

35) FOOD WASTES

Food processing wastes are those end products of various food processing industries that have not been recycled or used for other purposes. They are the non-product flows of raw materials whose economic values are less than the cost of collection and recovery for reuse; and therefore discarded as wastes. These wastes could be considered valuable by-products if there were appropriate technical means and if the value of the subsequent products were to exceed the cost of reprocessing.

Residues in this case cannot be regarded as wastes but become an additional resource to augment existing natural materials. Recycling, reprocessing and eventual utilization of food processing residues offer potential of returning these by-products to beneficial uses rather than their discharge to the environment which cause detrimental environmental effects. Successful food waste reprocessing involves (a) rendering recovered by-products suitable for beneficial use, (b) promoting marketability to ensure profitable operating, (c) employing reprocessing technology, and (d) creating an overall enterprise that is acceptable and economically feasible.

If effective utilization of food residues is to occur, food manufacturers should invest in specialized secondary industry to utilize the residues. Efforts are needed to develop new technologies and to institute suitable measures to promote waste reclamation; this can only be achieved if food residues are considered as complementary resources rather than as undesirable wastes.

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. Besides their pollution and hazard aspects, in many cases, food processing wastes might have a potential for conversion into useful products of higher value as by-product, or even as raw material for other industries, or for use as food or feed after biological treatment.

The composition of wastes emerging from food processing factories is extremely varied and depends on both the nature of the product and the production technique employed. For example, wastes from meat processing plants will contain a high fat and protein content, whilst waste from the canning industry will contain high concentrations of sugar and starches. Also, the waste may not only differ from site to site but also vary from one time of the year to another. Furthermore, the volume and concentration of the waste material will not be constant. This may cause some problems in managing a consistent working process due to fluctuations in the nature, composition and quantity of raw materials.

In general wastes from the food processing industry have the following characteristics (Litchfield, 1987):

1. Large amounts of organic materials such as proteins, carbohydrates and lipids
2. Varying amounts of suspended solids depending on the source
3. High biochemical oxygen demand (BOD) or chemical oxygen demand (COD)

In addition to food wastes, food industry also uses a large amount of water. A proportion of water used may leave as part of the products, for example in beer, but much of it is discharged

as effluent in a dirtier state than it entered. A large volume is discharged to surface waters, where the substances it contains may cause pollution.

UTILIZATION OF SELECTED FOOD WASTES

Dairy industry:

Dairy processing generates heavy loads of polluted effluents, which contain dilutions of whole milk, separated milk, whey and sanitizers used in the clean-in-place (CIP) system. Drippings from packaging process and accidental leaks as well as CIP water find their way into the sewer system. Yoghurt processing involves heating milk, addition starter and sodium stearate to improve consistency followed by incubation. White cheese processing consists of mixing skimmed and dry milk, heating, addition of salts and rennet; the mixture is left for separation. In the past, the separated whey was being discharged to the sewerage without pretreatment, thereby increasing production losses and aggravating pollution problems. In today's milk processing plants, the whey is being recovered and the dried whey is blended with basic food materials to produce less expensive foods such as fruit based beverages, custards and bakery goods. Reverse osmosis has been applied on a limited scale to produce a protein supplement; the technical and economical aspects of full-scale application of this advanced treatment remain to be evaluated in depth.

Being a major by-product of cheese production, whey is defined as the serum or watery part of milk remaining after separation of the curd that results from the coagulation of milk by acid or proteolytic enzymes. It is generated at a rate of about 9 kg for every 1 kg of cheese. Discharging of whey as waste creates severe pollution problems due to its high BOD (35-40 g/l). This high BOD is due mainly to the lactose, which is present at concentrations between 4.5-5 %. Although whey is utilised and converted to valuable products by the big factories, it is estimated that there are still some losses in the small factories.

Some researches have been done for utilisation of whey such as the production of single cell protein, concentrates and different food products such as: alcoholic and non-alcoholic beverages produced from whey, addition of whey to bakery products, enrichment of milk by whey proteins. Whey is used in different ways and can be classified in three categories:

1. Fermentation: production of ethyl alcohol, lactic acids, vitamins
2. Concentration: whey protein, dried whey, production of lactose
3. Pasteurisation: whey cream and pasteurised sweet whey

Membrane filtration techniques are used in milk processing and can be defined as the separation of two or more compounds from a fluid stream. Ultrafiltration (UF) is generally used for whey utilisation to separate the proteins from the permeate containing mostly lactose. Recovery of sugars, proteins and minerals in the waste effluents by crystallisation, evaporation and spray drying are practised in many dairy plants. However, the increased cost has made many of these operations economically unattractive. Applications of UF and RO for concentrating the whey solids have gained an importance. Whey protein concentrate is an item of worldwide commerce due to its nutritious composition (Table 2).

Production of biomass:

It is one of the major implications of biotechnology to food waste utilisation. In general, the composition of food wastes is such that they are suitable as growth media for micro

organisms. Biomass, or single cell protein (SCP), is the name given to the total dry matter of bacteria, yeast, moulds and higher fungi when used for animal feed or human food. The use in feed is related primarily to considerations of nutritional value and balance of the ingredients, whilst the level of utilisation in food is certainly limited by the concentration of nucleic acid in the final product. Regarding liquid wastes of an appropriate chemical composition, large quantities are produced in the food processing industry to be used as substrate for microbiological fermentations.

Table 2. Composition of whey

<u>Substances</u>	<u>Amounts</u>
Lactose	5%
Salt	7.5%
Total carbohydrate	5%
Protein	0.85%
Oil	0.3%
Ash	0.3%
Riboflavin	0.10mg/100 ml
Niacin	0.10 mg/100 ml
Fe	0.12 mg/100 ml
Na	14.5 mg/100ml
K	30 mg/100 ml
Ca	13.5 mg/100 ml
Water	92%
pH	5.5

Fruits and vegetables:

Large amounts of fruit and vegetable processing wastes are produced from packing plants, canneries, etc., which may be disposed in several ways including immediate use for landfill or drying to a stable condition (10 % moisture) in order to use as animal feed during out of season, or which, alternatively, may be processed biotechnologically in order to produce SCP. First choice is not economical, and the second one is expensive due to drying cost. Industry continues to make progress in solving waste problem through recovery of by products and waste materials such as peel, pulp, or molasses by the employment of fermentation process. The protein content of fruit and vegetable processing wastes with an adequate level of fermentable carbohydrates can be increased to 20-30% by using solid substrate fermentation. The composition of some fruit and vegetables indicates that many have a significant proportion of fermentable sugars. Of these, oranges, carrots, apple, peas have been successfully utilised as a substrate in the fermentation. Vinegar, citric acid, acetic acid are produced from the by products of fruit and vegetable industry. For example, apricot is one of the main agricultural products in Turkey. 60.000-80.000 tons dried apricots are produced annually. 180-200 tons dried apricot wastes are formed in the factories per year, which is not economical. Citric acid is produced using *A.niger* in the fermentors using dried apricot wastes as substrate. Additionally, brine, which is used in the production of pickles and olives, is an important environmental problem because there is about 20% and 7% salt in the effluents of olive and cucumber pickles, respectively. Also, wastes from potato and wheat starch processing factories can be fermented to ethanol.

Citrus by-products:

Due to the large amounts being processed into juice, a considerable by-product industry has evolved to utilize the residual peels, membranes, seeds, and other compounds. Residues of citrus juice production are a source of dried pulp and molasses, fiber-pectin, cold-pressed oils, essences, D-limonene, juice pulps and pulp wash, ethanol, seed oil, pectin, limonoids and flavonoids. Fiber-pectins may easily be recovered from lime peels and are characterized by high fiber contents. The main flavonoids found in citrus species are hesperidin, narirutin, naringin and eriocitrin. Peel and other solid residues of lemon waste mainly contained hesperidin and eriocitrin, while the latter was predominant in liquid residues. Citrus seeds and peels were found to possess high antioxidant activity. Both *in vitro* and *in vivo* studies have recently demonstrated health-protecting effects of certain citrus flavonoids.

Citrus-juice processing is one of the important food industries of the world, yielding an enormous quantity of processing residue. Juice recovery from citrus fruit is about 40-55%, with the processing residue consisting of peel and rag, pulp wash, seeds and citrus molasses. Citrus peel and rag are normally used either for pectin manufacture, or they are dried and sold as cattle feed. These citrus by-products and wastes have already drawn attention not only as important sources of dietary fiber for human consumption, but also as fermentable substrates for obtaining valuable chemicals and feedstock. Citrus by-products and wastes also contain large amount of colouring material in addition to their complex polysaccharide content. Hence, they are a potential source of natural clouding agents, which are in great demand by soft drinks industry. Commercial clouds presently used in the soft drinks industry are very expensive and may contain compounds restricting their use in certain countries. Little information is available on the composition, strength, or stability of commercial clouds.

Several researchers (Sreenath et al., 1995) conducted studies to utilize citrus industry by-products and wastes as natural sources for the production of beverage clouding agents using fermentation techniques, pectinolytic treatment and alcohol extraction. They also evaluated the strength and stability of prepared clouds in model test beverage systems to determine their similarities to commercially available beverage cloud types.

Oil Industry:

The by-products resulting from olive oil extraction are the vegetation water, also called black water or vegetable water, and the olive husk including skins and stones. Depending on the processing conditions, 50–110 kg of water result from 100 kg of olives. Most of the olive oil factories have no treatment systems and the discharge of this dark brownish wastewater causes serious environmental problems with high BOD (90-100 g/L). Many studies have been done to find an alternative ways to use this by-product. Composition of olive oil black water is given in Table 3.

The husk can be reprocessed for the recovery of olive oil, or extracted with an organic solvent to yield husk oil. Dried husk is utilized as fuel or animal feed. A process for the separation of the vegetation water from the solids by evaporation has been recently described. The remaining solid fraction representing 98% of the organic load could be mixed with the husk and used as a fuel. Olive oil wastewaters are rich in antioxidant compounds, particularly in hydroxytyrosol derivatives. Hydroxytyrosol strongly inhibited LDL oxidation stimulated by 2,2'-azobis (2-aminopropane) hydrochloride. Further investigations point out that hydroxytyrosol and oleuropein are potent scavengers of superoxide radicals.

Table 3. Composition of olive oil black water:

<u>Substances</u>	<u>Amounts</u>
Sugar	0.98 %
Protein	0.77 %
Oil	0.4 %
Dry matter	6.2 %
Ash	1.4 %
Fe	0.3 mg/100 ml
Ca	7.5 mg/100 ml
K	112 mg/100 ml
Na	39.5 mg/100 ml
pH	4.5

Several researchers have studied production of single cell protein from the black water of olive. In addition to SCP, olive oil black water has been studied for production of natural antimicrobials (Demirel and Karapinar, 2000). Naturally occurring phenolic compounds in black water such as phenolic glycoside, oleuropein and its hydrolysis products inhibit the growth of some fungi and a number of G(-) bacteria. Microbiological studies have shown that discharge of black water to soil inhibits the growth of aerobic spore forming bacteria, such as *B.megaterium*. In addition, it is shown that oleuropein is able to prevent the germination of *B.cereus*. Some studies, such as inhibition of growth of *S.aereus* and production of its toxins and also inhibition of growth of *A.flavus* and aflatoxin production, gives good results from the point of using these phenolics as natural antimicrobials. Additionally, usage of sludge as an organic fertilizer has been studied (Anaç et al., 1993).

The world's demand for energy grows rapidly, and therefore, the time has come to look for alternative sources of energy, such as renewable energy, to replace the rapidly depleting supply of fossil fuel. Producing energy from renewable oil wastes can contribute to avoiding the use of fossil fuel for this industry. The oil industry is one of the biggest industries in all over the world. Using the fiber and shell from the processing wastes as an alternative fuel for electricity generation for this industry can do a lot of savings. In Malaysia, where many giant palm oil plantations and processing industries have been developed, researchers (Mahlia et al., 2001) have dealt with energy conversion from the fiber and shell of the industry wastes as an alternative energy source. They proved that the fiber and shell could be conventionally used as fuel for a steam boiler. The calculations have shown that oil wastes can generate more than enough energy to meet the energy demand of the palm oil mill. Another advantage of using the fiber and shell as a boiler fuel is that it helps to dispose these bulky materials which otherwise would contribute to environmental pollution. The ash from the combustion process is also found suitable for fertilizer for palm oil plantation.

Meat industry

A major part of the materials handled by the animal by-products industry originate from slaughterhouses. By products are subdivided into edible and inedible material. A small proportion of the material is for the leather industry. The remainder consists of heads, feet, offal, bone, hair, blood and feathers. The inedible fraction amounts to almost 40% of the total weight of the animals killed.

About half of the chicken meat production by-products has not been utilized and especially most of the blood is discharged to outside. This causes a serious environmental problem. There are also many rendering plants producing meat meal, tallow and degreased bone. Meat meal is used in animal feeding and also in pet foods. Tallow is used for the production of soap, cosmetics, paints, polishes, etc. Degreased bone is used mainly for the production of pharmaceutical, photographic and edible gelatins. Slaughterhouse blood, which is a protein rich residue of meat production, can be utilized for the recovery of applicable protein preparates. There are proposed several ways of discoloration of the whole blood or its components. Some of them are based on destruction of haemoglobin and subsequent extraction of haemin by organic solvents, hydrogen peroxide or ozone; some are based on enzymatic hydrolysis. Discoloured blood is dried and blood proteins are obtained, which may find application in food and feed industry.

BY-PRODUCTS OF SUGAR PRODUCTION

Since the world sugar market is currently suffering from very high stocks and low prices, long-term options for the utilization of by-products are urgently required. Sugar cane and sugar beet are the most important crops for the production of sugar. Molasses represents the runoff syrup from the final stage of crystallization. It mainly consists of fermentable carbohydrates (sucrose, glucose, fructose), and of non-sugar compounds, which were not precipitated during juice purification. Furthermore, molasses contains substances formed chemically or enzymatically during processing and storage (betaine and other amino acids, *Maillard* products, *Strecker* decomposition products, lactic acid, mineral and trace elements, and vitamins especially of the B-group). Molasses is used as feed and as a source of carbon in fermentation processes, e.g. for the production of alcohol, citric acid, L-lysine and L-glutamic acid.

In volume, bagasse is the by-product of highest relevance. The fibrous residue from the extraction process is utilized as fuel and as a source of pentosans, for the production of furfural from pentosan-rich raw material, and for the recovery of fibrous products. Granulated activated carbon (GAC) produced from sugar cane bagasse showed some potential as a sugar decolorizer but was inferior to GAC produced from pecan shells.

Depending on the process, exhausted beet pulp has a dry matter content of 8–15%. Therefore, its economic utilization requires dewatering, which is mostly performed by mechanical pressing (pressed pulp), followed by thermal drying. Pressed pulp is an energy-rich animal feed the shelf life of which can be extended by ensiling. Enzymatic release of ferulic acid from sugar beet pulp and subsequent bioconversion to vanillin in a two-step process has been demonstrated. A freeze-dried arabinan substitute for gum arabicum and a fat substitute based on linear arabinan were also obtained from sugar beet pulp. Addition of sugar beet fiber to semolina increased dietary fiber content but adversely affected colour and cooking loss of spaghetti. Owing to its high content of acetyl groups and its low molecular weight, beet pectin has poor gelling properties and is of very limited commercial value.

Molasses (cane and sugar beet) been used most extensively as sources of C compounds and minerals for the growth of yeast. Molasses are deficient in nitrogen and phosphorus and these must be supplied to them. *Candida utilis* is a micro organism used to obtain SCP from effluents in sugar industry, and it may be an alternative way to treat the wastewater. Other fermentation products of molasses can be summarised as:

<u><i>Aerobic fermentation</i></u>		<u><i>Anaerobic fermentation</i></u>	
Micro organism	Product	Micro organism	Product
<i>A.niger,</i> <i>P.chrysogenum</i>	Gluconic acid	<i>Propionic acid</i> <i>bacteria</i>	Propionic acid
<i>A.niger, A.ventii</i>	Citric acid	<i>C.butyricum</i>	Butanole-acetone
<i>A.niger</i>	Oxalic acid	<i>C.butyricum</i>	Butyric acid
<i>Acetobacter</i>	Acetic acid	<i>L.delbruchi</i>	Lactic acid
<i>S.cerevisiae</i>	Yeast	<i>S.cerevisiae</i>	Ethyl alcohol
<i>R.nigricans</i>	Fumaric acid		

FOOD PACKAGING WASTES

Of all the manufacturing industries, the food industry makes the largest demand on packaging and finding ways to reduce this packaging quantity and its subsequent waste is a demanding task. In practice, optimised packaging criteria for the least environmental impact are often difficult to define without extensive dialogue. The needs of the consumer, the requirements of the supermarket and the optimisation available to the producer or manufacturer may variously conflict with one another. In order for waste minimization to provide continuing environmental improvement in the key areas of putrescible wastage and packaging, improved consensus and dialogue is required between purchasers, including both consumers and major supermarkets, and those that produce and manufacture. Food producers and manufacturer must give greater priority to reducing raw material wastage as far as practically possible and identifying the process options that result in a lower waste burden.

FOOD WASTE COMPOSTING

Composting is the natural process of decomposition and recycling of organic material into a humus rich soil amendment known as *compost*. For any business or institution producing food waste, this organic material can be easily decomposed into high quality compost.

Fruits, vegetables, dairy products, grains, bread, unbleached paper napkins, coffee filters, eggshells, meats and newspaper can be composted. If it can be eaten or grown in a field or garden, it can be composted. Items that cannot be composted include plastics, grease, glass, and metals -- including plastic utensils, condiment packages, plastic wrap, plastic bags, foil, silverware, drinking straws, bottles, polystyrene or chemicals. Items such as red meat, bones and small amounts of paper are acceptable, but they take longer to decompose

Food waste has unique properties as a raw compost agent. Because it has a high moisture content and 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 the mix. Bulking agents with a high C:N ratio, such as sawdust and yard waste, are good choices.

Pre-consumer food waste is the easiest to compost. It is simply the preparatory food refuse and diminished quality bulk, raw material food that is never seen by the consumer. This food waste is generally already separated from the rest of the waste stream generated, thus no change is needed to keep contaminants out of the future compost.

Post-consumer food waste is more challenging because of separation issues. It is simply the table scrap food refuse. Often, after the consumer is done with the food, the waste is subject to contaminants and a decision has to be made on how to separate food from other waste. Having an extra trashcan that is only used for food waste can do this. Either the kitchen staff or the consumer can separate it depending on the feasibility, flexibility, volume, labour, atmosphere, and attitude of the business or institution. For some operations it may be incorporated as an educational tool or method of demonstrating the company's proactive environmental policy.

Why Compost Food Waste?

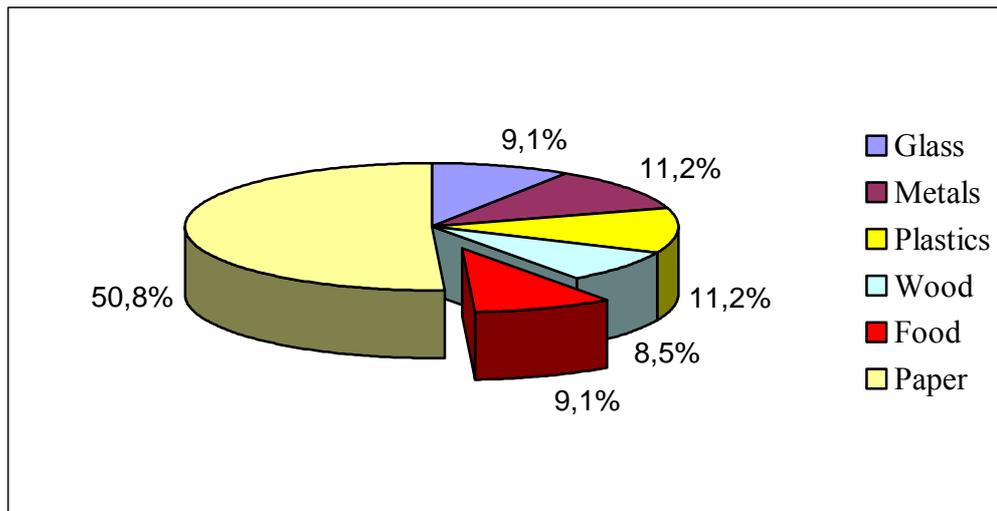


Figure 1. Materials generated in municipal solid waste by weight in US 1990 (Source: EPA - Summary of Markets for Compost).

Food waste that is not composted generally goes directly to a landfill. Composting provides a way in which solid wastes, water quality, and agricultural concerns can be joined. An increasing number of communities, businesses, institutions, and individuals are expected to turn to composting to divert materials from landfills and to lower waste management costs. Although waste stream managers view composting primarily as a means to divert materials from disposal facilities, the environmental benefits, including reduction in water pollution, and the economic benefits to farmers, gardeners, and landscapers can be substantial.

Benefits of compost to the food industry:

- a. Reduces solid waste disposal fees.
- b. Ends wasting large quantities of recyclable raw ingredients.
- c. Educates consumers on the benefits of food waste composting.
- d. Markets your establishment as environmentally conscious.
- e. Markets your establishment as one that assists local farmers and the community.
- f. Helps close the food waste loop by returning it back to agriculture.
- g. Reduces the need for more landfill space.

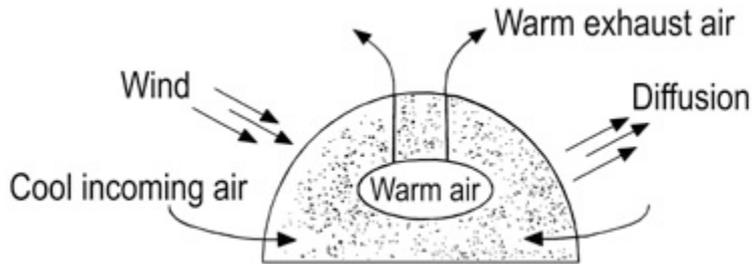
Benefits to the environment and agriculture:

Environment	Agriculture
<ul style="list-style-type: none"> • Water and soil conservation • Protects groundwater quality. • Minimizes runoff from agricultural areas. • Avoids methane production and leachate formation in landfills by diverting organics from landfills into compost. • Prevents erosion and turf loss on roadsides, hillsides, playing fields and golf courses. • Drastically reduces the need for pesticides and fertilizers. • Binds heavy metals and prevents them from migrating to water resources, being absorbed by plants, or being bioavailable to humans. • Off-farm materials can be brought in and added to manure to make compost. • Facilitates reforestation, wetlands restoration, and wildlife habitat revitalization efforts by amending contaminated, compacted and marginal soils. • Long-term stable organic matter source. • Buffers soil pH levels. • Off-farm materials can be brought in and added to manure to make compost. • Composted manure weighs about one-fourth as much as raw manure per ton. 	<ul style="list-style-type: none"> • Adds organic matter, humus and cation exchange capacity to regenerate poor soils. • Suppresses certain plant diseases and parasites and kills weed seeds. • Increases yield and size in some crops. • Increases length and concentration of roots in some crops. • Increases soil nutrient content and water holding capacity of sandy soils and water infiltration of clay soils. • Reduces fertilizer requirements. • Restores soil structure after natural soil micro organisms have been reduced by the use of chemical fertilizers; compost is a soil inoculant. • Increases earthworm populations in soil. • Provides slow, gradual release of nutrients, reducing loss from contaminated soils. • Reduces water requirements and irrigation. • Moves manure to non-traditional markets that do not exist for raw manure. • Brings higher prices for organically grown crops. • Minimizes runoff from agricultural areas.

Source: EPA: Compost - New Applications for an Age-Old Technology

Composting Methods:

Passive composting or **piling** is simply stacking the materials and letting them decompose naturally. This method is simple and low cost but is very slow and may result in objectionable odors.

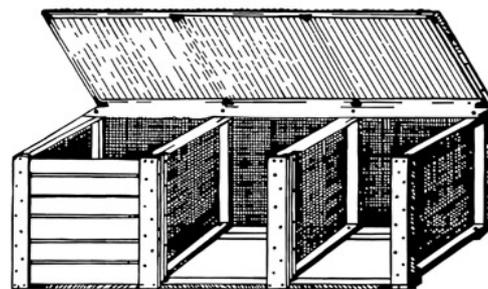


In **Aerated static piles** air is introduced to the stacked pile via perforated pipes and blowers. This method requires no labour to turn compost but is weather sensitive, and can have unreliable pathogen reduction due to imperfect mixing.



Windrows are long, narrow piles that are turned when required based on temperature and oxygen requirements. This method produces a uniform product and can be remotely located. However, turning the compost can be labour intensive or require expensive equipment. Windrows are typically used for large volumes, which can require a lot of space. In addition, windrows can have odor problems, and have leachate concerns if exposed to rainfall.

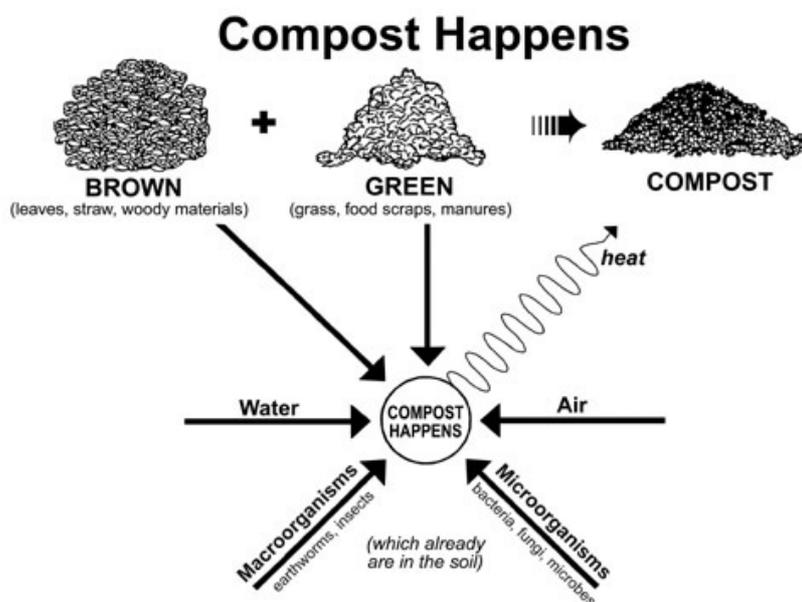
Bins using wire mesh or wooden frames allow good air circulation, are inexpensive, and require little labour. Three chamber bins allow for faster compost production utilizing varying stages of decomposition. Bin composting is typically used for small amounts of food waste.



In-vessel systems using perforated barrels, drums, or specially manufactured containers are simple to use, easy to turn, require minimal labour, are not weather sensitive, and can be used in urban and public areas. The initial investment can be high and handling volumes are typically low.

Vermicomposting uses worms to consume the food waste and utilizes its castings as high quality compost. This is usually done in containers, bins, or greenhouses. Typically 1 pound of worms can eat 4 pounds waste per week. Worm castings bring a premium price but the investment in worm stocking may be high depending on the size of the operation. If too much waste is added anaerobic conditions may occur. In addition, worms cannot process meat products.

Monitoring food waste compost:



- **Proper nutrient mix**, or carbon to nitrogen ratio (C:N) is important for bacteria to process organic material into compost. The optimum ratio to begin composting is **30:1**. If the ratio increases decomposition is slowed, if the ratio decreases foul doors and nitrogen loss can occur. Food waste is typically 15:1, fruit waste 35:1, leaves 60:1, bark 100:1, and sawdust 500:1. For example, a recipe using 1 part leaves and 1 part food waste by volume would achieve close to a 30:1 ratio. It may be worthwhile to contact your county agricultural extension agent or the University of Georgia for information on obtaining lab analysis of the feedstock in your compost mix.
- A **moisture content** of 60 percent is optimal for micro organisms to breakdown the compost. Moisture contents above 70 percent create anaerobic conditions, slow down the process and can create foul doors. Moisture below 50 percent also slows down the decomposition process. The moisture content of fresh food waste is 80 to 90 percent, sawdust is 25 percent, and yard waste is 70 percent. Compost with a proper moisture content will form a clump and will slightly wet your hand when squeezed. If the clump drips water, it is too wet and may require additional aeration or more bulking

agent. If the compost falls through your fingers, it is too dry and may need water additions or more food waste.

- **Aeration** or oxygen is essential for optimum micro organism populations to effectively breakdown the composting material. Turning, mixing, and the use of blowers, fans, aeration tubes, aeration holes, or raising the compost off the ground can do this.
- **Particle size** can affect the rate of decomposition of compost. The smaller the particles the more aeration the compost receives and micro organisms can break down smaller pieces faster. Shredding, chipping, chopping, or cutting composted materials before they enter the compost pile can accomplish this.
- **pH** levels from **6.0** to **7.8** are considered high quality compost. Proper C:N ratios should create optimum pH levels. Starting with a fairly neutral pH will ensure high levels of micro organisms for efficient decomposition.
- **Temperature** of the compost is important while biological activity takes place in the decomposition process. Low outside temperature slow down the process, while warmer conditions speed up the process. Mesophilic bacteria function between 50 and 113°F to begin the composting process. Thermophilic bacteria take over and thrive between 113 to 158°F. These high temperatures are what destroy weed seeds and pathogens in the compost. Some composting manures can reach temperatures of 200°F. However, temperatures above 158°F may char the compost or create conditions suitable for spontaneous combustion.

BY-PRODUCTS AS SOURCES OF FUNCTIONAL COMPOUNDS

There is a rapidly growing interest in the role of plant secondary metabolites in food and their potential effects on human health. Furthermore, consumers are increasingly aware of diet related health problems, therefore demanding natural ingredients, which are expected to be safe and health promoting. By products of plant food processing represent a major disposal problem for the industry concerned, but they are also promising sources of compounds which may be used because of their favourable technological or nutritional properties.

Apple: Production of pectin is considered the most reasonable way of utilizing apple pomace both from an economical and from an ecological point of view. In comparison to citrus pectins, apple pectins are characterized by superior gelling properties. However, the slightly brown hue of apple pectins caused by enzymatic browning may lead to limitations with respect to their use in very light-colored foods.

Apple pomace has been shown to be a good source of polyphenols, which are predominantly localized in the peels and are extracted into the juice to a minor extent. Major compounds isolated and identified include catechins, hydroxycinnamates, phloretin glycosides, quercetin glycosides, and. Since some phenolic constituents have been demonstrated to exhibit strong antioxidant activity *in vitro*, commercial exploitation of apple pomace for the recovery of these compounds seems promising. Inhibitory effects of apple polyphenols and related compounds on cariogenicity of streptococci suggest their possible application in dentifrices.

Grape: Apart from oranges, grapes are the world's largest fruit crop with more than 60 million tons produced annually. About 80% of the total crop is used in wine making, and pomace

represents approximately 20% of the weight of grapes processed. From these data it can be calculated that grape pomace amounts to more than 9 million tons per year. Its composition varies considerably, depending on grape variety and technology of wine making.

A great range of products such as ethanol, tartrates, citric acid, grape seed oil, hydrocolloids, and dietary fiber are recovered from grape pomace. Anthocyanins, catechins, flavonol glycosides, phenolic acids and alcohols and stilbenes are the principal phenolic constituents of grape pomace. Anthocyanins have been considered the most valuable components, and methods for their extraction have been reported. Catechin, epicatechin, epicatechin gallate and epigallocatechin were the major constitutive units of grape skin tannins. Since grape and red wine phenolics have been demonstrated to inhibit the oxidation of human low-density lipoproteins, a large number of investigations on the recovery of phenolic compounds from grape pomace have been initiated. From a nutritional point of view, these phenolics are highly valuable since they are absorbed to a large extent. The antioxidant activity of grape pomace has led to the development of a new concept of antioxidant dietary fiber.

Peach and apricot: Bitter apricot seeds are by-products of the apricot processing industry. Apart from the use of apricot seed oil in cosmetics, peeled seeds serve as a raw material for the production of persipan. This requires debittering by hydrolysis of amygdalin. Pomace of wild apricot proved to be a rich source of proteins but also contained low levels of amygdalin. Besides apricot seeds, peach seeds may also be used for the production of persipan. Recently, the recovery of pectin from fresh peach pomace has been described. Quality evaluation revealed that peach pectin is highly methoxylated and has favourable gelling properties. While storage of dry powdered pomace led to significantly higher pectin yields, quality parameters of the pectins deteriorated.

Mango: Mango is one of the most important tropical fruits. Mango and mango products experience worldwide popularity and have gained increasing relevance also in the European market. The major wastes of mango processing are peels and stones, amounting to 35–60% of the total fruit weight.

Mango seed kernel fat is a promising source of edible oil and has attracted attention since its fatty acid and triglyceride profile is similar to that of cocoa butter. Therefore, legislation has recently allowed mango seed kernel fat to be used as a cocoa butter equivalent. Mango seed kernels may also be used as a source of natural antioxidants. The antioxidant principles were characterized as phenolic compounds and phospholipids. The phenolics were assumed to be mainly gallic and ellagic acids, and gallates. Ethanolic extracts of mango seed kernels display a broad antimicrobial spectrum and are more effective against Gram (+) than against Gram (-) bacteria. A standardized method for the recovery of good quality mango peel pectin with a degree of esterification of about 75% has recently been developed. Mango peels are also reported to be a good source of dietary fiber containing high amounts of extractable polyphenolics.

Pineapple: World's annual pineapple production is about 13×10^6 tons. The pulpy waste material resulting from juice production still contains substantial amounts of sucrose, starch and hemicellulose, and may therefore be used for ethanol production. In contrast to papain from papaya, the proteolytic enzyme bromelain may also be recovered from the mature fruit. Enzymatic browning of fresh and dried apple rings is inhibited by pineapple juice. The antioxidant principles have been structurally elucidated, and methods for their recovery from pineapple juice and from pineapple processing plant waste streams have been described.

Banana: Banana represents one of the most important fruit crops, with a global annual production of more than 50 million tons. Worldwide production of cooking bananas amounts to nearly 30 million tons per year. Peels constitute up to 30% of the ripe fruit. About 1000 banana plants are estimated to yield 20–25 tons of pseudostems providing about 5% edible starch. Attempts at utilization of banana waste include the biotechnological production of protein, ethanol, α -amylase, hemicellulases and cellulases. Very recently, anthocyanin pigments in banana bracts were evaluated for their potential application as natural food colorants. It was concluded that the bracts proved to be a good and abundant source of anthocyanins of attractive appearance, as well as being a useful tool in anthocyanin identification since all six most common anthocyanidins (delphinidin, cyanidin, pelargonidin, peonidin, petunidin and malvidin) are present. Most of the carotenoids found in banana peels were demonstrated to be xanthophylls esterified with myristate, and to a lesser extent with laurate, palmitate or caprate.

Guava: Guava is a rich source of relatively low methoxylated pectins (50%), amounting to more than 10% of the dry weight. Since wastes constitute only 10–15% of the fruit, the use of guava for pectin production is limited. The seeds, usually discarded during processing of juice and pulp, contain about 5–13% oil rich in essential fatty acids. The results of very recent investigations indicate that peel and pulp of guava fruits could be used as a source of antioxidant dietary fiber.

Papaya: Papain, a proteolytic enzyme used as a meat tenderiser and as a stabilizing agent in the brewing industry, is recovered from the latex of papaya fruit. Furthermore, papaya fruits may also be used for the production of pectin. Owing to their spicy flavour, which is caused by glucosinolate degradation, the seeds are sometimes used as a substitute and even as an adulterant for pepper. The seed oil is low in polyunsaturated fatty acids, but defatted papaya seed meal contains high amounts of crude protein (40%) and crude fiber (50%).

Passion fruit: The waste resulting from passion fruit processing consists of more than 75% of the raw material. The rind constitutes 90% of the waste and is a source of pectin (20% of the dry weight). Passion fruit seed oil is rich in linoleic acid (65%).

Kiwifruit: Kiwifruit waste results from rejected kiwifruits, which comprise up to 30% of the total kiwifruit crop, and from kiwifruit pomace after juice production. A comprehensive review of the components and potential uses of kiwifruit waste has recently been given, inferring that only little work has so far been conducted on finding uses for kiwifruit pomace. The total dietary fiber content of kiwifruit pomace amounts to approximately 25% on a dry weight basis. Phenolic acids, flavanol monomers, dimers and oligomers, and flavonol glycosides have recently been characterized in kiwifruit pulp.

Tomato: Tomato juice is the most important vegetable juice with respect to per capita consumption, followed by carrot juice. About 3–7% of the raw material is lost as waste during tomato juice pressing. Tomato pomace consists of the dried and crushed skins and seeds of the fruit. The seeds account for approximately 10% of the fruit and 60% of the total waste, respectively, and are a source of protein (35%) and fat (25%). Tomato seed oil has attracted interest since it is rich in unsaturated fatty acids, especially in linoleic acid. Recently, the optimisation of degumming, bleaching and steam deodorization was reported. Sensory evaluation of products made with tomato seed and sunflower oil revealed no significant differences.

Lycopene is the principal carotenoid causing the characteristic red hue of tomatoes. Most of the lycopene is associated with the water-insoluble fraction and the skin. Therefore, skin extracts are especially rich in lycopene. A large quantity of carotenoids is lost as waste in tomato processing. Supercritical CO₂ extraction of lycopene and β-carotene from tomato paste waste results in recoveries of up to 50%. Enzymatic treatment of tomato marc enhances lycopene extractability. Recently, saccharification to obtain biomass from tomato pomace has also been reported.

Carrot: Carrot juices and blends thereof are among the most popular non-alcoholic beverages. Steady increase of carrot juice consumption has been reported from various countries. Despite considerable improvements in processing techniques including the use of depolymerizing enzymes, mash heating, and decanter technology, a major part of valuable compounds such as carotenes, uronic acids, and neutral sugars is still retained in the pomace which is usually disposed as feed or as fertilizer. Juice yield is reported to be only 60–70%, and up to 80% of carotene may be lost with the pomace. Total carotene content of pomace may be up to 2 g per kg dry matter, depending on processing conditions.

Various attempts were made at utilizing carrot pomace in food such as bread, cake, dressing and pickles, and for the production of functional drinks. However, consumer acceptance of such products still needs to be demonstrated, especially since sensory quality may be adversely affected. Pigments of spray-dried carrot pulp waste proved to be prone to degradation during storage, depending on storage time and temperature. It was suggested that the stability of carotenoid powder could be greatly enhanced by employing appropriate packaging methods and storage conditions. Freeze-dried powder shows a higher pigment stability during storage than the spray-dried product.

Onion: The amount of onion waste produced annually in the European Union is estimated at approximately 450,000 tons. The major by-products resulting from industrial peeling of onion bulbs are brown skin, the outer two fleshy leaves and the top and bottom bulbs. Owing to their strong characteristic aroma and their susceptibility to phytopathogens, onion wastes are not suitable as fodder. However, they are a source of flavour components and fiber compounds and particularly rich in quercetin glycosides. The major flavonoids of mature onion bulbs are quercetin 3,4'-*O*-diglucoside and quercetin 4'-*O*-monoglucoside, accounting for more than 85% of the total flavonoids. Since quercetin from onions is rapidly absorbed and slowly eliminated, it could contribute significantly to antioxidant defence.

Red beet: More than 200,000 tons of red beet are produced in Western Europe annually, most of which (90%) is consumed as vegetable. The remainder is processed into juice, colouring foodstuff and food colorant, the latter commonly known as beetroot red. Though still rich in betalains, the pomace from the juice industry accounting for 15–30% of the raw material is disposed as feed or manure. The collared portion of the beetroot ranges from 0.4 to 2.0% of the dry matter. Beets are ranked among the 10 most potent vegetables with respect to antioxidant capacity. A more recent investigation showed that total phenolics decreased in the order peel (50%), crown (37%) and flesh (13%). Epidermal and subepidermal tissues, i.e. the peel, also carried the main portion of betalains with up to 54%, being lower in crown (32%) and flesh (14%). Whereas the collared fraction consisted of betacyanins and betaxanthins, the phenolic portion of the peel showed L-tryptophane, *p*-coumaric and ferulic acids, as well as cyclodopa glucoside derivatives. Therefore, the exploitation of peel and pomace for phenolics and betalains is a real need.

Betacyanins were demonstrated to be strong antioxidants in various model systems, and their positive charge may increase their affinity to biological membranes, which are the preferred targets of oxidation. Literature data imply a low rate of betalain absorption, and a critical concentration for the bioactivity of these compounds in human plasma has yet to be established. High content in folic acid amounting to 15.8 µg/g dry matter is another nutritional feature of beets. Folic acid is one of 10 essential vitamins in human diet, and its value has been recognized in recent years by an important increment in governmentally recommended allowances from 400 to 800 µg for pregnant women in the US.

Potato: While consumption of potatoes has decreased, processed products such as French fries, chips, and puree have experienced growing popularity. Peels are the major waste of potato processing. Losses caused by peeling range from 15 to 40%, their amount depending on the procedure applied, i.e. steam, abrasion or lye peeling. Aqueous peel extracts were shown to be a source of phenolic acids, especially of chlorogenic, gallic, protocatechuic and caffeic acids. The antioxidant activity of freeze-dried water extracts of potato peels was comparable to that of butylated hydroxyanisole. The extracts displayed species-dependent antibacterial but no mutagenic activity

FUTURE TRENDS

The exploitation of by-products of fruit and vegetable processing as a source of functional compounds and their application in food is a promising field, which requires interdisciplinary research of food technologists, food chemists, nutritionists and toxicologists. In the near future, we are challenged to respond to the following research needs:

1. Food processing technology should be optimised in order to minimize the amounts of waste arising.
2. Methods for complete utilization of by-products resulting from food processing on a large scale and at affordable levels should be developed. Active participation of the food and allied industries with respect to sustainable production and waste management is required.
3. Natural and anthropogenic toxins such as solanin, patulin, ochratoxin, dioxins and polycyclic aromatic hydrocarbons need to be excluded by efficient quality control systems. Minimization of potentially hazardous constituents, e.g. solanin, amygdalin, and optimisation of valuable compounds such as carotenoids and betalains may also be achieved by plant breeding.
4. There is a need for specific analytical methods for the characterization and quantification of organic micronutrients and other functional compounds.
5. The bioactivity, bioavailability and toxicology of phytochemicals need to be carefully assessed by *in vitro* and *in vivo* studies.

Undoubtedly, functional foods represent an important, innovative and rapidly growing part of the overall food market. However, their design, i.e. their complex matrix and their composition of bioactive principles, requires careful assessment of potential risks which might arise from isolated compounds recovered from by-products. Furthermore, investigations on stability and interactions of phytochemicals with other food ingredients during processing and storage need to be initiated. Since functional foods are on the boundary between foods and drugs, their regulation still proves difficult. In any case, consumer

protection must have priority over economic interests, and health claims need to be substantiated by standardized, scientifically sound and reliable studies.

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