A REVIEW ON THE UNTAPPED POTENTIAL OF AGRO-INDUSTRIAL WASTES IN DEVELOPING COUNTRIES: A CASE STUDY OF NIGERIA

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Abstract: Food waste results from processing organic raw materials to foodstuffs, which is typically effected by the extraction or separation of the nutritionally valuable portion of the raw materials. Product-specific waste unavoidably accumulates as a result of processing raw materials. It is produced during the various steps of production, in which the desired components are extracted from the raw materials. After extraction there are still other potentially useful components present in the remaining materials. Principles of agro industrial waste conversions were identified to include compositing, anaerobic digestion, solid state fermentation and delignification. The potentials of agro industrial waste particularly in a developing country like Nigeria were highlighted including utilization of waste from milk and dairy industry, fruits and vegetable, oil seeds, brewery and cereals and legumes based industries. Important products that could be obtained include lactose, ethanol, lactic acid, dietary fiber, carotenoid, pectin, lycopene, protein concentrates/isolates, colorant, antioxidants, yeast and biogas. Agro-industrial by-products thereforeshould not be considered as wastes but as raw materials to develop new products of high quality.

Keywords: Untapped potentials, agro-industrial wastes, developing country, Nigeria.

Introduction

Waste is defined as any material which has not been utilized; i.e. the left-over from production and consumption. These include agricultural, industrial, municipal wastes and residues (Vidhyalakshmi, 2012). The fact that these substances are removed from the production process as undesirable ingredients makes them, by definition of most European legislations, wastes (Oreopoulou & Russ, 2007). The term ‘‘by-product,’’ which is common in industry, infers that these are mostly ulterior usable substances, often with a market value (Oreopoulou & Russ, 2007).

Food waste results from processing organic raw materials to foodstuffs, which is typically effected by the extraction or separation of the nutritionally valuable portion of the raw materials (Russ & Schnappinger, 2007). The unused remains primarily consist of organic material; however, further utilizationas food source is limited, because it possesses little nutritional value or contains inedible components (Ha *et al*., 2014). Product-specific waste unavoidably accumulates as a result of processing raw materials (Russ & Schnappinger, 2007). It is produced during the various steps of production, in which the desired components are extracted from the raw materials. After extraction there are still often other potentially useful components present in the remaining materials (Gustavsson *et al*., 2011).

Waste in the food industry is characterized by a high ratio of product-specific waste. This not only means that the generation of this waste is unavoidable, but also that the amount and kind of waste produced, which consists primarily of the organic residue of processed raw materials, can scarcely be altered if the quality of the finished product is to remain consistent (Risse, 2003). The utilization and disposal of product specific waste is difficult, due to its inadequate biological stability, pathogenic nature, high water content, potential for rapid autoxidation, as well as high level of enzymatic activity (Russ & Schnappinger, 2007). The diverse types of waste generated by various branches of the food industry can be quantified based upon each branches’ respective level of production. Wastes from food processing industry have: large amounts of organic materials such as proteins, carbohydrates and lipids; varying amounts of suspended solids depending on the source and high biochemical oxygen demand (BOD) or chemical oxygen demand (COD) (Risse, 2003).

Food industry produces large volumes of wastes, both solids and liquid, resulting from the production, preparation and consumption of food. These wastes pose increasing disposal and potential severe pollution problems and represent a loss of valuable biomass and nutrients (Gekas & Nikolopoulou, 2007). Food wastes also contribute wholly or partly to water pollution, poor working condition and hence, unhealthy workforce and food spoilage (USAID, 2009). These can lead to increased costs for labour and sometimes fees for waste disposal (Pap *et al*., 2004). In addition, high volumes of burden some waste, whether placed in a landfill or treated and disposed off, may place a serious strain on limited land resources (Pap *et al*., 2004).Several waste management approaches have been reported. These include: disposal; reduction at source and zero-point discharge (Gekas & Nikolopoulou, 2007). Waste disposal is one of the major problems facing most food processing plants. New kinds of process engineering and resultant new products and markets make the utilization of waste increasingly interesting (Oreopoulou & Russ, 2007). The magic word expressing the peculiarity of food wastes is ‘‘recovery.’’ Agro-industrial by-products should not be considered as wastes but as raw materials to develop new products of high quality (Gekas & Nikolopoulou, 2007).

Food wastes and agro-industrial by-products are heterogeneous in nature. The bulk of the wastes are not suitable for food and fodder as they are too fibrous to be digested by man and many animals, respectively (Ha *et al.*, 2014). These substances which contains 3-70% carbohydrates of various forms and proportions can be treated chemically, physically and biologically to improve their utilizations for man and animals (Fillaudeau *et al.*, 2006). This paper therefore reviews utilization of various by-products from food and agriculture sectors in Nigeria.

Agro-industrial Wastes in Nigeria

Nigeria is the most populous country in Africa, with a population of over 150 millionpeople (Taiwo *et al*., 2012). It has an area of 923,768 km^2, and located between Latitudes 4° 16' N and 13° 52' N, and Longitudes 2° 49' E and 14° 37 'E. It is stretched across dimensions of 1,200 km from east to west and 1,000 km from northto south (Taiwo *et al*., 2012). Its domestic economy is dominated by agriculture, which accounts for about 40% of the Gross Domestic Product (GDP) and two-thirds of the labour force. Agriculture supplies food, raw materials and generates household income for the majority of the people (Akande, 2015). The external sector is dominated by petroleum, which generates about 95% of Nigeria's foreign exchange earnings while agriculture contributes less than 5%. Trade imports are dominated by capital foods, raw materials and food. Nigeria is currently preoccupied with the challenge of diversifying the structure of its economy (Adeyinka *et al*., 2005)

The food sub-sector of Nigerian agriculture parades a large array of staple crops, made possible by the diversity of agro-ecological production systems. The major food crops are: cereals - sorghum, maize, millet, rice, wheat; tubers-yam, cassava; legumes - groundnut, cowpeas and fruits and vegetables (Akande, 2015). Agro-industry particularly the food industry generates large amount of solid wastes which emerge mainly from processing operations. The composition and quantity of agro-industrial wastes depend on the raw materials as well as the nature of finished products, operations and processing steps (Prasertsan *et al*., 2014). Agro-industrial wastes derived from agricultural activities include materials such as straw, stem, stalk, leaves, husk, shell, peel, lint, seed/stones, pulp or stubble from fruits, legumesor cereals (rice, maize, sorghum etc.), bagasses generated from sugarcane, sorghum milling, spent coffee grounds, brewer's spent grains, and many others. These wastes are generated in large amounts throughout the year, and are the most abundant renewable resources on earth (Shilev *et al*., 2007). They are mainly composed of sugars, fibres, proteins, and minerals, which are compounds of industrial interest. Due to the availability of rich compounds that could be used in other processes, there is a great intereston the reuse of these wastes, both from economical and environmental view points.

The economical aspect is based on the fact that such wastes may be used as low-cost raw materials for the production of other value-added compounds, with the expectancy of reducing the production costs. The environmental concern is because most of the agro-industrial wastes contain phenolic compounds and/or other compounds of toxic potential; which may cause deterioration of the environment when the waste is discharged to the nature. Large amount of the agro-industrial wastes are mainly composed by cellulose, hemicelluloses and lignin, collectively called "lignocellulosic materials". In the lignocellulosic materials, thesethree fractions are closely associated with each other constituting the cellular complex of the vegetal biomass, and forming acomplex structure that act as a protective barrier to cell destruction by bacteria and fungi. Basically, cellulose forms a skeleton which is surrounded by hemicellulose and lignin (Shilev *et al*., 2007).

Livestock is other important part of agriculture. The industrial livestock complex is an artificial ecological system. The amount of wastes from livestock and especially of liquid manure is quite large. Liquid manure contains different microorganisms that are dangerous to humans as well asanimals. On the otherhand, the manure has high energy potential and it is significant source ofrenewable energy (Shilev *et al*., 2007).

Principles of Agro-industrial Waste Conversion

Composting

The term ''composting'' is used here to define the process of controlled biological maturity under aerobic conditions, where organic matter of animal or plantorigin is decomposed to materials with shorter molecular chains which is more stable, hygienic, humus rich and finally beneficial for the agricultural crops and for recycling of soil organic matter (Sequi, 1996). The process is mediated by different microorganisms actuating in aerobic environment: bacteria, fungi, *Actinomycetes*, algae, and protozoa, participate spontaneously in the organic biomass or are added artificially (Tuomela *et al*., 2000). The process can be described by the follow equation:

Organic matter + O_2 $\rightarrow$ Compost + CO_2 + H_2O + NO_3^- + SO_4^{2-} + heat (Shilev *et al*., 2007)

The interest regarding composting process is related to the following points:

1. Environmental point of view, because during this process the biomasses aretransformed to material rich in nutritional substances that can improve thestructural characteristics of the soil (Sommer & Dahl, 1999).
2. Hygienic point of view, because during the process the organic matter is disinfected by the influence of the high temperatures (Dumontet *et al*., 1999).
3. Energy management point of view, because during the process energy isreleased through the degradation of large organic molecules (Schaik *et al*., 2000; Sonesson *et al*., 2000).

The term ''composting'' is usually used for thedescription of aerobic stabilization of the organic matter (solid wastes), obtained without separation of different fractions (Sequi, 1996; Tuomela, 2002). Compost offers many benefits to the landscape and garden. For example, compost improves soil tilth condition and structure; increases the soil's ability to hold water and nutrients; supports living soil organisms; helps to dissolve mineral forms of nutrients; buffers soil from chemical imbalances; may provide biological control of certain soil pests; and helps to return organic materials tothe soil and keeps them out of landfills and waterways. Compost can be used asa mulch, a liquid fertilizer, or incorporated into the soil. Because it has high moisture contentand low physical structure, it is important to mix fresh food waste with a bulking agent that will absorb some of the excess moisture as well as add structure to themix. Bulking agents with a high C:N ratio, such as sawdust aregood choices. Shilev *et al*. (2007) highlighted the benefits of compost to the food industry as follows:

1. Reduces solid waste disposal fees.
2. Ends wasting large quantities of recyclable raw ingredients.
3. Makesthe establishment to be environmentally conscious.
4. Makesthe establishment as one that assists local farmers and the community
5. Helps close the food waste loop by returning it back to agriculture.
6. Reduces the need for more landfill space

Anaerobic digestion

Anaerobic microbial conversion of organic matter into a renewable energy source, so-called biogas, is a well-established process and state of the art. New techniques and technologies offer possibilities to treat pasty and solid organic wastes by meansof anaerobic digestion (AD) as well as liquids (Pesta, 2007).The primary aim of AD depicts a single substrate treatment, mainly animal manuresat agricultural biogas plants for producing biogas and supplying a well-balanced liquid fertilizer. Further traditional applications are municipal wastewater treatment plants, where surplus sewage sludge is stabilized by using an AD process as wellas industrial plants, pretreating organically high-loaded wastewaters (Pesta & Meyer-Pittroff, 2005).

In recent times, AD has offered an alternative treatment for a wide range of substrates ofboth agricultural and industrial origin. Basically, any liquid or solid organic wastesfrom food/agricultural industry or municipal waste collections, like whey, slaughter house wastes, flotation fat, manure and energy crops can be utilizedfor AD (Pesta, 2007). The degradation of substrate by anaerobic bacteria takes place within two mainphases: hydrolysis (decomposing of organic material) and methanogenesis (production of biogas). The degree of degradation as well as biogas quality can be affected in various ways by technological and procedural measures (Pesta & Meyer-Pittroff, 2005). As a result of the anaerobic digestion process, biogas is produced. Biogas is amixture of methane (CH_4, 50–85% by volume), carbondioxide (CO_2, 15–50% by volume), and trace gases, e.g. water (H_2O), hydrogen sulfide (H_2S), or hydrogen (H_2). Although small concentrations of these trace gases have little effect on thephysical properties of biogas, they influence the selection of technologies forcleaning and utilizing biogas. At least dewatering and the removal of H_2S are necessary before biogas is utilizable (Mata-Alvarez *et al*., 2000).

The benefits of anaerobic digestion are obviously and mainly economical, and to a lesser extent technological and ecological, such as dilution of potential toxic compounds, improved balance of nutrients, synergistic effects of microorganisms, increased load of biodegradable organic matter, and better biogas yield. There are additional advantages including hygienic stabilization, increased digestion rate when the process occurs under thermophilic conditions (Sosnowski *et al*., 2003).

Solid state fermentation

Solid substrate fermentation (SSF) has been exploited for the production of value-added products (antibiotics, alkaloids, plant growth factors, etc), biofuel, enzymes, organic acids, aroma compounds for bioremediation of hazardous compounds, biological detoxification of agro-industrial residues, nutritional enrichment, bio-pulping, biopharmaceutical products, etc. (Perez-Guerra *et al*., 2003). This technology has gained renewed attention from industry because it has become a more attractive alternative to liquid fermentation for many productions because SSF was found to produce a more stable product, with lessenergy requirements, in smaller fermenters and smaller volumes of polluting effluents (Perez-Guerra *et al*., 2003).

Substrates that have been traditionally fermented by solid-state include a variety of agricultural products such as rice, wheat, millet barley, grains, beans, corn and soybeans. However, non-traditional substrates which may also be of interest in industrial process development include an abundant supply of agricultural, forest and food-processing wastes such as wheat bran and soy flakes (Perez-Guerra *et al*., 2003). The ability of microorganisms to grow on a solid substrate is a function of their requirements of water activity, their capacity of adherence and penetration into the substrate; and their ability to assimilate mixtures of different polysaccharides due to the complex nature of the substrates used.

The filamentous fungi are the best-adapted microorganisms for SSF owing to their physiological, enzymological and biochemical properties. The hyphal mode of fungal growth gives the filamentous fungi the power to penetrate into the solid substrates. This also gives them a major advantage over unicellular microorganisms for the colonisation of the substrate and the utilization of the available nutrients. In addition, their ability to grow at low water activity (*aw*) and high osmotic pressure condition (high nutrient concentration) makes fungi efficient and competitive in natural micro flora for bioconversion of solid substrates (Zheng, 2002). Bacteria and yeasts have also been used in traditional cultivation in SSF processes (Vallejo *et al*., 1999). Bacteria have been used for enzymes production, composting and ensiling (Zheng, 2002). Moulds have been mainly used for ethanol production (Animashaun *et al*., 2013) and protein enrichment of agricultural residue (Ezekiel & Aworh, 2013).

In SSF, two types of process can be distinguished depending on the nature of the solid phase. In the first and the most used, the solid serves both as a support and a nutrient source. These substrates are heterogeneous water insoluble materials from agriculture or by-products from food industry, which have an amylaceous or ligno-cellulosic nature (grains and grain by-products, cassava, potato, beans and sugar beet pulp) (Perez-Guerra *et al*., 2003). In the second, an inert support (sugar cane bagasse, hemp, inert fibres, resins, polyurethane foam and vermiculite) is impregnated with a liquid medium, which contains all the nutrients (sugars, lipids, organic acids, etc). The use of a defined liquid medium and an inert support with a homogenous physical structure aids controlling and monitoring of the process; and the reproducibility of fermentations (Perez-Guerra *et al*., 2003). In both cases, the success of the process is directly related to the physical characteristics of the support, which favour both gases and nutrients diffusion and the anchorage of the microorganisms (Zheng, 2002).

From a practical point of view, the following physical characteristics of the solid matrix must be taken into account because of their influence on the development of SSF: particle size and shape, porosity and consistency of the material (Robinson & Nigam, 2003). SSF has been used for the production of high added value compounds (such as enzymes, organic acids, biopesticides, biofuel and flavours). In recent times, new applications of SSF in the environmental control have been developed including bioremediation and biodegradation of hazardous compounds and the detoxification of agro-industrial residues (Robinson & Nigam, 2003; Ezekiel & Aworh, 2013).

Delignification

The structural carbohydrates in the plant cell wall are wrapped up inlignin, which is an inert polymer that protects the plant and consequently constitutes an important barrier to fermentation. Therefore, a very effective wayto significantly increase biomass digestibility is lignin degradation or separation (delignification). The operation is aimed to increase the digestibility of constituent sugarsthrough increase in gross material pore size (Sierra *et al*., 2008). It is challenging due to the recalcitrance of lignin and may require expensive chemicals and relatively high temperatures and pressures for acceptable reaction rates. Otherwise, at mild conditions (i.e.use of microorganisms or purified enzymes), it takes long time. Other ways to increase lignocelluloses digestibility include partial to total solubilization of hemicelluloses, and separation of acetyl groups that link hemicellulose and lignin (Zhu *et al*., 2008).

Chemical separation of lignin and carbohydrates can be achieved through the use of acids, alkalis, and solvents, which promote selective solubilisation of either component (Mosier *et al*., 2005). Chemical processes may not be as selective as biological processes but may represent advantages related to required time, scalability, and process control (Zhao *et al*., 2009).

Biological delignification can be conducted using either microorganism, which produce a set of enzymes that work synergistically. The most widely used microorganisms are fungi from the *Basidiomysetes* family. Nevertheless, bacteria from *Pseudomonas*, *Flavobacteria*, *Xanthomonas*, *Bacillus*, *Aeromonas* and *Cellulomonas* strains can also decompose lignin and its derivatives. Biological lignin degradation can be conducted by culturing the microorganism in submerged, semisolid or solid cultures where enzymes such as lignin peroxidase, xylanase, lactase, and manganese peroxidase (among others) perform selective lignin degradation (Sanchez *et al*., 2011).

Potentials of Agro-indusrial Wastes

Utilization of whey from milk

Whey is a by-product in milk processing, the world production amounts to about 82 million metric tons, and especially the acid whey is seen as a waste product. Ingeneral three types of whey have to be differed: sweet, acid, and casein whey (Pesta *et al*., 2007). Without regard to its origin, the main component of whey is the carbohydrate lactose. The amount oflactose exceeds 70% of total dry matter (DM). Proteins and inorganic substances (ash) follow with differing weight proportions (Pesta *et al*., 2007). Whey may be separated by means of ultrafiltration or reversed osmosis into its maincomponents: protein, lactose, and delactosed permeate (DLP). Whey with an averagedry matter of 6% is first deproteinized and whey protein concentrate (WPC) is sold. Furthermore, the deproteinized permeate is concentrated to a dry matter ofabout 60%, followed by a crystallization of the lactose (Pesta *et al*., 2007).

The production of ethanol is considered to be a feasible technique to enhance theprofit from the by-products of whey treatment and can be used for production of spiritsor liquid fuels. Ethanol production can be performed either as a fermentation withor without enzymatic pretreatment. Many of the microorganisms are not capableof direct converting lactose to ethanol, thus enzymatic pretreatment with ß-galactosidase is required. The fermentation is feasible with *Aspergillus niger* ata pH between 3.5 and 4.5 or *Streptococcus lactis* at a higher pH level ranging from 6 to 7 (Fischbach, 1987).

The anaerobic fermentation of whey with lactic acid bacteria for the production oflactic acid is feasible but probably not profitable (Fischbach, 1987). The worldwideneed is only approximately 20,000,000 – 25,000,000 kg/annum. Lactic acid is produced by homofermentative lactic acid bacteria such as *Lactobacillus bulgaricus* or *Lactobacillus plantarum* (Sanderson and Reed, 1985). Lactic acid is separated from the fermented solution by electro-dialysis after neutralization with $Ca(OH)_2$ or $CaCO_3$ (Sanderson & Reed, 1985; Moebus & Teuber, 1986;).

Experimental feeding of ruminants has shown that 27% of total nitrogen of the feed can be replaced by nitrogen of fermented whey containing ammonium lactate (Moebus & Teuber, 1986). For the production of ammonium lactate, whey or permeate are fermented under anaerobic conditions with *Lactobacillusbulgaricus*. The reaction broth is continuously neutralized with ammonia, resulting in fermented ammoniated condensed whey (Zadow, 1988).

Industrial microbial biomass (single cell protein) production from cheese whey for use as foodstarted in France (Gonzalez-Siso, 1996). The capacity in 1986 was about 250,000–300,000 kg whey per day (Moebus &Teuber, 1986). An industrial process for producing bakery yeast (*Saccharomyces cerevisiae*) was adopted by the Nutrisearch Company, Cincinnati, Ohio, United States. After enzymatic treatment with immobilized ß-galactosidase, an inoculation with yeast strains that are able to metabolize galactose is required (Gonzalez-Siso, 1996; Zadow, 1988).

Utilization of by-products from fruits and vegetable

Processing of fruits and vegetables results in high amounts of waste materials such as peels, seeds, stones, and oilseed meals (Oreopoulou & Tzia, 2007). It is well known that agro-industrial by-products from fruits and vegetables are rich in dietary fibers, someof which contain appreciable amounts of colorants, antioxidant compounds or other substances with positive health effects. The beneficial role of dietary fibers in reducing risk of coronary heart disease and certain types of cancerhas been pointed out by several epidemiological studies (Oreopoulou & Tzia, 2007). A general flow diagram for the recovery of various dietary components from fruitpeel is presented in Fig. 1. Depending on the fruit, some of the indicated stepsmay be omitted.

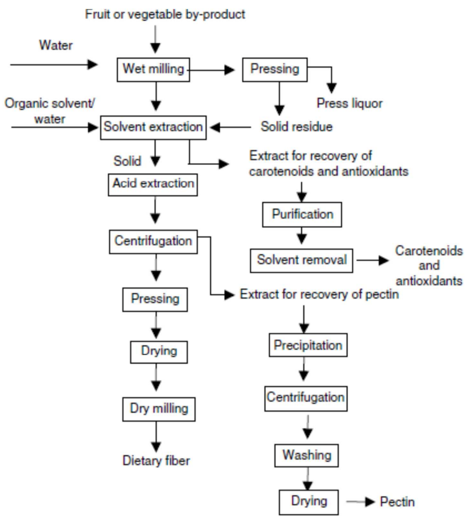

Fig. 1: A general flow diagram for the recovery of various dietary components from fruit peel (Oreopoulou & Tzia, 2007).

Citrus fruits

Citrus is the largest fruit crop worldwide, with approximately 100 million metrictons produced annually (FAO, 2005).Oranges account for 60% of the total citrus production and the major utilization is processing for juice recovery (FAO, 2005). Citruspeel, remaining after juice extraction, is the primary waste fraction, amounting to almost 50% of the fruit mass (Braddock, 1995). It is processed to dried pulp and molasses; the latter being incorporated into cattle feed or fermented forthe production of alcohol or other products. Pectin is also produced from the peel byacid extraction, dietary fibers by mechanical processing, while the recovery of flavonoids and carotenoids are new potential applications (Kimball, 1999). Juice pulp from the finishing process and essences recovered from the juice and the peelpress liquor, amounting to approximately 5% of the fruit mass, also are by-productsthat find industrial utilization. Citrus seeds amount to 0.1–5% of the fruit mass, depending on the variety. They can be used for oil extraction and recovery ofterpenoids, while the meal remaining from the extraction is a good source ofproteins. However, the cost of collecting sufficient quantities of seeds in oneplace limits commercial exploitation (Braddock, 1995).

Plantain

Annual world production of bananas is about 70 million metric tons (FAO, 2005). Cooking bananas (plantains) production approximates 30 million metric tons worldwide (FAO, 2005).Banana peelscomprise 30% of the ripe fruit(Schieber *et al*., 2001).Several attempts for their utilization have beenreported. They include the production of bioprotein, ethanol, and several enzymes (α-amylase, hemicellulases, cellulases). The recovery ofanthocyanins and carotenoids seems promising, according to recent investigations (Pazmino-Duran *et al*., 2001).

Tomato

The world production of tomatoes for processing totaled around 29.6 million metrictons in 1999/2000 (Schieber *et al*., 2001). About 3–7% of the raw material is lost aswaste during processing for tomato juice or similar products. The pomace consists of the crushed skins and seeds of the fruit. It is rich in protein (20–23% on dry basis) and fat (12–18%, mostly located in the seeds), while crudefibers comprise the third main component (12–30%) (Liadakis, 1999). Tomato seedoil has a high content in unsaturated fatty acids, especially linoleic acid; therefore, it is extracted, refined, and used as edible oil or as an ingredient in cosmetics. The defatted material (tomato seed meal) is exploited as animal feed, though protein isolation attracted interest, since protein amounts to 40–55% of the dry mealand presents a high nutritional value (Liadakis *et al*., 1995; Liadakis, 1999). Othervaluable components are carotenoids, especially lycopene, which are principally located in the skins (Baysal *et al.*, 2000).

Utilization of by-products from oilseeds

Oilseeds yield two products: oil, chiefly for human consumption, and meal (cake), which isactually used as animal feed. Soybeans are the major processed crop (around 50% of the total) (Orepopoulou & Tzia, 2007). Oilseed meals come from oil processing after the recovery of the oil by mechanical expression or solvent extraction. Oilseed meals derived after desolventization are significant protein sources due to high protein content, low price, and high availability (Friedman, 1996). The nutritional properties of the oilseed meal proteins are determined by their amino acid composition and they can be converted into edible-grade products. Their utilization in human nutrition is limited because of the presence of phenolic substances, reduced sugars, oreven toxic factors.

Many methods and processes have been developed for the production of protein products by purifying or isolating the proteins from proteinaceous food materials (Lusas *et al*., 1982). More particularly, these processes comprise either proteinpurification by removal of non-protein components or protein recovery by extractionand precipitation. Products deriving from these processes are protein concentratesor protein isolates, respectively (Orepopoulou & Tzia, 2007). The completeutilization of oilseeds as protein sources providing various protein products, whichis industrially applicable, is presented in Fig. 2.

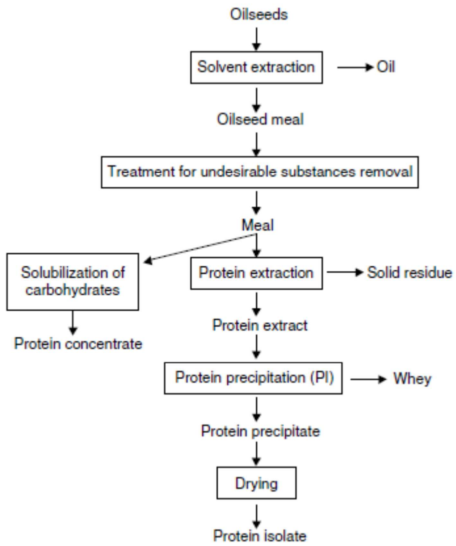

Fig. 2: Complete utilization of oilseeds as protein sources (Considine & Considine, 1982)

Utilization of agro-industrial wastes as functional foods

Antioxidants and colorants have been extensively incorporated as additives into foods to improve their quality. In the past decades, synthetic ingredients have been used, but the toxicity of certain compounds as well as the recentconsumer demand for ‘‘all natural’’ foods has increased the interest of the food industry tothe use ofcompounds of natural origin. Natural colourants and antioxidants are found inmany agro-industrial by-products and their recovery and purification might be abeneficial solution. Moreover, all these compounds impart health benefits, aspointed out by several researchers, therefore, their incorporation into food mayupgrade the latter to functional food, increasing consumer acceptance (Orepopoulou & Tzia, 2007).

Carotenoids and other colorants

Carotenoids can be extracted mainly from carrot pomace, orange peel, and tomatopomace. Organic solvents can be used for the extraction (Orepopoulou & Tzia, 2007) and acetone results in the highest yield compared toethanol, petroleum ether, and hexane (Aravantinos-Zafiris *et al*., 1992). If freshwet raw material is used, initial washing with water removes most free sugarsand other soluble compounds, like flavonoid glycosides, and increases the

purityof the extracts. A sequential washing with acetone removes water and facilitates carotenoid extraction. Successive extractions are needed for quantitative recovery, e.g., two extractions with acetone, at a solvent-to-peel ratio of 2:1 and ambient temperature removes approximately 90% of the total carotenoids from orange peel (Aravantinos-Zafiris *et al*., 1992). Maceration of the raw materialby enzymic preparations increases yield but may affect negatively the quality of pectin (Stoll *et al*., 2003).
The extracted carotenoids may be obtained as a crude pigment, after solvent evaporation at low temperature, if preceding washings were accomplished. Alternatively, a purification step is needed by solvent–solvent transfer to hexane (Aravantinos-Zafiris *et al*., 1992).

Antioxidants

The common plant phenolic antioxidants are to copherols; flavonoids and related compounds like coumarins, cinnamic acid derivatives, and chalcones; phenolicditerpenes; and phenolic acids. They act as free-radical scavengers, retard oxidativerancidity, and thus protect oils, fats, and fat-soluble components and delay thedevelopment of unpleasant flavours and odours resulting from oxidation. By-products like grape skins and seeds (Castillo *et al*., 2000; Louli *et al*., 2004), citrus peel and pulp (Benavente-Garcia *et al*.,1997; Miyake *et al.*, 1997), potato peel waste (Rodrigues de Sotillo *et al*.,1994), onion by-products (Suh *et al.*, 1999; Chu *et al*., 2000), bean hulls (Dur *et al.*, 1997) etc., are rich in compounds with antioxidant activity.

Utilization of by-products from the brewery industry

In the food industry, the brewing sector holds a strategic economic position with the annual world beer production exceeding 1.34 billion litres in2002 (FAO, 2003). Beer is the fifth most consumed beverage in theworld behind tea, carbonates, milk and coffee and itcontinues to be a popular drink with an average consumption of 23 litres/person per year. Thebrewingindustry has an ancient tradition and is still a dynamicsector open to new developments in technology andscientific progress (FAO, 2003).
Spent grains, sludge and yeast surplus represent the major wastes in the brewery (Fillaudeau *et al.*, 2006). The mashing process is one of the initial operations in brewery, rendering the malt and cereal grain content soluble in water. After extraction, the spent grains andwort (water with extracted matter) are called mash andneed to be separated. The amount of solid in the mash is typically 25-30%. At present, spent grains (often mixed with yeast surplus and cold break (trub separation after cooling of wort)) are sold as livestock feed. At the end of the separation process, diatomaceous earth sludge (containing water and organic substances) has more than tripled in weight. From the environmental point of view, the diatomaceous earth is recovered from open-pit mines and constitutes a natural and finite resource. After use, recovery, recycling and disposal of Kieselguhr (after filtration) are a major difficulty due totheir polluting effect. In brewing, surplus yeast is recovered by natural sedimentation at the end of the second fermentation and maturation. Commercial sale of this yeast: can be madeto the animal feed industry. This brewing by-product has dry matter content close to 10% w/w and generates beer losses (or waste) of between 1.5 and 3% of the totalvolume of produced beer (Fillaudeau *et al*., 2006). Many wastes from the brewery can serve as substrates for the production of valuable products such as enzymes, metabolites and biogas using appropriate technologies (Prasertsan *et al*., 2014).

Utilization of By-Products from Cereals

The proportion of straw or stover to grain varies from one crop to another and according to yield level. The yield is a function of total biomass and the harvest index (the grain to straw ratio). A harvest index of 0.5 indicates that the biomass produced comprises 50 per cent grain and 50 per centstraw. Lower harvest index means higher proportions of straw (Shaban *et al*., 2010). Crop residues are organic and biodegradable. Utilization technology musteither use the residues rapidly, or the residues must bestored under conditions that do not cause spoilage orrender the residues unsuitable for processing to the desired end product (Shaban *et al*., 2010).
Many cropresidues have been used directly as animal feed (Ha *et al*., 2014), however many of these residues are not readily digestible by animals. Transforming wastes into animal foodstuffs would help in a greater deal in overcoming this deficiency. This is because the sewastes have a high content of fiber, low protein, starch and fat that make them not easily digestible and thesize of the waste in its natural form might be too bigor tough for the animals to eat. To overcome these two problems several methods have been used to transform the agricultural waste into a more edible form with ahigher nutritional value and better digestibility (El-Haggar *et al*., 2004).
Mechanical and chemical treatment methods are used to transform the shape of the roughage (waste) into an edible form. The chemical treatment method with urea or ammonia is more feasible than the mechanical treatment method. It is recommended to cover the treated waste with a wrapping material usually made of polyethylene (2 mm thickness). After 2 - 3 weeks, the treated waste is uncovered and left for 2-3 days to release all the remains of ammonia before use as ananimal food (El-Haggar *et al.*, 2004). On the other hand, rice straw is highin lignin and silica (Shaban *et al*., 2010). Both of these components play an important role in reducing the digestibility of straw. Digestibility of the nutrients of rice straw can be improved by ammoniation using urea or anhydrous ammonia. When urea is used in the wetensiling system, the usually recommended level is 4 kg urea per 100 kg air-dried straw. In addition, response to ammoniation has two components: an increase in digestibility due to partial specification of the lignin-cellulose-/hemi-cellulose linkages and a greater feed intake arising from the greater supply of ammonia to the rumen microorganisms. The feeding of molasses-urea blocks is anotherrelated technology widely used for improving animal performance on fibrous crop residues bringing about increases in feed intake and also in digestibility (Xuan *et al*., 1992). Pre-treatment with a source of ammonia such asurea or ammonium bicarbonate can greatly enhance both the intake and digestibility of straw, and will improve the productive performance of the animals (Liu, 1995).

Conclusion

Agro-industry particularly the food industry generates large amount of solid wastes which emerge mainly from processing operations. The composition and quantity of agro-industrial wastes depend on the raw materials as well as the nature of finished products, operations and processing steps. Agro-industrial wastes derived from agricultural activities include materials such as straw, stem, stalk, leaves, husk, shell, peel, lint, seed/stones, pulp or stubble from fruits, legumes or cereals (rice, maize, sorghum etc.), bagasses generated from sugarcane, sorghum milling, spent coffee grounds, brewer's spent grains, and many others. These wastes are generated in large amounts throughout the year, and are the most abundant renewable resources on earth. They are mainly composed of sugars, fibres, proteins, and minerals, which are compounds of industrial interest. Appropriate application of agro industrial waste conversion techniques: compositing, anaerobic digestion, solid state fermentation and delignification will create raw material for secondary industries and will also greatly improve the recovery of some valuables that are usually lost; and also create a safe and less hazardous environment.

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