products using traditional methods. Furthermore, a series of examples of key food waste valorization schemes and value added products as case studies to demonstrate the advancement in traditional bioconversions are described, bringing out the opportunities and challenges for the Cameroon bioeconomy.

Key Words: Food waste, pollution, feed-stock, valorization, Value-added products, Bioeconomy

1. INTRODUCTION

The ever increasing demand for food coupled with higher environmental standards is re-shaping agricultural activities toward ecologically sustainable and efficient systems (Ominski *et al.*, 2021). While the existing literature has mainly focused on increasing food production, the magnitude of waste and by-products are too large to be ignored (Irfanoglu *et al*., 2014, FAO, 2019b). Agricultural production and agro-industrial processing generate high amounts of food by-products and waste, which have been reported to have at times a nutritional or functional content higher than the final product (Ayala *et al.*, 2011). Roughly, one-third of the edible parts of global food produced for human consumption is estimated to be lost or wasted (FAO, 2015), and these losses have been valued at 1 trillion USD (FAO, 2013). Fruit and food waste is also generated by damage during transportation, storage, and processing. 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 beneficial nutrients and bioactive compounds (Torres-Leon et al., 2018).Many waste valorization methods could achieve sustainable development, methods that could not only improve agro-food waste management but could also lead to the production of industrially important bio-chemicals, food ingredients and food products, in essence, valuable end products from waste.

Food by products are generally secondary products derived from primary agro-food production processes, and they represent an interesting and cheaper source of potential functional ingredients (Faustino *et al.*, 2019). On the other hand, food waste is “unwanted or unusable material, substances, or by-products” that are “eliminated or discarded as no longer useful or required after the completion of a process” (Markus *et al.*, 2019). Food by-products and waste remain a global dilemma, with negative environmental, social, and economic consequences (Ominski *et al.*, 2021) associated with estimated annual losses of approximately one-third of all edible food (1.3 billion metric tonnes, MMT) across the supply chain (FAO, 2011). 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 land fills. 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). Most of studies on food waste and by-products in sub-Saharan Africa, particularly in Cameroon concerned with estimating the extent of waste and by-product generation, without, however, worries of the technological importance and potential on development of bio-economy.

Traditionally, food waste is usually incinerated or disposed of in landfills leading to subsequent air/water pollution, and soil/food contamination. To decrease these problems, the European Union (EU) is promoting the reduction of food wastes, and the search for new end-uses for food by-products (Wunder *et al.*, 2018).Following these recommendations, food waste from several agro-food industries (vegetables, fruits, beverages, sugar, meat, aquaculture and marine products, seafood, etc.) represent an interesting and cheaper source of potentially functional or bioactive compounds.In this context, the biorefinery concept has emerged as the development of integrated and combined extraction or recovery processes for the conversion of biomass into many added-value products (Herrero and Ibañez, 2018; Mazzutti, 2020).

Food waste is abundant in sub-Saharan Africa, especially in Cameroon, and previous studies on waste management in Cameroon have focused on waste collection and disposal practices and their environmental implications (Vermande and Ngnikam, 1994; Ngnikam, 2000) with little consideration on the valorization into value added products and biochemical. In Cameroon for example, food crops such as maize (*Zea mays*), rice (*Oryza sativa*), cassava (*Manihot esculenta Crantz*) and some fruits like oranges, lemons and pineapple are widely cultivated for subsistence alongside vegetables such as amaranth (*Amaranthus cruentus*) (Njukwe *et al.,* 2014; Tata *et al.,* 2016). Numerous reports (Lipinski *et al.*, 2013; Foresight, 2011; FAO, 2011a; Stuart, 2009) have underlined the significance of food by-products and waste and the need to reduce them to improve food security and sustainability of food systems.

The available disposal options in under-developed technological poor countries like Cameroon still largely remain slash and burn or land fillings, producing large quantities of greenhouse gases (GHG). Incineration and composting also produce greenhouse gases, and wastewater from anaerobic digestion causes eutrophication and acidification of local ecosystems (Salemdeeb and Al-Tabbaa, 2015; Whiting and Azapagic, 2014).The processing and conversion of agro-food by-products and waste generated in the poor regions of the world for the production and formulation of novel foods and biochemicals will directly benefit the local communities.In Cameroon, for example, the use of Plantain and Banana byproducts has been suggested as the main raw material for the production of traditional food salts, commonly called Nikkihused in yellow achu-soup preparation due to emulsification properties (Ngwasiri*et al.*, 2021).

The valorization of residues and byproducts generated in the poor regions of the world for the formulation of novel foods will directly benefit the local communities (Luque and Clark, 2013). The valorization of agro-food byproducts and waste into different high-value products has been reviewed by numerous studies, (Maina et al., 2017; Mirabella et al 2014; Lin et al., 2013; Tuck et al., 2012) while others (Xiong et al., 2019; Serna-Loaiza et al., 2019; Fritsch et al., 2017; Pleissner et al., 2016) investigated and described the chemical processes involved in the conversion. However, these reviews focused on valorization using advanced technology, affordable to developed and industrialized countries, with little focus on the contribution of agro-food waste valorization for food security in undeveloped African countries. In this review paper we will therefore try to frame the key issues associated with traditional valorization of agro-food waste into value added food products and biochemicals within the context of the emerging bio-economy and circular-economy, suggesting that valorizing these agro-food wastes can significantly contribute to solving malnutrition and hunger in undeveloped African countries, especially in Cameroon. 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.

2. AGRICULTURAL BY-PRODUCTS AND WASTE GENERATION IN CAMEROON

Cameroon is located in the Gulf of Guinea between Gabon, Guinea Republic and Nigeria with 26,55 million inhabitants as of 2020. The importance of agriculture,fishery and livestock and their contribution to the economy of Cameroon is significant as it is highly dependent on it, which provides 70 percent of its active population employment opportunity. Due to the high agricultural activities, both plantation and non-plantation waste biomass are abundant, which are highly under-utilized. In Cameroon for example, plantation agriculture under the CDC (the second largest employer after the government), Pamol and, SOCAPALM, among others, are legacies of European administration. Due to its abundant natural resources, Cameroon stands as a major global producer of goods like cocoa, coffee, bananas, palm products, tobacco, rubber and cotton. Other important products include: cereals (maize, millet and sorghum, paddy, etc.), roots and tubers (cassava, cocoyam, taro, potato, yam, etc.), oilseeds such as groundnut, cottonseed, etc., fruits and vegetables, including citrus, pineapple, tropical fruits, legumes and pulses, spices and condiments, leafy vegetables and mushrooms, plants and ornamental flowers, etc (Benoit Daviron et al., 2004).

The agricultural sector is one of the main sectors generating the largest quantities of waste and by-products, if allowed to accumulate indiscriminately will constitute nuisance to global health and threat to food security (European Commission, 2015, Bracco et al., 2018).In Cameroon for example, food crops such as maize (Zea mays), rice (Orita sativa) and cassava (Manihot esculenta Crantz) are widely cultivated for subsistence alongside vegetables such as amaranth (Amaranthus cruentus) (Njukwe *et al*. 2014; Tata *et al*. 2016).These food crops generate wastes such as corncob, rice husk and groundnut husk, for example, Kouame *et al*. (2013) reported a 10% and 20% rates of postharvest loss of amaranths and black nightshades, respectively. These waste are not used as fuel because of their low heating value and the volume of smoke produced (Kung *et al*. 2015; Kumer *et al*. 2015). Low bulk density and slow decomposition also limit their use in agriculture as a soil amendment (Steiner *et al*. 2010; Enders *et al*. 2012) whereas they contain appreciable quantities nutrients, bioactive compounds and phytochemicals which could offer both nutrition and health benefits.

Cameroon,as in the case of most sub-Saharan African countries, is currently facing one of its most serious food crises. (World Food Program, 2017). The number of food-insecure households in Cameroon is estimated at around 16% (about 3.9 million people), of which 1% are in a situation of severe food insecurity. There are many reasons for this. While food unavailability and inaccessibility are incriminated, food wastage is rampant. Estimated annual food quantitative losses and waste in the supply chain represent approximatively 40 to 50% of the world's fresh products—30% for cereals and 20% for oilseeds, meat, and milk products. (Gustavsson et al. 2011) Food losses and waste refer to the decrease in quantity or quality of food along the food supply chain (FAO, 2019). In the case of perishable foods such as fruits, waste also occurs along the post-harvest chain at the retail level due to a wide variety of factors. Microorganisms and residues of pesticides and other toxic chemicals or organic inputs that are used to improve crop production can also accelerate the process of post-harvest losses and lead to population health problems (Goletti *et al*. 1999., Blanke *et al*. 2015). It is recognized that toxic exposures. may worsen the micronutrient status, e.g., by increasing the nutritional requirements; vice versa, imbalanced diets and micronutrients deficiencies may increase the vulnerability to the effects of toxic substances and alter body defense systems (Frazzoli et al 2020). Estimates of postharvest losses of fruits and vegetables vary considerably in developed and developing countries (Kader 2005). In some African countries, about 30% of products are lost, and this figure can rise to 50% for very perishable foods, such as fruits and vegetables. 48.5% postharvest loss was reported in Nigeria (Kughur *et al*. 2015). 45.9% postharvest banana loss reported in Ethiopia, of which about 15.7%, 22.1%, and 8.1% were incurred at the farm, wholesale, and retailer levels, respectively (Zenebe *et al.* 2015). This rate of post-harvest losses of fruits and vegetables varies from 20 to 40% in Bangladesh (Wills *et al* 2004). In Cameroon, 10% and 20% rates of postharvest loss of amaranths and black nightshades was reported, respectively (Kouame *et al.* 2013). Most of these studies were concerned with estimating the extent of losses without, however, worries of the causes and consequences on the health of populations.

Though Cameroon coffee production fluctuated substantially in recent years, the total production in 2020 was 36,207 tonnes (ICO, 2021).One of the main concerns in relation to the sustainability of the coffee production chain involves the recovery of a large amount of its generated by-products (Kasuya *et al*., 2015; Oliveira and Franca, 2015).The residues and the by-products of coffee processing constitute around 60% of the wet weight of the fresh fruit, represent a relevant source of pollution and environmental threat (Rathinavelu *et al*.,2005; Franca and Oliveira, 2009; Hughes *et al*., 2014). Among the solid residues, the peel is the first to be generated. It represents 39% of fresh weight or 29% of fruit's dry matter, while the parchment represents around 12% of the fruit (Matos, 2015).The production statistics from Cameroon clearly indicates availability of large about of coffee peels and parchment, which are highly underutilized.

The production of plantain and banana, which is an essential component in the diet of West and Central African populations (Folefack *et al*. 2017), is an environmental challenge due to the large volume of waste and by-products generated. Cameroon, which is the fourth largest plantain and banana producer in West and Central Africa, does not escape this situation (Folefack et al., 2017) with about 1.6 million tonnes produced annually(Lescot, 2017). Plantain and Banana peel waste are the solid waste derived from the processing of plantain and banana and, it constitutes about 40% of fresh fruit weight.Bananas contain 60% pulp and 40% peel, 7.25 kg of peel produced from a banana box of 18.14 kg (Sharma et al., 2016). However, the shell contains carbon-rich organic compounds such as cellulose (7.6–9.6%), hemicellulose (6.4–9.4%), pectin (10–21%), lignin (6–12%), chlorophyll pigments and some other low molecular weight compounds. If not treated properly, these wastes create an annoying odor due to the natural decomposition and produce gases that contribute to the greenhouse effect (Tibolla et al., 2018).

3. CURRENT USES AND VALORIZATION OF AGRICULTURAL BY-PRODUCTS AND WASTES IN FOOD PREPARATION IN AFRICA AND CAMEROON

Most of studies on waste in Cameroon concerned with estimating the extent of food waste, by-products and losses and their disposal without, however, worries of sustainable valorization of these waste into value added products.It is important that these wastes are identified and properly valorized in order to reduce losses of valuable nutrients and potential raw materials, and protect the dwellers in the community as well as the environment because waste is directly linked to human development, both technologically and socially (Tobias *et al*., 2014).

3.1. Value added food products from plantain and banana wastes and by-products

Plantain (*Musaparadisiaca*) is a large herbaceous perennial crop belonging to the family Musaceae. The family Musaceae also includes bananas (*Musa sapientum* and *Musa cavandish*). Plantain (Musa spp) is one of the world's most important fruit. This plant widely cultivated in tropical countries for its valuable applications in food industry. Bananas and plantains have been said to be the 2th largest fruit crop of the world (FAO 2014). The peel of banana represents about 30-40% of the total weight of fresh banana and has been underutilized. The world production is estimated to be 139 million tons, in which tropical Africa alone produces about 17 million tons of bananas annually. It has become a basic food crop for over 70 million people in Africa. Over 50 species of Musa are in existence, in which the main groups of edible bananas or plantains are derived from Musa acuminata and Musa balbisiana (Onyegbado et al, 2004). Plantains and bananas belong to the same family and have the same method of growth and development, but can be differentiated from one another by form of stem, colour and size, leaf colour, fruit (finger) shape and size, composition of nutrients in fruits (food and peel), and the composition of plantains is mostly carbohydrates while in bananas, it is sugar (Ogidi *et al.*, 2018). The parts of the banana and plantain plants which are generated as byproducts after cultivation and processing include the peels, leaves, sheaths, peudostem, pith and male bud (Mohapatra *et al.*, 2010).

3.1.1 Traditional food salts (Nikki) from Banana and plantain peel

Plantain and banana peels are valorized using traditional technologyfor the production of a traditional food salt or potash, commonly called “nikkih” in many regions of Cameroon, especially the West and North West Regions. This traditional food salt (nikkih) is the crude brownish or blackish extract produced traditionally by leaching the ashes of combusted agro-food waste with water to obtain a potassium-carbonate-rich crude bio-extract (Oyegbado et al. 2004; Adewuyi et al. 2008). Nikkih can either be obtained from peels boiled at 90^{o}C before drying, or directly dried raw peels which are combusted to produce ash that is leached with water to obtain the crude blackish or brownish extract (Ngwasiri *et al.*, 2021). Their chemical composition shows that they are a mixture of salts and thus, made of cations and anions, the major cation being generally sodium or potassium whereas the major anions are generally carbonates, bicarbonates, sulfates, and chlorides (Saidou et al., 2015; Osano et al., 2013).These bio-base functional plant extracts are fast replacing the common lake salt called ‘kangwa’, as they are regarded as cheaper, safer, less-toxic and readily available from food waste biomass and their production from waste biomass contributes to environmental protection.

Nikkih is now used in the preparation of a variety of foods due to its functional properties since it serves as emulsifier, tenderizer, thickener, seasoning, potentiating adjunct and preservative (Ajiboye et al., 2013). The functionalities of nikkih have been attributed to the alkalinity of the aqueous solution (Onwuka et al., 2003). With respect to its functionality, the ability to reduce cooking time has been studied (Bergeson et al., 2018; Doumta et al., 2012). It is an important household ingredient which is traditionally used in many food preparation processes in Cameroon, and also in food industries. It is used in the preparation of yellow “achu” soup, and gives vegetables a good texture and appearance during their preparation. In the dairy industry, when cream is separated from whole milk during the production of butter, lime water is often added to the cream to reduce acidity prior to pasteurization.

3.1.2 Flour from banana and plantain pseudostem

The banana pseudostem is particularly rich in cellulose, hemicellulose, protein, fat and dietary fibres along with other nutritive elements. One of the most popular ways of exploiting the underutilized plant resources has been through the preparation of composite flours, such as Banana and plantain pseudostem flour.Banana and plantain pseudostem flour is a product obtained by peeling the epidermis of the stem, after which the peeled pseudostem is washed, cut, boiled (for 10 minutes), sliced, dried (at 60°C for 24 h), ground in a blender and sieved to obtain a fine powder (Aziz *et al.*, 2011). Flour made from banana pseudostem is rich in fiber, macro minerals like potassium, sodium, calcium, magnesium and phosphorus, and it can be used in the enrichment of food products such as dairy and bakery products (Thorat and Bobade, 2018).

Studies showed that by the partial replacement of wheat flour with banana pseudostem flour in bakery products, the dietary fiber content was increased (Tiroutchelvame*et al.*, 2019). Composite flours are mixtures of several flours obtained from cereals, legumes or other plant resources with or without the presence of wheat flours. Composite flours have gained much importance owing to its enriched nutritional profile and better digestibility (Melini et al., 2017). Moreover, the usage of composite flours can help overcome the production deficit of wheat in several tropical countries.

3.1.3 Banana and plantain leaf extract

Banana and plantain leaves have been traditionally used for packaging of certain foods, but new techniques for the valorization of these byproducts are being studied (Fiallos-Cárdenas *et al.*, 2021), such as making use of the leaf extracts. Banana leaf extract is produced by passing the washed leaves three times through a mill called "trapiche", after which the juice is collected and stored at low temperatures for further use (Fiallos-Cárdenas *et al.*, 2021). It has been shown to be potent in the prevention of enzymatic browning and quality deterioration of freshly cut guava slices during storage (Shomodder *et al.*, 2021). This implies that banana leaf extract can potentially be used in the prevention of enzymatic browning in other food products as well. Studies have also shown that banana leaves present anti-diabetic properties such as a decrease in glucose levels and increase in glycogen and plasma insulin levels when administered to hyperglycemic rats (Kappel *et al.*, 2013), and can therefore serve as a good raw material in the development of functional foods for diabetes patients. Rutin, a pharmacologically active phytochemical that decreases glycemia, increases insulin secretion and inhibits α-glucosidase is the major component responsible for the antidiabetic activity of banana leaves (Kappel *et al.*, 2013).

3.1.4 Banana and plantain inflorescences

Banana inflorescences have been used in some parts of the world to make pie fillings, salads, increase the yield of meat-based meals, and when converted into flour via drying and grinding, these inflorescences can be used in food enrichment and functional food development due to their low caloric content, high fiber, and high potassium content (Fingolo *et al.*, 2012). They have also been shown to have antioxidant, antidiabetic, antimicrobial, anti-inflammatory, anti-cancer and cardio-protective properties (Lau *et al.*, 2020). Extracts of banana inflorescences have been used in the production of both a beverage and flour which were rich in alkaloids, saponins, glycosides, tannins, flavonoids, and steroids, showed antioxidant activity, and helped to increase breast milk production in lactating mothers (Amornlerdpison *et al.*, 2020).

3.2. Value added products from pineapple waste and by-products

Pineapple is one of the most produced fruits, of which Costa Rica, Philippines, Brazil, Thailand and India are the primary pineapple producers (Mohd *et al.*,2020). Cultivated in tropical and subtropical zones, pineapple belongs to the Bromeliaceae family and has a unique shape with wide leaves and fruits that differentiates them from other monocotyledons plants (Wali *et al*., 2019). Besides, pineapple has 47.8 mg of vitamin C and 13 mg of calcium per 100 g of pineapples. There has been a growing demand for pineapple fruits and products for the past few years. Pineapple (*Ananas comosus*) is a tropical fruit with attractive sensorial (mechanical properties, flavor, acidity/sweetness ratio, color) and nutritional (vitamin A, B and C, minerals, fibers, and antioxidants) characteristics. During pineapple processing, transportation and storage, about 80% of the parts such as the crown, peels, leaves, core and stems, are discarded and end up as waste (Hamzah *et al.*, 2021). 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). Apart from processing, pineapple wastes are also generated from poor handling and storage of fresh fruit, or lack of good and reliable transportation systems (Rabiu *et al.*, 2018). Pineapple's composition, including high sugar content, trace elements (potassium,calcium and magnesium) and polyphenolic compound, has raised the interest in converting these wastes to valuable products. Pineapple can be utilized in the production of various valuable products including nanocrystals, bromelain enzyme, bioactivec ompound, wine, vinegar, biopolymer, bio-packaging, organic acid, adsorbent, biofuel and biogas. Previously, pineapple waste has also been utilised to form phenolic antioxidants, anti-dyeing agents and animal feed (Hossain *et al*.,2016, Upadhyay *et al.*, 2013).

Increasing demand for pineapple contributes to an enormous pineapple production, and as a consequence, a large amount of waste is generated. About 80% of pineapple parts, including the crown, peels, leaves, core and stems, are discarded during pineapple processing, transportations and storage and ends as waste (Roda *et al*., 2019, Zainal *et al.*, 2020). It is essential to know the composition and characteristics of pineapple waste before converting them to valuable products. The identification of major polyphenolic compounds from pineapple waste amounts to 31.76 mg of gallic acid, 58.51 mg of catechin, 50 mg of epicatechin and 19.5 mg of ferulic acid per 100 g of dry extracts (Li *et al.*, 2014). Recent research by Dahunsi (Dahunsi *et al.*, 2019) observed that pineapple waste contains 19.4% lignin, 32.4% cellulose and 23.2% hemicellulose.

3.2.1 Wine and Vinegar from pineapple peels

High sugar content in pineapple waste, especially peels, makes them notable as a source for wine and vinegar production. Therefore, it increases the possibilities of utilising pineapple waste for alcohol and acetic acid to produce vinegar (Roda *et al*., 2019). Beverages such as wine and beer can be made through the alcohol fermentation process and require an additional step such as oxidation to produce vinegar (Roda *et al*., 2017). Production of vinegar from pineapple peek using three different acetic acid bacteria strains showed that optimum acetic acid yield (6.15 g/L) was found at 72 h fermentation time using propionic bacterium acid ipropionici acetic acid bacterial strain. Umaru. (Umaru *et al*., 2015) used the juice from pineapple waste to produce wine with 10.8% alcohol content by Saccharomyces cerevisiae. Then, it underwent oxidation to acetic acid (vinegar) and contained a total acidity of 3%. In contrast, lower alcohol content (7%) was observed from wine prepared using pineapple's peels and core (Roda *et al*., 2017). However, 5% acetic acid was obtained despite the low alcohol content, which is higher in the previous study. The difference was due to the different fermentation methods used by the authors. Correspondingly, there is lower alcohol content in wine produced from pineapple wine produced by Saccharomyces cerevisiae (6.60%) and Saccharomyces bayanus (6.75%) (Ekechukwu *et al*.,2021) compared to the alcohol content in (Umaru *et al*., 2015). In another research, (Roda et al., 2017) reported that physical and enzymatic combination before alcohol fermentation were required to produce good quality wines. By varying the Saccharomyces cerevisiae strain and temperature, a substantial difference in the wine's fruity character was detected. Other than that, the sensory evaluation of pineapple organic side-stream syrup revealed its potential when combined in bakery products (Tortoe *et al*., 2013). Although the sestudies proved that pineapple residues could be utilized as food enhancers and beverages, further studies should explore more the pineapple residue's utilisation potential in the food and beverage industries, in terms of its production by focusing on the quality and purity.

3.2.2 Cellulose Nanocrystals from pineapple leaf waste

The composition of pineapple leaf waste has been shown to be 13.05% lignin, 21.02% hemicellulose and 41.15% cellulose (Hamzah *et al.*, 2021). As a result, pineapple leaves have been used in the development of nanofibers with desirable properties which can be applied in the food packaging sector (Wahyuningsih *et al.*, 2016), and being plant fibers they can serve as a good potential alternative to synthetic fibers from petroleum-based non-renewable resources (Gaba *et al.*, 2021). Pineapple leaves have also been used for the extraction of ethanol, which is rich in phytochemicals such as *p*-coumaric acid, 1-*o*-*p*-coumaroylglycerol, caffeic acid and 1-*o*-caffeoylglycerol, and when administered to diabetic rats it inhibited the increase in blood glucose and postprandial triglycerides (Upadhyay *et al.*, 2010). Pineapple leaf waste was shown by dos Santos *et al.* (2013) to be a suitable raw material for the production of cellulose nanocrystals, which can be used as a source of dietary fiber in functional foods, and for the production of food thickeners, stabilizers and flavor carriers (Mua *et al.*, 2019). Cellulose nanocrystals (CNC) derived from the abundance of cellulose in the biomass are one of the most favourable materials for nanocomposites. Currently, CNC serve as a reinforcing agent in the nanocomposites field. CNC have a large surface area, high mechanical strength, are non-toxic, hydrophilic, biocompatible and biodegradable (Raquel et al., 2018, Dos et al., 2013).

3.2.3 Bromelain Enzyme from pineapple peel waste

Pineapple peels are used to process fruit juices both locally and industrially, acting as flavor enhancers in juice making. Pineapple peel drying has been adopted in Cameroon as a strategy to extend the shelf life for the pineapples peels. Waste from pineapple processing could provide a range of value added ingredients for the food industry, including the enzyme bromelain. Bromelain is a proteolytic enzyme that is usually extracted from the stems or juice of pineapple. Bromelain helps the digestion process and is essential in various applications. The main protease that exists in the bromelain enzyme is identified as stem bromelain (EC 3.4.22.32) and fruit bromelain(EC3.4.22.33) (Nor et al., 2015). It has been used commercially in the food industry where it is known for meat tenderizing, brewing, baking and for the production of protein hydrolysates, among other things (Ketnawa *et al.*, 2012).

Pineapple peels have also been used in the alkali extraction of ferulic acid, which is a widely used phenolic antioxidant in the food and cosmetic industries (Upadhyay *et al.*, 2010). These peels which account for 35 to 50% of total pineapple fresh weight (Chongkhong and Tongurai, 2019) have been shown to be a potential raw material for the production of biofuels such as ethanol and hydrogen (Choonut *et al.*, 2014). Work done by Cornelia and Kristyanti (2021) showed that pineapple peels can be used in the production of cider, which is rich in phenolic compounds and has potential antioxidant activity. Gallic acid, catechin, epicatechin and ferulic acid were identified as the main polyphenolics in pineapple peels (Li *et al.*, 2014). Vinegar can also be produced from pineapple peels via fermentation with acetic acid bacteria (Chalchisa and Dereje, 2021). The addition of pineapple peel flour to wheat flour in the production of biscuits led to an increase in the proximate composition and the calcium, potassium, sodium and copper contents of the biscuits (Adeoye *et al.*, 2017), indicating that pineapple peel flour can be used to enrich food products.

3.2.4 Bioactive Compound

Pineapples and their wastes serve as a good source of antioxidants. The formation of free radicals caused by the oxidation of biological molecules can be prevented by an antioxidant, for example, a phenolic compound which has antioxidant, antimicrobial and anticancer properties (Van *et al.*,2013). Sepúlveda *et al*., 2018 reported that the extraction of pineapple waste using the auto hydrolysis process resulted in obtaining polyphenols with high antioxidant activity. The study also revealed that pineapple waste is a good source of antioxidants compared to readily available antioxidants in the market, and all pineapple waste extracts showed higher antioxidant activity.

3.3. Value added products from potato peels

Due to increasing urban populations and rising incomes of people living in developing country, the demand for processed food has dramatically increased (Maria *et al.*, 2010). Potato chips are the most common food processed potato product which produce a large amount of potato peels as by-product. Potato peel is a zero value by-product, which occurs in huge amounts after processing. Depending on the peeling method used, it ranges from 15 to 40% of the first product mass. In food processing industries, the most common cause of environmental pollution is associated with organic waste decomposition which occurs when bacterial and other biological forms use the compounds as a source of food. To avoid such problems, the use of potato waste as an antioxidant in food systems due to its high phenolic content has been explored (Sepelev and Galoburda, 2015).

Potato is the world's fourth-largest food crop, following maize, wheat and rice. Its production (225 to 285 million tons) occurs in 10% of cultivated area (Pandey *et al*.,2008). It is a significant food crop in developing countries, and is often grown at a significant scale in more than 130 countries around the world. Cameroon accounts for 0.1% of the world's total production of potato and 0.8% of Africa's total production (220,000tons of 29 million tons) (FAOSTAT 2019). Nowadays, types of processed potato products have increased from time to time to meet the tremendous interest of consumers. Food processing factories produce many volumes of wastes as a byproduct (Charmley *et al*, 2006; Schieber & Aranda, 2009). Potato popularly known as "the king of vegetables" because it grows in more than 100 countries. In developing countries, potato production has increased at an average rate of five percent per year. Currently the total share of developing countries to global potato production rose from 20% to 52%. This is a remarkable achievement, considering the past two decades (FAO, 2008). Potato waste contains valuable chemical components like phenols which are suitable to apply in food preservation and pharmaceutical industries (Grunert, 2018). Food processing industries generate phenolic- rich vegetable by- products, and this has been an area of research investigations as a sources of antioxidants and antimicrobial for food preservation (Pezeshk *et al*., 2015). The entire tissue of fruits and vegetables is rich in bioactive compounds or phenols but the by- products have higher contents of antioxidant (Sonia *et al.*, 2016). Potato peel is one of the most important waste products with sufficient amount of phenolic compound so this could be used as a replacement for the current synthetic antioxidant and antimicrobial.

Synthetic food preservatives could be used alone or in combination with natural preservatives both synthetic and natural antioxidants been used in food industry; however, application of synthetics preservatives has potential carcinogenic effects but use of natural preservatives alone has a better advantage for human health with low side effect. As a result, attention has being given to vegetable waste with rich source phenols (Sonia *et al*., 2016; Tiwari *et al*., 2009). Phenolic compound is found ubiquitously in plants and is of noticeable interest due to their antioxidant and antimicrobial properties (Pezeshk *et al*., 2015).

3.3.1 Antioxidant activity of potato peel extract

Antioxidants inhibit oxidation of lipids in foods and consumption of high concentration synthetic antioxidant has carcinogenic effects, unlike the natural antioxidants (Thorat *et al.*, 2013). The antioxidant activity of potato peel extracts has strong radical scavenging ability and prevents oxidation reactions in oily foods (Koduvayur *et al.*, 2010). The dominant phenolic compounds of potato peel extracts are chlorogenic and gallic acids, which are natural antioxidants that prevent oxidation of vegetable oil, and they have been shown to inhibit soybean oil oxidation reactions by minimizing peroxide, totox, and p-anisidine indices (Amado *et al.*, 2014; Mohdal *et al.*, 2010). In terms of its ability to prevent vegetable oil oxidation, potato peel extract has equal performance with synthetic antioxidants such as butylhydroxyanisole (BHA) and butylhydroxytoluene (BHT). In comparison with mature potato, young potato peels are an excellent source of bioactive phytochemicals with antioxidant potential (Arun *et al.*, 2015). However, as compared to the application of synthetic antioxidants, potato peel extracts need to apply in higher amount but still looking the advantage of natural antioxidants than the synthetic, it is a promising source of natural antioxidant that could be used as eco- friendly product on food industries.

3.3.2 Antimicrobial activity of potato peel extract

Potato peel extracts have also shown antimicrobial activity against bacteria and fungi, which could be due to the presence of flavonoids and terpenes (Haftom *et al.*, 2018). Potato peel has bacteriostatic ability with non-mutagenic behavior, making it safe for use in food processing industries (Amanpour, 2015). Therefore, potato peel extract is the future against foodborne pathogenic microbes, and the broad spectrum nature of the plant has potential for the discovery of new chemical classes of antibiotic substances that could serve as food preservatives in food processing industries (Haftom *et al.*, 2018). Therefore, potato peel extract is the future and natural against foodborne pathogenic microbial and the broad spectrum nature of the plant help to discover new chemical classes of antibiotic substances that could serve as food preservative in food processing industries.

3.4. Value added products from tomato waste and by-products

Tomato, (Lycopersicon esculentum Mill.), is the second most important vegetable crop worldwide and is a key component of the Mediterranean diet; its consumption is directly associated with reducing the risk of inflammatory processes, different chronic diseases, and carcinogenesis, as well as the inhibition of the oxidation of low-density lipoproteins, thus helping to lower the level of blood cholesterol (Pinela *et al*., 2016). Over 130 million tons are processed every year, and approximately eight million tons represent the waste generated as estimated by the World Processing Tomato Council (WPTC) (2020). In fact, a considerable number of produced tomatoes are not suitable for fresh consumption due to unacceptable color, maturity, or shape, thus representing an economic loss for producers and a negative environmental impact (Lovdal *et al*.,2019). Additionally, large quantities of tomato peel residues are generated from the processing industry. Therefore, the recycling of tomato waste is currently among the top environmental stakes, and alternative uses need to be proposed

The solid residue remaining after the industrial processing of tomatoes, i.e., tomato pomace, consists of large amounts of tomato peels and seeds that currently find use as animal feed and fertilizers or are sent to landfill (Strati *et al*.,2014, Rossini *et al*.,2013). However, it is still rich in highly beneficial phytochemicals such as carotenoids, phenolic compounds, and vitamins, among which lycopene is the most important antioxidant present in the ripened tomato, representing 80–90% of the total pigments (Szabo *et al*.,2018, Kalogeropoulos *et al*.,2012). Many epidemiological data support a correlation between carotenoids, especially lycopene intake, and several nutritional and health benefits, including the prevention of carcinogenesis and cardiovascular diseases (Naziri et al., 2014, Kaur et al., 2018, Nayak et al., 2019,). In addition, phenolics are recognized for their antimicrobial and antioxidant activity and for their contribution in preventing various oxidative stress-associated diseases (Szabo et al., 2019)

In this line, given their antioxidant or nutritional properties, numerous approaches have been proposed for the valorization of the unused parts of tomato in various sectors, including the recovery and isolation of carotenoid compounds to be used for the formulation of functional foods, as well as for pharmaceutical and cosmetic products, instead of chemically synthesized molecules (Al-Wandawi *et al.*, 1985, Zuorro *et al*., 2011, George *et al*., 2014, Stoica *et al*., 2018). On the other hand, the conventional extraction procedures to obtain bioactive compounds suffer from a huge amount of toxic organic solvents, low extraction selectivity, and decomposition of thermo labile compounds. Therefore, to overcome these limitations, the development of innovative and sustainable approaches in the extraction of these substances must be applied

3.4.1 Carotenoid Extraction

Carotenoids are natural lipid-soluble pigments which are accumulated in the chloroplasts and chromoplasts in the outer skin layer during the ripening process of tomatoes (Pataro *et al*., 2015). Considering their structure, they are divided into two major groups: carotenes, which are hydrocarbon carotenoids that are either cyclized (such as α-carotene and β-carotene) or linear (lycopene), and oxygenated carotenoids called xanthophylls (suchaslutein, zeaxanthin, and β-cryptoxanthin) Indeed, the fundamental carotenoids that occur in tomatoes are lycopene and β-carotene. In peel byproducts, lycopene content corresponds up to 90% of the total carotenoids; instead, β-carotene represents the major carotenoid in seeds. Furthermore, most of the literature data agree on the fact that the highest quantities of carotenoids are found in tomato waste. In particular, tomato peel typically contains the highest lycopene content (about 377 μg/g).

Lycopene is a bright red carotenoid found in tomatoes and other red fruits, vegetables (red carrots, watermelons, gac, and papayas) and phytosynthetic algae. Due to the strong color and its solubility in organic matters, lycopene is useful as food coloring (registered as E160d) and is approved for use in the USA by the US Food and Drug Administration since 2005. Promising data from epidemiological as well as cell culture and animal, studies suggest that the consumption of lycopene-containing foods may improve human health. To this end, several advanced drug delivery systems have been developed, to enhance the in vivo delivery of lycopene (Caseiro et al., 2020; Kaur et al., 2017). In recent years, tomato peels have been proposed as a low-cost source of lycopene, compared to fresh tomatoes or Blakeslea trispora, a fungus of the division of Zygomycota, industrially used due to its ability to produce carotenoids (Górecka et al., 2020; Martínez-Cámara et al., 2018). There are numerous variables that can influence the yield of lycopene extraction, but the solvent type is widely considered to be the most important (Kaur et al., 2008). Organic solvents and their mixtures are the most investigated due to their affinity with lycopene (Briones-Labarca et al., 2019; Pandya, 2017; Zuorro, 2020).

Established protocols for lycopene extraction from tomato utilize traditional solvent extraction methods based on the use of conventional organic solvents and different combinations of solvent mixtures (Roldán-Gutiérrez *et al*., 2007, Strati *et al*., 2011, Saini *et al.*, 2018). A recent study showed that highly efficient solvents for the direct recovery of lycopene from tomato peels can be easily prepared using a mixture design approach . A mixed-polarity solvent mixture composed of n-hexane–ethanol– acetone resulted in a lycopene extraction yield higher than 95%.

3.4.2 Cutin extraction

Cutin is the polymeric building block of the plant cuticle. It represents 40–80% wt. of the dry peels and consists of esterified fatty acids (Domínguez et al., 2015; Heredia, 2003). Cutin is mainly composed of mixture of C16 and C18fatty acids (Domínguez et al., 2011). These long-chain fatty acids (called cutin acids) represent innovative building-block chemicals for the synthesis of novel bio-resins and lacquers suitable as internal protective coating for metal food packaging. However, these natural compounds are not currently available commercially

(Cifarelli et al., 2019). Tomato pomace and tomato peels have been proposed as a renewable source of this biopolymer, due to their high content in cutin and their availability. Cifarelli et al. (2019) reported three efficient, easy and environmentally safe procedures that could be commercialized for the extraction of cutin acids from tomato peels without the use of organic solvents, these include:

i) alkaline hydrolysis of the tomato peel,
ii) acid-free selective precipitation of cutin and
iii) hydrogen peroxide-assisted hydrolysis.

Notably, those authors noticed that the products were different depending on the method used in terms of appearance, solubility, degree of observed crosslinking and molecular weight. They also noted that cutin obtained through alkaline hydrolysis resulted the best raw material for bio-resin preparation (Cifarelli et al., 2019). Manrich et al. (2017) proposed a hydrophobic edible film consisting of tomato cutin and pectin, obtained using extraction of cutin using the procedure proposed by Cigognini et al. (2015).

3.4.3 Pectin extraction

Pectin is a well-known, naturally occurring biopolymer that is finding increasing applications in the pharmaceutical and biotechnology industry. It has been successfully used for many years in the food and beverage industry as a thickening medium, a gelling agent, and a colloidal stabilizer. Although pectin is found in most plant tissues, the number of sources that may be used for the commercial manufacture of pectins are very limited. Del Valle et al. (2006) reported that tomato peels contain pectin at 8% wt. on dry basis. Grassino et al. (2016) developed a method to produce pectin from tomato peels; in their experiments, pectin was extracted from dried tomato peels using ammonium oxalate and oxalic acid as extracting solvents, in two steps. According to their results, it can be concluded that tomato peels are a suitable source for pectin that can be used to produce corrosion inhibitors and a valuable additive in food industry. (Alancay et al. 2017). Optimized the pectin extraction from tomato processing waste by using a mineral acid, i.e. HCl, thus obtaining a maximum yield of 280 g/kg of tomato pomace.

3.5. Value added products from cereal waste and byproducts

The term “cereals” refers to members of the Gramineae family and determines nine species: wheat (Triticum spp.), rye (Secale spp.), barley (Hordeum spp.), oat (Avena spp.), rice (Oryza spp.), millet (Pennisetum spp.), corn (Zea spp.), sorghum (Sorghum spp.), and triticale (x Triticosecale Wittmack)—which is a hybrid of wheat and rye. Cereals are cultivated for the edible components of their grain or the kernel. Strictly speaking, a cereal is a caryopsis which is composed of the fruit coat (pericarp) and a seed. The fruit coat adheres tightly to the seed coat surrounding the remainder of the seed consisting of germ and endosperm. The aleurone layer lies next to the pericarp. This layer is rich in protein and minerals. The endosperm is the large central portion of the kernel made up mostly of starch, and the germ/embryo is the small structure at the lower end of the kernel (Delcour and Hoseney, 2010). Cereal grains are usually milled to remove the fibrous bran, which is one of the major by-products of cereal processing.

Although the micronutrients are generally present in higher concentrations in the outer part of the grain, it is often undervalued and used as animal feed (Hemery *et al.*, 2011). Cereal bran is a nutritional storehouse of the grains. The Chemical composition of cereal bran is highly complex and the multiple beneficial effects of cereal bran could be exploited by incorporating it into the daily diet. Besides regular nutrients like proteins, vitamins, minerals, and fats, cereal bran is a good source of functional food ingredients in the form of bioactive compounds such as dietary fiber, phytosterols, polyphenols and phenolic acids which may provide a wide spectrum of biological activities and other health benefits as seen among populations consuming diets based on cereal grains (Patel, 2012).

3.5.1 Products obtained from rice bran

Rice bran is the most attractive byproduct generated during rice processing because even though it accounts for only 9% of the rice weight, it contains about 65% of the nutrients of the whole rice grain and is rich in proteins, oil, fiber, micronutrients such as vitamins, and minerals, such as aluminum, calcium, chlorine, iron, magnesium, and manganese (Garofalo *et al.*, 2020). It can be used in the production of rice bran oil and as a dietary fiber source in bakery products since it has anti-oxidant and anti-inflammatory properties (Friedman, 2013; Min *et al.*, 2011). The production of rice bran oil is one of the most common uses of rice bran due to the fact that rice bran oil is very rich in γ-oryzanol, tocopherols, tocotrienols, and phytosterols, a powerful antioxidant mixture of bioactive molecules (Garofalo *et al.*, 2020; Lavanya *et al.*, 2017). Rice bran oil can be used as an alternative to bakery shortening, and has shown improvement in the baking quality when added to baked products (Gul *et al.*, 2015). The presence of Gamma-oryzanol in rice bran makes it a very attractive potential food ingredient because this compound has been shown to decrease animal serum-cholesterol levels and anti-inflammatory activities while inhibiting cholesterol oxidation in vitro (Esa *et al.*, 2013). Due to its high fiber content, rice bran can give texture, gelling, thickening, emulsifying and stabilizing properties to certain foods (Gul *et al.*, 2015), which is very useful in the food industry. Rice bran wax has been used in the formation of corn germ oil oleogels, and this formulation showed potential to act as a replacer of commercial shortening in the baking industry (Zhao *et al.*, 2019).

Other than oil, rice bran also has a 10-15% protein content, and these proteins have been found to be of high quality and application in food and pharmaceutical industries due to their unique hypoallergenicity and anticancer effects (Esa *et al.*, 2013). The partial replacement of gelatinized corn flour with rice bran flour in the production of corn flakes and tortilla chips led to an increase in the protein content of these products (Özdestan *et al.*, 2014), making rice bran a potential beneficial ingredient for the enrichment of bakery products. A protein formulation based on rice bran can be used to target and overcome protein related nourishment disorders (Gul *et al.*, 2015) in some of the underdeveloped countries of the world.

3.5.2 Products obtained from corn bran

Corn bran is mainly made of insoluble fiber, cellulose, hemicellulose, and xylooligosaccharides making it indigestible by enzymes in humans and monogastric animals, but it can be degraded by colon bacterial communities (de Almeida *et al.*, 2021). It can be used as a natural food additive in cellulosic fiber gel (commercially available as Z-Trim), cellulose fiber gum and in corn fiber oil. Submerged fermentation of corn bran with *Monascus purpureus* led to the production of pigments belonging to a group known as azafilones which can be used as colour additives in the food industry (de Almeida *et al.*, 2021). Purple corn bran can be used for the recovery of anthocyanins, which are water-soluble pigments that can provide attractive colors to foods and have potential beneficial health effects such as antioxidant, anti-inflammatory, anticancer, antiobesity, and anti-diabetic properties (Chen *et al.*, 2018). Corn bran hydrolysates have been used in the production of pullulan, which can be used in food stabilization, coating and the production of packaging materials (Haghighatpanah *et al.*, 2021). It can be concentrated and dried to produce crude bio-based fiber gums which can serve as emulsifiers in the food industry (Yadav *et al.*, 2015). Corn bran has also been used in the production of ferulic acid which has many beneficial functions such as antioxidant, antimicrobial, anti-inflammatory, anticancer and free radical scavenging activities (Zhao *et al.*, 2015).

3.6. Value added products from palm kernel waste and byproducts

The oil palm (*Elaeis guineensis* Jacq) is a native plant of the humid tropics of West Africa. Cultivation originated where oil palm trees were inter-planted in traditional agricultural production systems along with other annual and perennial crops. After the extraction of oil from the palm kernel, several by-products are generated such as the empty fruit bunches, palm pressed fibers and shells which are mainly composed of lignin, cellulose, hemicellulose and other carbonaceous materials (Tan, 2006).

3.6.1 Products from palm kernel cake

Palm kernel oil is obtained from the seed (the kernel or endosperm) which contains about 50 per cent oil. When the oil has been extracted, the residue known as "palm kernel cake" (PKC) is rich in carbohydrates (48%) and proteins (19%), and the ash contains large amounts of potassium. A portion of these wastes is used as feed supplements for livestock (Oluwaseun *et al.*, 2006).

According to Sahin and Elhussein (2018), palm kernel cake is rich in various phytochemicals such as caffeic acid, vanillic acid, d glucuronic acid, ferulic acid, glutaric acid, protocetechuic acid, quinic acid p-coumaric acid, p hydroxybenzoic acid, salicylic acid, shikimic acid, sinapic acid and syringic acid, which have a great role to play in extending the shelf life of several products as well as providing added-value properties with their antioxidant and antimicrobial properties.

Phenolic extracts of palm kernel cake can be used as antioxidants in the food industry, due to the fact that their experimental addition to sunflower oil showed an increase in its induction time by more than 50%. (Tsouko *et al.*, 2018). Hydrolysis of palm kernel cake protein using different proteases led to the production of useful protein hydrolysates or bioactive peptides which showed radical scavenging activity, with the protein hydrolyzed by papain resulting in the production of thehydrolysate with the highest antioxidant activity (Zarei *et al.*, 2012). This further supports the potential of palm kernel cake in the production of antioxidants for use in the food industry.

In a study carried out by Belo *et al.* (2018) to evaluate the potential of polysaccharides extracted from palm kernel cake for use as prebiotics, it was found that these soluble polysaccharides showed high resistance to hydrolysis when subjected to artificial human gastric juice and promoted the proliferation of *Lb. plantarum* and *Lb. rhamnosus* with a decrease in the pH of the medium and the production of organic acids. This implies that palm kernel cake polysaccharides can be exploited as probiotics.

Through solid-state lacto-fermentation, low molecular weight peptides were generated from palm kernel cake and when added to bread, these peptides increased its shelf life by inhibiting fungal growth since they showed strong antifungal activity against *Aspergillus flavus*, *Aspergillus niger*, *Fusarium* sp., and *Penicillium* sp. (Asri *et al.*, 2020). This shows that peptides extracted from palm kernel cake have potential to be used in the food industry to extend the shelf life of bakery products and other food products thereby promoting food safety, security, and sustainability. Via solid state fermentation, palm kernel cake has also been used in the production of tannase, the enzyme which catalyzes the hydrolysis of tannic acid by breaking its ester and depside bonds releasing glucose and gallic acid. This enzyme is has various uses in the food industry such as the processing of tea, production of gallic acid, treatment of tannery effluents, stabilization of malt polyphenols, clarification of beer and fruit juices, and for the prevention of phenol-induced madeirization in wine and fruit juices (Sabu *et al.*, 2005).

3.6.2 Products from palm pressed fibre

Palm pressed fiber is a form of recovered fiber from pressed palm fruits which is rich in carotenoids, vitamin E (tocopherol and tocotrienols), and sterols, and has been used for the recovery of palm pressed fiber oil which contains significant quantities of carotenoids (4000–6000 ppm), vitamin E (2400 3500 ppm), sterols (4500–8500 ppm), and coenzyme Q10 quantities greater than those found in crude palm oil (Neoh *et al.*, 2011). As a result, palm pressed fiber oil has antioxidant and anti-inflammatory properties (Teh *et al.*, 2019) which can be applied in the development of functional foods. The presence of phosphorus in palm pressed fiber oil further enhances its antioxidant properties, and this phosphorus can be extracted for use as a food additive (Majid *et al.*, 2012).

3.6.3 Products from palm kernel shells

Palm kernel shell is a natural fiber which is rich in lignin, cellulose and hemicellulose, and can be used in the production of fiber-reinforced plastics, thereby contributing to the food packaging sector (Baffour-Awuah *et al.*, 2020). It can also be used as an adsorbent for the treatment of heavy metal contaminated water (Baby *et al.*, 2019), making it a useful material for food wastewater treatment processes.

3.6.4 Products from empty palm kernel fruit bunches

Palm kernel empty fruit bunches are rich in cellulose and nanocellulose. and they have the lowest phenolic content among all the side streams derived from the palm oil production process (Tsouko *et al.*, 2018). However, their phenolic extracts still showed antioxidant activity. Cellulose and nanocellulose have been extracted from empty fruit bunches (Sundalian *et al.*, 2021), and these compounds can be used as food additives or in the development of food packaging materials. Xylan can also be extracted from these fruit bunches and used as a thickening agent, or converted to xylo-oligosaccharides which are prebiotics (Sundalian *et al.*, 2021). These empty fruit bunches can also be converted into valuable compounds such as ethanol, biovanillin, p-hydroxybenzoate and lignin-containing cellulosic nano fibrils (Rame, 2018; Sudiyani, 2013).

3.7. Value added products from mango wastes and byproducts

Mango is one of the most important tropical fruits in the world and currently ranked 5th in total world production among the major fruit crops (Wyman., 2001, Berardini *et al*., 2005, Abdeldaiem *et al*., 2012). The total amount of mango production in the world was around 35 million tonnes by the year 2009. The amount of mango production in Africa during 2009 is 13.6 million tonnes (Ajila *et al*., 2013). 1-2% of the production is processed to make products such as jelly powders, nectars, jams, juices, fruit bars, flakes concentrates, and mango chips but the majority of mango production is consumed fresh (Ajila *et al*., 2010b, Abdeldaiem *et al*., 2012, Ajila *et al*., 2013). Mango processing industries dispose of seeds (seed coat and kernel), cull fruits: fresh fruits unsuitable for human consumption, and peel as a by-product.

The waste generated from the mango processing industry, derived mainly from the epicarp and endocarp has been estimated at 75000 MT (Dorta *et al.*, 2012), and is on the rise due to growth in mango fruit production and processing industry. However, there is virtually no commercial utilization of mango seed kernel which in most cases is discarded as waste in the fruit processing industry.

Mango seed is a good source of carbohydrates (58-80%), protein (6-13%) with good 135 profiles of essential amino acids and lipids (6-16%) rich in oleic and stearic acids (Siaka, 2014). The seed has a high protein content with the presence 139 of all essential amino acids at higher levels than those referenced by the FAO as good quality 140 protein. The seed also has high lipid content, these have typical characteristics of a vegetable 141 butter (Muchiri *et al.*, 2012).

Carotenoids play a potentially important role in human health by acting as biological antioxidants, protecting cells and tissues from the damaging effects of free radicals and singlet oxygen and are used as natural colorants in the food industry (Oreopoulou and Tzia, 2007). The carotenoid content was found to be 4–8 times higher in ripe mango peels compared to raw fruit peels.

The dietary fiber content in mango peels of different varieties has been estimated. The total dietary fiber content in dry peel varied from 45 to 78% (Palafox-Carlos *et al.,* 2010). The soluble dietary fiber content in both raw and ripe mangos peels are more than 35% of total dietary fiber. Insoluble dietary fiber relates to both water absorption and intestinal regulation whereas soluble dietary fiber associates with cholesterol in blood and diminishes its intestinal absorption.

Mango seed kernel oil has been reported to be a good source of polyunsaturated fatty acids such as oleic and linoleic acids which have health benefits (Kittiphoom *et al.*, 2013). The potent antimicrobial activity demonstrated by the mango kernel extracts could be attributed to the presence of specific phytochemicals such as flavonoids, terpenes, tannins, and coumarins. High antimicrobial and antifungal activity against Staphylococcusaureus, Bacillus subtilis, Pseudomonas aeruginosa, Escherichia coli, and Candida albicans has been reported in kernel powder of South African mango variety (Ahmed *et al.,* 2005).

3.7.1 Starch extraction:

Starch, the principle carbohydrate constituent of most plant materials, merits a detailed investigation to better understand its biochemical and functional characteristics as well as its variations. Extensive research has been conducted on the structure and functional properties of the main starches of commerce, such as wheat, corn, potato, and rice, due to their ready availability and their extensive utilisation in food and non-food applications. The result revealed that mango by-products are a potential starch source due to their high starch content (more than 50%). Using aqueous extraction technique one can extract starch from those sources (Tesfaye *et al*.,2015, Tamrat *et al*.,2016). The extracted starch could be used in textile industries for yarn sizing, for paint, paper, pharmaceuticals, leather, and Bioplastics industries.

3.7.2 Enzymes production:

From the physicochemical properties of mango by-products, the result revealed that this waste could be used in the production of carboxymethyl cellulose, pectinases, and cellulase enzyme Carboxymethylcellulose and cellulase enzyme could be used in food industry as a viscosity modifier or thickener, and to stabilise emulsions in various products including ice cream, as toothpaste, laxatives, diet pills, water-based paints, detergents, lubricants, textile sizing, and various paper products. As mango by-products are a rich source of pectin, (Malviya *et al*., 2010, Koubala *et al*., 2013) so degrading pectin using any microorganisms could be used for fermentative production of pectinases. Pectinase enzymes could be used in processes involving the degradation of plant materials, especially in wine production.

3.7.3 Lactic acid fermentation

Lactic acid is used as a food preservative, an ingredient in processed foods and is used as a decontaminant during meat processing curing agent, and flavouring agent. It is also used as a starting material in the production of polylactic acid polymer. Lactic acid is produced commercially by fermentation of carbohydrates such as glucose, sucrose, or lactose, or by chemical synthesis but the production of this substance is very costly (Ajila *et al*., 2010b). The use of agro-industrial wastes would provide an alternative way to produce lactic acid from less costly raw materials. Seeing that the chemical composition of mango by-products they could be used as a source of lactic acid (Chen *et al*., 2004). The production of lactic acid takes place through a two-step procedure; pretreatment followed by acid hydrolysis of the by-product followed by microbial fermentation. The production of lactic acid from mango by-products seems to have a practical advantage because the method is economically viable since the cost of the raw material (mango by-product) has low cost.

3.8. Value added products from citrus fruit wastes and byproducts

Citrus fruits (CF) are a family of widely consumed fruits worldwide. Citrus plants belonging to the family of Rutaceae which include fruits such as orange. Mandarin, lime, lemon, orange and grape fruit appear as a well known promising source of multiple beneficial nutrients to humans.

In contrast with other types of fruits, citrus fruits have a small edible portion. Hence, large amounts of waste material, such as peels and seeds, are discarded during juice and food processing. Residues of citrus juice production are a source of several compounds, principally by water, soluble sugars, fiber, organic acids, amino acids and proteins, minerals, oils and lipids, and also contains flavonoids and vitamins.

Citrus peel is one of the most underutilized and most geographically diverse biowaste residues on the planet. After juice extraction the residual peel accounts for 50 wt% of the fruit, presenting an environmental problem. (Marn *et al.*, 2007). There is a real challenge to utilize this resource, with 15.6 million metric tonnes of waste produced from 31.2 million metric tonnes of processed citrus fruit annually. (Djilas *et al.*, 2009). Waste orange peel (WOP) is composed of 20% dry matter (sugars, cellulose, hemicellulose, pectin, and d-limonene) and 80% water. (Bampidis *et al.*, 2006). However, research carried out on citrus waste valorization has nearly always focused on production of a single component, such as d-limonene, (Espina *et al*., 2011) pectin or bioethanol. (Widmer *et al*., 2010).

By-products from Citrus fruits, including exhausted peel, seeds, pressed pulp, secondary juice (obtained by pressing the residual pulp after the primary juice extraction) and leaves, are a source of polyphenols (i.e., flavonoids and phenolic acids), sugars (i.e., glucose, fructose and sucrose), dietary fibers (i.e., pectin and cellulose), proteins, lipids (i.e., linolenic, oleic, palmitic and stearic acids), organic acids (i.e., citric, malic and oxalic acids) carotenoids (i.e.,caroteneandlutein), vitamins (i.e.,vitamin C and vitamin B complex) and monoterpenes (i.e., limonene and linalool) (Mahato *et al*., 2018). Molecular composition of each by-product may vary depending on the type of cultivar, the cultivation method, the harvesting time and the degree of ripeness of the fruit.

CF peel represents almost 50% of the wet fruit mass after juice extraction (Sharma *et al*., 2017), and is particularly high in fragrant compounds, dietary fibers, pectin, natural pigments as well as polyphenols (Rafiq *et al*., 2018). CF peel is mainly employed for the extraction of essential oils (EOs), which are contained in the oil sacs of both peels and cuticles, although they can also be isolated from seeds or leaves in much lesser quantities. Chemical composition of EOs consists of monoterpenes and sesquiterpenes compounds (i.e., hydrocarbons with two or three isoprene units in their structure) and oxygenated derivatives (i.e., alcohols, ketones, aldehydes and esters). Limonene is the major constituent of EOs extracted from Citrus by-products, whereas β-pinene, sabinene and β-ocimene are characteristic of the EOs from Citrus leaves (Chi *et al*., 2018). CF EOs have long been used as flavorings in preparation of food, cosmetic and pharmaceutical products and, more recently, have been re-evaluated for their health beneficial properties (Dosoky *et al.*,2018, Bruni *et al*.,2019).

Exhausted CF peels are a source of pectin and dietary fibers, which are also present in juice and pulp (Dimopoulou *et al*.,2019). Pectin is a complex polysaccharide composed of D-galacturonic acid units linked together by α-1,4 glycosidic bonds, partially esterified with methanol or acetic acid. It commonly exists in complex or insoluble forms, from white to light brown color and, being a naturally gelling agent, it is used as a thickener, emulsifier, texturizer and stabilizer in the preparation of confectionery, jams and jellies, as well as biodegradable products. Dietary fibers are non-starch polysaccharides including at least ten carbohydrate units, not easily digested nor absorbed in the intestine, and they can exist in soluble (i.e., gum, pectin and a part of cellulose) and insoluble forms (i.e., cellulose, hemicellulose and lignin) (Dimopoulou *et al*.,2019).

Secondary CF juices are a great source of carotenoids and flavonoids that are present also in peels. Carotenoids are pigments biosynthesized in different fruits and vegetables and can be subdivided into two classes: oxygenated carotenoids (or xanthophylls), such as lutein and violaxanthin, and hydrocarbon carotenoids (or carotenes), such as β-carotene and lycopene. (Saini *et al*., 2018, Sharma *et al*., 2021). They are precursors of vitamin A, which is involved in epithelial tissues growth, strengthening of the immune system and promotes proper functioning of vision (Widjaja *et al*., 2018).

Flavonoids are a wide class of secondary metabolites, synthesized by plants to protect against ultraviolet radiation or pathogenic injuries. They are subdivided into six groups, which are flavones, flavanones, flavonols, isoflavones, anthocyanidins and flavanols (Barreca *et al*., 2017, Durazzo *et al*., 2019, Barreca *et al*., 2020, Abbate *et al*., 2021). Citrus flavonoids have been extensively studied for their anti-cancer (Cirmi *et al*., 2016), anti-inflammatory (Musumeci *et al*., 2020) and neuroprotective activities (cirmi *et al*., 2016). In particular, naringin, hesperidin, hesperetin, neohesperedin, narirutin and rutin were quantified as the main flavanones of “satsuma mandarin” juice processing waste (Kim *et al*., 2016).

Another interesting application of citrus fruits by-products is as cattle feed, especially for ruminants. The most important by-products that can be used are fresh or dried pulp, citrus silage, citrus meal and fines, citrus molasses, citrus peel liquor, and citrus activated sludge. Bampidis and Robinson, (2006) characterized physical and nutrient composition, digestibility, fermentation and effects on ruminants (weight and lactating production) of these feeds. Authors stated that these wastes could be effectively used as feedstuff in rations that support growth and lactation in ruminants.

3.9. Value added products from coffee wastes and byproducts

Nowadays, coffee plants are cultivated in more than 70 countries. Coffee berries are obtained from two usually grown species: Coffea canephora (Robusta), the most widely cultivated variety, especially in Central Africa, Southeast Asia and Brazil and Coffea arabica (Arabica), cultivated in Latin America, Eastern Africa and Asia. About 60% of coffee beans worldwide production is arabica and the rest of 40% is Robusta (Batista *et al*., 2016).

Coffee berries are picked when ripped, then are processed and dried, becoming coffee beans. Roasting of coffee beans constitutes a very important stage in coffee obtaining process, because it influences physically and chemically properties of beans and determine their sensorial quality, especially flavour and colour. Roasted beans are grinded and brewed with near-boiling water, in order to obtain the coffee beverage. Coffee is one of the most commercialized commodities worldwide, after petroleum. In the same time, it is the second most popular beverage, next after water (Mussatto e*t al.,* 2011b; Girotto *et al.,* 2018). Thus, there is a great worldwide interest for its production and commercialization.

As world total coffee consumption increases every year, an important problem becomes to be the major quantities of organic waste resulted from coffee industry: by-products from beans processing and roasting (>50% of the fruit mass) and spent coffee grounds (SCG), from beverage preparation (Campos-Vega et al., 2015a). SCG is the solid residue which remains after roasted coffee beans are grinded and brewed, both in coffee shops chains and in industry, for obtaining instant coffee and represents the most abundant coffee by-product (45%) (Murthy and Naidu, 2012).

SCG chemical composition Spent coffee grounds contain important quantities of organic compounds (phenolics, lipids, proteins, lignin, cellulose, hemicellulose and other polysaccharides), which determine its importance as a real source of valuable products (Kourmentza *et al*., 2018). Polysaccharides fraction covers about 50% of SCG total mass, of which about 50% are galactomannans, 25% arabinogalactans and 25% cellulose (Oosterveld *et al*., 2003). Presence of mannose, galactose, glucose and arabinose, polymerized into hemicellulose and cellulose (Ballesteros *et al*., 2014; Mussatto *et al*., 2011a) and high content of galactomannans are highlighted in SCG, lignin being also present in a significant amount (Pujol *et al*., 2013). Dietary fiber represent about 43% of total SCG dry weight (42% insoluble, 1% soluble fibre respectively), which are approved to be used as raw material to develop functional foods. The fibre from SCG includes, among others, resistant starch, oligosaccharides and manno-oligosaccharides (Campos-Vega *et al*., 2015b; Vázquez-Sánchez *et al*., 2018; Tian *et al*., 2017). There are also present some bioactive secondary metabolites, such as diterpenes, sterols, chlorogenic acids, flavonoids and caffeine (Massaya et al., 2019). Caffeine is a major biological active compound of spent coffee grounds (Cruz *et al*., 2012b). Till present, several important applications have been experimental developed for spent coffee grounds valorisation, especially as biofuels, composts and animal feed, a functional ingredient for food products with real health benefits, bio-composite materials, decontaminants of waste waters.

In addition to SCG application in animal feed, currently there are studies which support the usage of this by-product as a nutraceutical or food functional additive, improving both nutrition and health (del Castillo *et al*., 2014). SCG constitutes a valuable source of phenolic compounds and melanoidins, which can be further included as functional ingredients in human diet (Borelli et al., 2004; Mussatto *et al.,* 2011c; Zuorro and Lavecchia, 2012; Xu *et al*., 2015). Thus, it was demonstrated the SCG antioxidant, antihypertensive and antimicrobial activities in intestine microbiota (Campos-Vega *et al*., 2015a), with an important role in preventing diseases related to free radicals (Wang *et al*., 2011). Phytochemicals from SCG can be digested, absorbed and fermented in colon, exerting healthy effects by influencing the metabolic activity of the microbiota (López-Barrera *et al*., 2016). SCG phenolic extracts can also be used as anti-inflammatory additives (Lopez-Barrera *et al*., 2016) and dermatological antimelanogenesis agents (Huang *et al*., 2016). Regarding extracting of natural antioxidants and caffeine from SCG, there were proposed different methods, such as solid-liquid extraction using aqueous alcohol solution (methanol, ethanol and isopropanol) (Mata *et al*., 2018) or by pressurized liquid extraction (PLE) method with water and ethanol (Shang *et al*., 2017).

Other potential use of SCG is obtaining of valuable bio-sugars, such as oligosaccharides, manno-oligosaccharides and mannose, after its delignification and defatting, process which proved large-scale feasibility (Nguyen *et al*., 2019). Peshev *et al*. (2018) revealed utilization of SCG for obtaining water extracts with sufficiently high caffeine concentration. Appliance of nano filtration to these extracts, by using a suitable membrane, conducted to valuable products, as permeate and retentate fractions. Permeate can be further used for soft and energy drinks, while retentate for coffee drink or as functional food ingredient.

3.10. Value added products from fish wastes and byproducts

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 emulsifier (Cristian *et al.*, 2018). These wastes can be valorized by obtaining fish oil with high content of long-chain omega-3 polyunsaturated fatty acids (PUFAs). This oil can enrich a wide range of dairy and non-dairy foods (Ilyasoglu & El, 2014). Fish protein contains many bioactive peptides that are easily absorbed and can be used as a functional ingredient in bakery products, soups, and infant formulas (Atef & Mahdi Ojagh, 2017). The cooking effluents generated by snow crab processing facilities, usually considered as waste, can be concentrated, and turned into a natural aroma for the food industry (Tremblay et al., 2020). 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 to meet their requirement for protein supplement.

Fish waste are used to substitute for protein in animal feed. This is done by drying the waste, it could be traditionally by sun light, or baked or dehydrated. After proper drying, it is crushed into power which is then incorporated into the other components of the feed, mostly maize, rize brand and soybeans.

3.11. Value added products from Aframomum meleguta (alligator pepper) wastes and byproducts

Alligator pepper (Aframomum meleguta) otherwise known as grains of paradise is a perennial deciduous herb of the Zingiberaceae family of plants native to the swampy areas on the West African coasts. Others in that family include A. danielli, A. citratum and A. exscapum. Widely known for its hot, spicy, and aromatic seeds, it is also called as mbongo spice, Afrika kakulesi, or Guinea pepper in some parts of Africa. (Desai *et al*., 2013).

Alligator pepper seeds have been known for ages among spices and ingredients for different African tradomedicinal and socio-cultural applications in many parts of Africa and some parts of Asia. (Anupam *et al*., 2018). It is widely documented as an antidote for some ailments in human health such as body pains, diarrhea, sore throat, catarrh and rheumatism. Based on current research, different parts of the plant possess specific secondary metabolites such as flavonoids, phenolic compounds, alkaloids, tannins, terpenoids, saponins, and cardiac glycosides that have healing potential and medicinal and therapeutic purposes. In addition, Ethanol extracts from the seeds indicated antibacterial and antiseptic properties found useful for wound-care and antidote for certain infections (Okwu 2004). The active compounds found in alligator pepper are in the class of naturally occurring food preservatives. In some traditional African meetings and events like naming ceremonies, marriages and funeral, it is snacked upon with bitter kola and kola nuts in customary rites. Apart from its medicinal applications, Sunil et al. (2018), documented that alligator pepper seeds contain few calories of energy and substantial amount of iron, magnesium, and calcium (Yashin *et al*.,2017). Okunade et al. (2019), reported that it contains 7.5, 4.78, 2.84, and 13.01 g/100 g dry matter of fat, crude fibre, ash, and protein, respectively. It is therefore no surprise that alligator pepper also has culinary applications as ingredient in assorted dishes such as pepper soup and barbecues. Its essential oil has been documented as having pharmaceutical and industrial applications in flavors and perfumery. The pulp and peels of this wild fruit can be used to produce pectin which can be used in the food industry as a gelling agent.

4. CHALLENGES IN AGRO-FOOD WASTE AND BY-PRODUCT VALORIZATION IN CAMEROON

The industrial recovery of valuable compounds from food by-products is a story that started few years ago. Nowadays, at least 50 companies around the world recover valuable compounds from food waste and sell them as clean-label ingredients for processed food products (e.g., natural preservatives to maintain shelf-life requirements, functional compounds), without impacting flavor or texture (Galanakis *et al*., 2016). These commercially available applications inspired the scientific community to intensify its efforts for the valorization of all kinds of food by-products for recovery purposes. However, the industrialization of such processes and the implementation of the “Universal Recovery Strategy” is not an easy task. It typically includes laboratory research, transfer to pilot plan and full-scale production, protection of intellectual properties, development of definite applications and commercialization problems. For example, waste emerges seasonally and often in large quantities, whereas it is prone to microbial spoilage. Proper management of collection processes, cooling of the material and addition of preservatives can provide solutions.

Other problems such as the broad content of wasted by-products may be modified by adding a pretreatment step. Besides, transition of batch to continuous processes is usually accompanied with extension of mixing and heating time, heavier handling, increased air incorporation and higher degree of scrutiny. Subsequently, process cost is increased, as industrially recovered compounds are used in food formulations in higher concentrations compared to laboratory-recovered compounds. Therefore, solving these issues are necessary in order to ensure the sustainability of the process, the economic benefit and the perpetual establishment of the derived products in the market (Galanakis *et al.*, 2016).

A commercially feasible product can be generated only if a certain degree of flexibility and alternative solutions can be adapted in the developing methodology, e.g., less extraction steps are cheaper and scale up easier. However, they generate cruder products with lower concentrations of target compounds; thus it is recommended to use nonthermal technologies, green solvents and safer materials (possessing GRAS-status) to improve efficiency and clarification of the final product. The development of precise applications for well-defined markets is also very important (Galanakis, 2012). For example, natural antioxidants like polyphenols to be used in fresh, mom-approved and kid-friendly foods with clean ingredient lines and a minimum of three-month refrigerated shelf-life. Besides, modern new products should aim at the fulfillment of consumer needs and the realization of consumer value rather than at the development of products or enabling technologies per se. This means that the developed products should meet the high expectations of the consumers in an increasingly competitive market, e.g., development of “green” “organic” and “Protected Designation of Origin” products. Unlike the needs to delight the consumer and minimize environmental impact, developers should also ensure that the final product and process meet particular specifications, e.g., provide clean-label ingredients without impacting flavor or texture. Currently, the manufacturer’s label typically provides only limited information about the origin and composition of the used extract in the final product formulation. A clearer label of the products containing recovered compounds would enable nutritionists and/or pharmacists to be more confident when recommending these products.

In addition, legal authorities regulate the way in which companies can advertise health benefits. However, those regulations (driven by the need of protecting consumers from dubious claims) create implications for the food industry. This is mainly because the demonstration of health benefits is very costly (constituting a high cost especially to small and medium-sized companies) and the risk of claims rejection by the corresponding authorities is too high. So far, only a small number of compounds and products have been approved, whereas the overwhelming majority of health claims has been declined by regulatory bodies (Galanakis et al., 2015c). The legislation challenges regulating health beneficial dietary products are lying to the nature of the products, which have the characteristics of both food and biologically active ingredients. For instance, EFSA of EU has approved health claims for only a small number of compounds (e.g., hydroxytyrosol in olive oil) (Galanakis *et al*.,, 2016). This means that if you recover hydroxytyrosol from OMW in order to fortify foods (e.g., bakery, meat products or even oils), it is not allowed to add the health claim on the label.

Considering all the above innovation challenges, it can be concluded that food waste recovery may be an interesting but difficult to implement opportunity for food companies (compared to food waste valorization for nonfood applications). Decision upon recovery or valorization strategy should always be taken account in relation to the substrate and industry’s goals.

5. CONCLUSION

To solve the future and current problems of the global environment issue, conversion of food waste into environmentally friendly product through conversion to value added products is mandatory and timely. The wastes and residues from agriculture and related food processing wastes that cause pollution problems threatening human and environmental health could be used to produce a valuable product like pectin, animal feed, essential oil and others but this remains a principal challenge to the economy of Cameroon. To address such challenges, implementing concepts in the food industry plan for the valorization of food waste will create added- value and innovation for various industrial sectors. 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. Local educational campaigns should be set up to educate the community on how to make proper use of their bio waste materials.

COMPETING INTERESTS DISCLAIMER:

Authors have declared that no competing interests exist. The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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