Enabling Food Innovation Project

Food and drink waste utilization

A paper to introduce and inform SMEs in the D2N2 area about food and waste utilization to motivate them to adopt knowledge and practice it.

Mohamed A. Gedi

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Introduction

This paper intends to introduce this topic “food waste utilization” to small and medium-sized food and drink producers in the UK (with the focus on those around Nottingham/Nottinghamshire and Derby/Derbyshire), to explain what it is, why it is important and how it can be relevant and be applicable to those businesses in their commercial development.

It seeks to bring a subject that is probably known by those businesses in some form to give a more comprehensive, holistic understanding, to define terms and "bust the jargon"/break through the fog, so that they can then consider using the knowledge and practices within their operations.

We intended to develop the paper and use it as the basis of a workshop held on 28th Nov. 2017 as part of the University of Nottingham's Enabling Food Innovation project. This was successfully achieved with excellent feedback from those who attended the workshop (SMEs, students and academicians/staff).

This paper may also benefit local government authorities working on food waste management; and a new collaborative network between these authorities, food processing industries with food/drink wastes/by-products and food/drink wastes academic researchers could be created. Local (i.e. UK) Food/drink SMEs based at various other sites of the UK could also join this network.

Bearing in mind the massive amounts of foods wasted in different stages of food chain supply, the increasing growth of populations worldwide, and the techno-scientific opportunities available, food waste utilization is not only one great prospect that could contribute to the feeding of the estimated world population of 9 billion people by 2050, but also an aspect that should be looked from its business potentials, which is worth to be invested.

Executive summary

This document covers seven chapters seen as of utmost relevance to this topic. Although food/drink waste occurs in various stages of the food chain supply, such as in the farm, retail, household, hospitality and services, and in the manufacturing stage, it is this last stage (manufacturing/ processing) that this document will mainly focus on.

Firstly, the definition of food/drink waste, why food/drink waste is an issue, major food/drink types wasted and categorization of food/drink waste is presented in chapter one.

In the second chapter, the reason why food/drink waste is of interest and different factors affecting this is elucidated.

Market related information, current activities and technologies, government funds and some research activities on food/drink waste is enclosed in chapter three, which tries to look food/drink waste from the business point of view.

In the subsequent chapter (four), opportunities and options on food/drink waste utilization is discussed, and five sectors of utilizing food/drink waste such as utilization of food/drink waste for new food products, new added value food ingredients, for animal feeding, for food packaging, for energy generation, for composting, and for miscellaneous applications is identified and explored each separately.

Food/drink waste regulations, including EU and UK food/drink waste related legislations was briefly touched in chapter five.

Food/drink waste service companies around Nottingham and Derby, as well as some in the UK, was also considered in chapter six, and finally, some case studies on food/drink waste were reported in chapter seven.

Chapter 1. What is food and drink waste

1.1. What is food waste?

In the scientific literature food/drink waste or food/drink lose are often used to identify materials intended for human consumption that are subsequently discharged, lost, degraded or contaminated (2).

According to the Food and Agriculture Organization (FAO) of the United Nations (UN) food/drink waste is defined as any change in the availability, edibility, wholesomeness or quality of edible material that prevents it from being consumed by people. This definition by the FAO was provided for the post-harvest period of food ending when it comes into the position of the final consumer.

Another definition by Gustavsson, Cederberg (3) stated a similar definition of food waste, but included also the production stage of food supply chain instead of only postharvest and processing stages.

A Dutch commercial company involves in shipping 200,000 tonnes per year of house hold waste/biomass (food waste) from Italy to Rotterdam to use it as a feedstock for electricity generation in Dutch power plants (4), which suggests biomass/food and drink waste to be a lucrative business or as Northern English people say ‘’where there’s muck there’s brass’’.

Millions of tonnes of foods are annually wasted in the global. An example of global food waste is shown in figure 1.

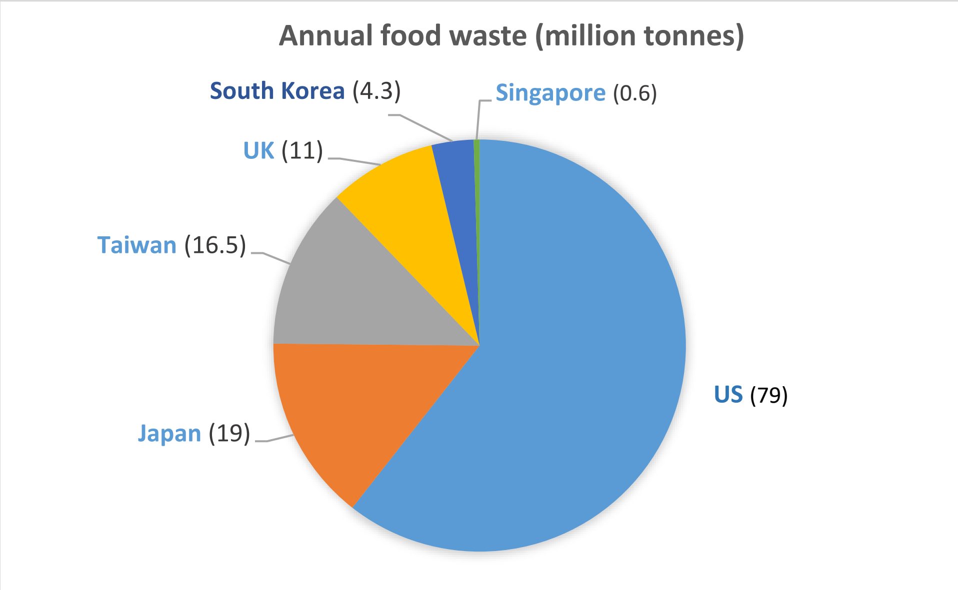


Figure 1 Annual food waste (million tonnes). Data adapted from Melikoglu, Lin (1)

This translated into pound amount, industrialized and developing countries waste £519 and £236 billion per year, respectively. Industrialized countries mostly waste in the household stage, whereas underdeveloped countries waste food mainly during production, handling and retail stages (I mean both in before and after harvest stages) due to limitations in necessary technologies/logistics.

1.2. Where food is wasted and what is the issue

In the UK alone around 12 million tonnes of foods and drinks is wasted in the food chain per year, households being the highest proportion of food & drink waste (Figure 2). This costs the average family with children around £700 a year or £60 per month. “Love Food Hate

Waste" is a national (UK) initiative trying to help reduce food waste (https://www.lovefoodhatewaste.com/).

Food processing firms come as the second largest food waste sector, and it's this sector where a great shift of food waste utilization undergoes as food manufacturing companies are trying to cover their waste disposal costs by valorising their own wastes by means of re-processing to add value or selling it to other companies capable of the necessary technologies.

Figure 2 UK food and drink waste through the food chain (**million tonnes**). Data obtained from Department for Environment Food & Rural Affairs via https://www.edie.net/news/5/Supermarkets-slash-food-waste-by-20-000-tonnes/.

1.3. Which type of foods do we waste the Most?

Despite it is hard to quantify the thousands of the different foods wasted globally, through the literature review, **fruit & vegetables, meat & poultry** and **bread & bakery** products are the top three major food wastes produced in the developed countries (1). Others include root and tubers, oil crops and pulses, and fish and sea foods (Figure 3).

Figure 3 sourced from http://inhabitat.com/what-food-do-we-throw-away-the-most-infographic/

1.4. Categorization and identification of food items wasted

Several ways of wasted food categorization exist. According to Waste and Resources Action Programme (WRAP) of the UK, food waste could be classified into three groups: i) avoidable: foods discarded because it is no longer wanted or has allowed to go past its best such as, bread, fruits and vegetables etc., ii) possibly avoidable: foods that some people will eat and others will not (potato peels, apple peels etc.)., iii) inedible parts such as meat bones, eggs shells and hard vegetable or fruit peelings. Additionally, food waste could be generally classified based on its origin. Based on origin, food waste can be classified into two main groups, which are plant and animal based food wastes, each with various sub-categories. The later categorization (based on origin) will be followed in this document.

1.4.1. Plant based waste/by-products

Foods originating from plants are the major portions of food waste/by-products occurring in our global and in the UK. Among these are cereals, roots and tubers, oil crops and pulses, bakers and confectionaries, sugar cane, coffee, fruits and vegetables and beverages.

1.4.1.1. Cereals

Primary wastes and by-products from cereals are generated during harvest, after harvest and after production. Examples of wastes from cereals include wastes from wheat straw, wastes from wheat, rice, oat, and barley mill fractions, and wastes from barley malt.

The bulk of straw is normally used as feed for ruminants and for bedding animals or storage of other crops. Straw is also utilised as building materials, as a fuel, in paper making or as a raw material for the chemical industry (e.g., for the production of furfural).

1.4.1.2. Root and tubers

The major root and tuber crops, which are raw materials for food processing industries are potato, sweat potato, cassava, and yams. Roots and tubers have the highest wastage rates after fruits and vegetables (5).

Primary wastes generated from these crops include peels, liquid effluent, solid bagasse and distillery stillage. These wastes could be utilized in several ways including animal feed, commodity chemicals, biofuels and energy.

1.4.1.3. Oil crops and pulses

Oil seed cakes are rich in dietary fibre, proteins and bioactive compounds (e.g. colorants and antioxidants)

1.4.1.4. Bakeries and confectioneries

The primary processing of wheat milling generates large amounts of by-products such as brand and germ, after the target starchy endosperm (in most cases) is recovered. In general, 28% of the grain is wasted during the production of white flour. The wasted parties (usually brand and germ) are relatively rich in fibres, vitamins, minerals, and also fatties. The milling of by-products is mostly used for animal feeding. These by-products are also utilized for dietary fibre and protein from bran/germ for inclusion in the human feeding.

In the bakery and confectionary stage, a large variety of baked products are produced, but bread is the most popular product. Bread is extremely downgraded from high-quality food to feed or waste. Generally surplus bread ends up as animal feed. Similarly, overages, production errors (e.g. misshaped), and out-of-spec bread in the bakeries are downgraded to animal feed. At best, bakers/retailers may get a small fee if they manage to sell it as animal feed.

Knowledge of the chemical composition, particle size, and physical properties of the bakery and confectionary wastes will contribute to their optimal recycling and identification of their appropriate applications.

This could be achieved by using the by-product either as raw material for secondary processes or as animal feed, as operating supplies or as ingredients of novel/innovative products.

1.4.1.4.1. Commercial prospective of bakery and confectionaries wastes

The surpluses of bakery and confectionaries are generally fed to animals or used for beer making, and if they could not be utilized, they are then sent to the bottom levels of the waste management hierarchy (composting, landfill etc.). However, numerous other valuable substances of commercial significance could be formed from the waste of bakery and confectionaries, these include enzymes, pigments, flavours, functional ingredients, micronutrients, nutraceuticals, active pharmaceutical ingredients, phytochemicals (plant based substances), biofuel and biomaterials.

1.4.1.5. Sugarcane

Sugar cane is the major source of table sugar (sucrose) in the sugar industry. Sugarcane main residues (wastes/by-products) generated and disposed of are:

- Cane tops (sugar industry produces ~200 million tons yearly)
- Trash (dried leaf bases) (sugar industry produces ~60 million tons yearly)
- Bagasse (sugar industry produces ~200 million tons yearly)
- Molasses (sugar industry produces ~16 million tons yearly)
- filter cake/press mud (sugar industry produces ~5 million tons yearly)

Products of great utility can be recovered from each of these residues, and 38 products derived from sugarcane as by-products was considered potentially important items for business(6).

1.4.1.6. Coffee

Large volumes of coffee processing by-products such coffee pulp and husk, are generated. From each tone of commercial coffee produced using dry processing treatment, 1 tone of husk is wasted. Coffee spent-ground, the residue obtained during the processing of raw coffee powder to prepare “instant coffee” is another waste from coffee.

1.4.1.7. Fruits and vegetables

The wastes/by-products from fruits and vegetables processing is estimated around 45%(7). These by-products include by-products in the form of peel/skin such as citrus fruit, mango, carrot, apple, grape etc., by-products in the form of pomace e.g. apple, grape, kiwi, pear, carrot, tomato, etc., and by-products in the form of seeds/kernels e.g. apricot, black currant, mango, tomato, etc. as shown in in Table 1.

1.4.1.8. Beverages

Generation of waste and by-products takes place at each step of the beverage life cycle. During beverage production a number of by-products are generated, which are often beneficially reused. Bagasse, pomace, spent grains, spilled products and wastewater are among these by-products.

For example, the spent grain from beer production and the peels from orange juice are sold as cattle feed.

1.4.1.8.1. Spent grain and its commercial significance

The residual solid fraction left during beer production is known as spent grain. By composition, it comprises lignocellulosic (lignin and cellulose) materials of 17% cellulose, 28% non-cellulosic polysaccharides (complex sugars from sources other than cellulose) and 28% lignin (8).

Spent grain represents around 31% of the original malt weight. For its high content in polysaccharides (complex sugars that after breakdown finally become simple sugars like glucose) and associated proteins and minerals, brewers spent grain is a source of high biotechnological value, which could be used in various ways including.

i. Substrate for cultivation of microorganisms: e.g. mushrooms, the single cell protein
ii. Substrate for enzyme (reaction accelerators): production of e.g. xylanase, a class of enzymes which degrade the linear polysaccharide/complex sugars
iii. Additive or carrier in brewing: e.g. reuse of spent grain as anti-foaming agent or as alternative for yeast immobilization
iv. Source of added value products: e.g. after break down of complex sugars in spent grain into their basic units (like glucose) and then the use of them as food grade-chemicals, as energy or in microbial fermentation.
v. Animal feed: this is the predominant application of brewers spent grain, mainly for cattle for its high content of fibre and protein
vi. Bioenergy production: this could be done either by direct combustion or by fermentation to produce biogas.

1.4.2. Animal based waste/by-products

Animal based waste /by-products in this context include meat, dairy, and fish and see food. Valuable food or food ingredients can be obtain from animal based waste/by-products

1.4.2.1. Meat products

The parts considered as waste/by-products in meat includes blood, fat, stomach, tendons, membranes, liver, heart, skin, bone, lung feathers and hair. Many of these materials are rich source of valuable components including protein, lipid and minerals.

The steps to stabilize these by-products are relatively low in cost and so the added value of the final product also remains quite low. These steps include washing, mincing, rendering, and smoking, slicing or soaking. By recovering any high value functional components (protein, lipids, proteoglycans etc.) from these by products may provide increased market opportunities for the meat sector.

1.4.2.2. Dairy products

Although it is now difficulty to label whey as a waste for its useful applications in the food industry, whey is the major by-product from dairy products.

In the UK buttermilk, is a low-value, underutilised co-stream (waste) generated following the manufacture of butter, with current UK volumes at least 40,000 tonne per annum. Butter oil (anhydrous milk fat; ghee) is recovered from buttermilk, the process itself generating 'waste' streams that may still contain polar lipids (e.g. phospholipids, a nutritionally important lipids with health and food application benefits) that may have a value if recovered.

1.4.2.3. Fish and seafood

At least 25-30% of the total fish or seafood weight goes wasted(9). Fish and seafood by products/wastes contain valuable components for different applications, these include proteins, peptides, collagen, gelatine, fatty acids, natural pigments, etc.

Chapter 2. Why food waste utilization is of interest

2.1. Overview

Approximately 33-50% of all food produced worldwide goes uneaten, and the value of this wasted food is worth over $1 trillion(10). When food is wasted that means waste of land, water, fossil fuel and the labour that was used to grow that food. Further, food waste leads to environmental problems, for example, due to excessive food wasted (besides other non-food related factors), rainforest deforestation and depletion of fish in oceans is a major issue in the world today. Application of The three "R", namely reduce, reuse and recycle make the food utilization an attracting and fitting topic to the concept of waste management and utilization, which EU nations and US started adhering strictly.

2.2. The need for food waste management

Waste management is one of the key issues that necessitates utilization of food waste and by-products. Some of the common approaches proposed for food and drink waste management include:

i. Prevention or reduction of food waste (very difficult, though).
ii. Reuse to feed people particularly hungry people "One person's food waste, another person's treasure" (https://www.youtube.com/watch?v=M4fu8a9JBvI), or for animal feeding if not palatable for human.
iii. Recycle for anaerobic digestion (AD) or composting (for farming fertilizers)
iv. Recover for energy by means of incineration
v. Dispose such as waste incinerated without energy recovery, waste sent to landfill and waste sent to sewer. The figure (4) below shows hierarchy of the steps for food waste utilization, green being the best and red the least.

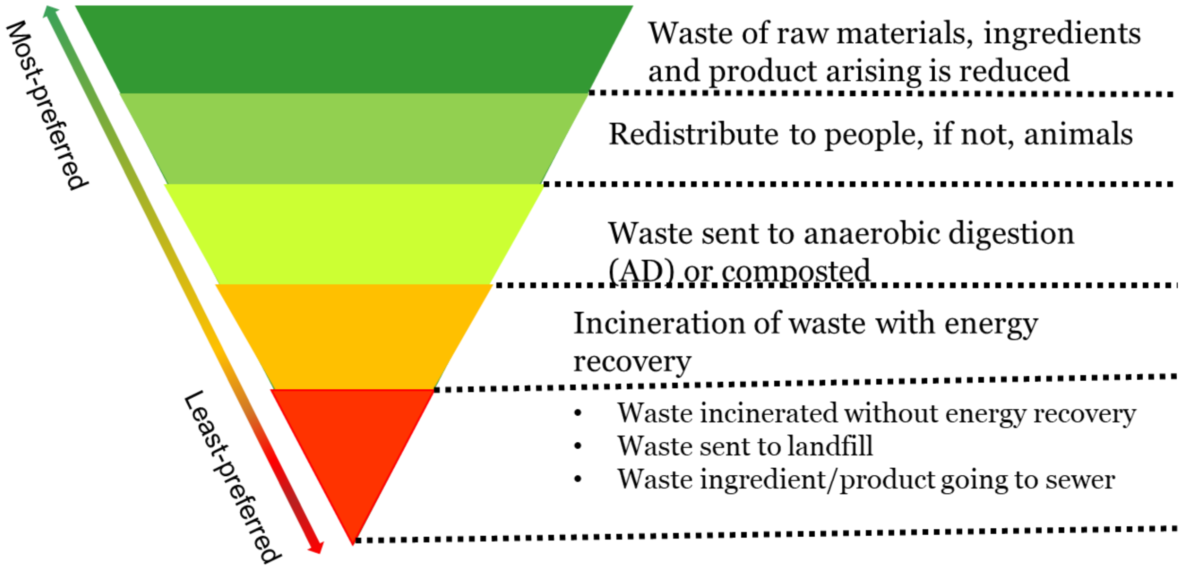
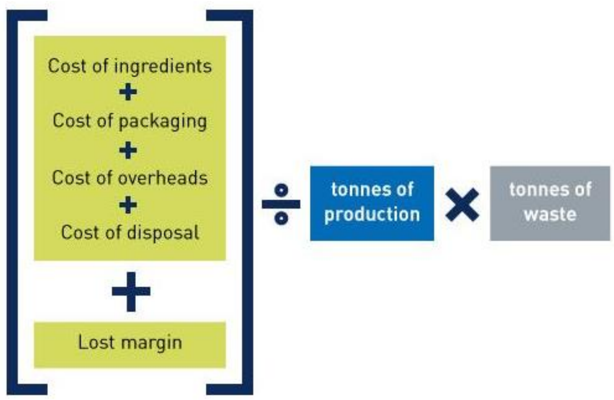


Figure 4 Amended from conference presentation (2016) by Roger Ibbett, University of Nottingham.

Waste and Resources Action Program (WRAP) has shown following as key actions to tackle and reduce food and drink wastes.

a. Measure the waste: Companies often do not have a real understanding of how much waste they actually producing.
b. Cost it properly: Companies cost calculations rarely provide the true cost of the waste and so WRAP recommends a true cost of waste calculations formula:



c. Set a target for waste reduction; challenge 'tolerance' levels, and ensure key performance indicators encourage the correct behaviour.
d. Take action on the highest waste areas
e. Embed a culture of waste prevention

2.3. Population growth

By 2050, India population will exceed that of China and the overall world population is expected to reach around 9 billion (currently around 7 billion). This population rapid increase is not compensated for surpluses food supply. Therefore, nations need to practice efficient methods for utilising available resources i.e. sustainable development approaches.

2.4. Decline in agricultural productivity

One of the important factors contributing to a significant agricultural productivity is the fertility of the soil. The continued trend in using chemical fertilizers to boost productivity is now considered a short term solution that has a big drawback in the future. This is because these chemicals have an adverse effect on the soil microbial flora and the chemical composition of the soil, which ultimately makes the soil infertile. Environmental changes due to the air pollution from gaseous emissions led to global warming and consequently low agricultural productivity. Food waste utilization, has therefore, the potential to provide additional food sources to fill the gap.

2.5. Underutilization of the available recourses

In most cases, the product of the interest is the main focus for any industry, with less or even no utilization of the by-products and wastes. An array of examples include, starch and potato processing, fruit and vegetables processing, oil crops, brewing and bread making etc. Lack of complete scientific knowledge of the biochemical composition of food wastes/by-products may be the reason why their utilization is currently limited.

2.6. Increased productivity cost

In addition to direct production costs, including raw materials, storage, processing, labour costs, utility bills etc., industries should also deal with their disposals and treat their waste streams before pouring it into the environment, which is an extra cost normally imposed by the local authorities. These costs cut into their profit margin and force these industries to add up into their production costs. For this reason companies lookout for economically viable technologies, cost-effective processes and cheaper input materials. As such, the idea of utilizing their own by-product either by reprocessing or selling to other companies becomes a priority for various industries to reduce their production costs.

2.7. Economic sustainability improvements

Effective waste management is crucial to increase profitability levels of food chain members. The principle is utilizing material that otherwise will have been thrown away and using that material in an efficient way. For instance, potato peels and processing waste water could be used for the recovery of phenols (bioactive compounds supposed to be antioxidants and consequently anti-aging). Cheese processing whey is another example, which could be used to produce monosaccharides (single sugars, such as glucose, galactose etc.)

Reuse of waste water is another economic improvement that could be obtained by recovering valuable compounds out food waste. For example, olive oil mill wastewater could be utilized as source of bioactive phenols and pectin.

The recovery of high added-value material could result in the development of innovative products.

Chapter 3. Where are we in food waste utilization?

3.1. Overview

Food waste has continued to spark global outcry as massive the levels of food wasted globally accounts for greenhouse gas emissions. The growing levels of activity in the effective management of food waste has continued to increase within the past few years as businesses are beginning to see the cost implication when it comes to dealing with food waste. The estimated output of wasted food globally amounts to 1.3 billion tonnes, with the UK contributing 15 million tonnes worth around £17bn each year to this figure. The good news is that some large, medium and small businesses are taking measures besides governmental partners and local authorities to tackle food waste issue by not only going green but also getting profit out of it.

Currently, the level of activity involves every kind and type of business, as different businesses have looked to tap into the valorisation trend when it comes to wasted food. It is known that when food is wasted, all the resources put into the production of food is wasted along with it.

Efforts are also underway to curb household generated food waste by better informing consumers how to interpret consumption related dates such as the “best before” and “use by” dates. The aim therefore is to minimize food waste at every stage of the food chain.

3.2. Market related information

Market related opportunities for the utilisation of food waste in the value chain lies in ability of businesses to find markets for converted food products. However big businesses, grocers and retailers at the upper end of the supply chain are the one taking the lead and pushing activities forward in the utilisation and reduction of food waste. According to Mintel, Leisure centres like Starbucks have recently joined movement by reducing the price of food items nearing their expiry date by 50%. This is in line with research that confirms that 82% of consumers who purchase food from leisure centres are interested in receiving discounts, and 40% of consumers are encouraged to visit more by offering a time limited discount. Starbucks and Pret a Manger, are in the line of improving brand image through charity by donating proceeds from food that could potentially go to waste, building up the companies goodwill.

3.3. Innovation, current activities and technology

Activities involving the utilisation of food waste are ongoing to create value from food waste. These have garnered activities from Individuals such as Chefs, start-up organisations, SME’s and majorly governments globally.

3.3.1. Individuals

Recently chefs have been actively involved in the food waste movement in order to change the attitudes of individuals towards rejected and wasted food ingredients in the UK. Some of such activities include the pop –up restaurant WastED created at Selfridges by Dan Barber to repurpose waste food that was classified as too ugly for sale, including stale bread, rejected pastries and the cooking liquid from canned chickpeas. Other activities includes educational movements such as that of James Oliver to offer cookery lessons teaching children to cook with every part of the ingredients and Skye Garnell and Merlin Labron that launched a six-course lunch made from edible food waste, including cut offs and fruit peelings.

3.3.2. Start-up activities in food waste Utilisation

Start-ups engaged in food waste utilization include ChicP that transforms leftover fruit and vegetables into hummus. The founder combined her hate for wasting food ad uses ugly vegetables and vegetables rejected by super market. The dips are available in UK stores and online and the company is looking to expand its business. The business is currently listed on Tesco BackI

t to reach more consumers and secure more suppliers, as the dips are only currently sold in the UK. Outside of the UK, companies have been involved in the utilization of waste. Danish fruit juice companies are investing in processing equipment to create value from the pulp waste. They are creating granules that can be used as natural additives to pancakes and other baked products. In Scotland, CuanTec, uses chitosan from shells and sea food waste to create biodegradable plastics for seafood products.

3.3.3. Information and communications technology (ICT) and food waste

Consumers and technology are also not left out in the battle against food waste. In a survey of 2051 grocery shoppers in the UK, 22% indicated that they would love to have applications that would help them with food waste, the second biggest reason why they would want food applications, the biggest reason was to help with grocery shopping and finding the cheapest deals.

In the digital world today, a smarter approach to reach out as many people as possible to make them aware of the importance of not wasting foods but instead utilizing it, is to create internet based networks like apps. According to the Guardian, Supermarket ASDA, has recently attempted to use technology to tackle food waste with the launch of an app (https://surplusswap.asda.com/?captcha=4c532) that allows suppliers to buy and sell excess produce.

Another app termed OLIO (https://olioex.com/) has also been launched, which allows neighbours, shops, cafes and markets within a geographical area to share surplus food for free or donate it to charity. Speaking to the Telegraph the app co-founder, Tessa Cook has been quoted saying, "We piloted the app in 2015, then made it available across the UK in

January 2016. “Since then we have reached more than 130,000 users and shared more than 175,000 food items – equivalent to more than 35 tonnes of food and 80,000 meals.”

Irish start up food cloud has also created an app that helps to curb food waste. The Dublin based startup has food cloud for retailers and food cloud hub for manufacturers. Retailers like Tesco and Aldi have adopted the service. The app aims to help communicate details on what surplus food is available and where and how it can be collected and distributed.

3.4. Renewable Energy

Food waste in recent years has garnered increased use for the generation of renewable energy, as the energy embedded in food waste can be recovered in various ways, especially anaerobic digestion and combustion. These biofuels produced are used to generate electricity and power vehicles. Renewable energy companies such as ReFood have established anaerobic digestion facilities around the UK. The company recently opened up a facility in Dagenham which is able to power 126000 homes per annum to add to its facilities for food waste recycling. Also, companies like Bavaria, Ben and jerrys and Lamb Weston produce biogas for electricity from wastewater, which is fed back into the electric grid.

3.5. Governments

Across the European Union, Funded projects for SME related food waste innovation are also ongoing, PUReOPE which is an EU eco innovation funding frame has developed a methodology for the extraction of phenolic compounds of high value from brewing, distilling and cereal production waste. Whey2value under the EU SME- instrument frame deals with cheese whey, aiming to bring to market a unique bio-process for the utilization of acid whey as a key ingredient in microbial fermentation to produce Vitamin B12. Across the EU, the agricultural industry has continued to put in place different practices to reduce food related waste. The EU aims to use 100% of agricultural raw materials, making use of parts that cannot go into the main product to create renewable energy feedstock or even animal feed.

3.6. Research

Research carried out by the University of Aberdeen indicates that the increase in the prices of food products has led to lesser amounts of food waste, keeping the average amount of food consumed constant. Also, studies carried out by the coalition 1.23 showed that businesses spending money on eliminating food waste and working towards food supply efficiency see a 14 fold return on investment. This study was carried out on 1200 business sites in 17 countries. The UK is one of the most active governments engaged in trying to reduce food waste and the government has been able to achieve a 20% reduction in food waste through its Love food hate waste campaign saving about 7.5 billion euros on purchase value of food and 99m euros in disposal costs for local governments.

3.7. Other notable uses of diverted food waste

3.7.1. Soil Enrichment

One of the ways in which food waste has been utilized is as bio-fertilizers in aiding soil enrichment, acting as an alternative to chemical fertilizers. This is often obtained from the digestate produced from composting and biogas creation. Also, the sludge from food and drink processing has also been used in the enrichment of soil.

*Examples of Ingredients and Chemicals:*Products and ingredients made from food waste include

- Aquafaba obtained from a can of chicpeas can be used as eggwhite replacement, other products that can be obtained include egg free mayonnaise, dairy free ice-cream and even soy-free cheese
- Pulp from cold-pressed juice can be repurposed as a cake dough for gluten free brownies, veggie burger and meat substitute
- dietary fibres created from vegetable waste
- fish oil obtained from fishery-by products,
- proteins gotten from cheese whey, meat processing and by-products of fish skin
- lycopene from tomato waste,
- oil and proanthocyanidins from grape sees,
- keratin extracted from the feathers of chickens,
- polyphenols from pine bark,
- flavonoids and sugars obtained from citrus peels
- yeast extract obtained from Sugar beet pulp
- Albumin from Soy protein Isolate
- Chitosan from shrimp Shells
- Antioxidants from Olive mill waste water
- By products from grape and coffee processing

3.8. Value chain: suppliers and retailers of food waste products

The value chain and market in the utilisation of food waste depends on the end product from the waste. Some of the end products made from waste utilisation, include ingredients, remodelled food or even animal feed when human consumption is not an alternative.

Examples of utilized and reprocessed waste include Potato processors using the cut-offs from the processing to create potato flakes and puree, other products from potato processing include hash browns and starch. The starch from the potatoes has applications in the starch manufacturing and utilisation industries. Sonnevald which is a dutch company is involved in the conversion of wasted bread into sourdough, and the company is moving to convince small bakeries to make use of this product and reduce food waste in the baking industry. Molson Coors, which is a beer producer in the UK, makes marmite and animal feed using excessive yeast, and has saved more than 60,000 pounds in landfill tax in two years.

Damhert uses whey from cheese to create tagatose which is a sweetener. PepsiCo factory in Leicester recovers starch from potato processing and uses it to make ingredients for quavers and walkers French fries. Trotec, which is a Belgian firm, converts plant based foods such as pastry bases, and incorrectly packed products into animal feed. Sugar producer Suiker Unie is currently piloting the production of bioplastics and bio-polystyrene from beet-pulp. Current activity by the European Technology platform, food for life suggests the creation of biodegradable packaging materials made of food waste as a future area of research consideration.

3.9. Key notes

Reducing and Repurposing food waste makes sense, as it increases profit margins. Chefs, Restaurants and businesses are involved in the innovation experience using food waste. Flavour innovation and repurposing of food waste could as a concept could get into mainstream foodservice. Globally, governments are also looking at developing measures to curb food waste

Chapter 4. Opportunities and options on food/drink waste

4.1. Overview

Food waste could be utilized in several ways such as raw materials for the production of new food products, food ingredients, for animal feeding, as food packaging materials, as commodity chemicals for other industries, as biofuel or energy source and as composting materials (soil fertilizers). When all these approaches are not possible, waste minimization to cut waste disposal costs is the least option; in this case food/drink waste ends up to landfill.

4.2. Food waste utilization- turn food waste into further food products

In numerous cases food waste is utilized as food or food ingredients. Examples include banana surplus (waste) as biscuits, use of wastes from fruits and vegetables as functional food ingredients, protein extraction from potato peels, and pectin recovery from citrus fruits, as well as other sources.

4.2.1. Fruits, vegetables and SPG

The wastes/by-products from fruits and vegetables processing is estimated around 45%(7). These by-products include by-products in the form of peel/skin such as citrus fruit, mango, carrot, apple, grape etc., by-products in the form of pomace e.g. apple, grape, kiwi, pear, carrot, tomato, etc., and by-products in the form of seeds/kernels e.g. apricot, black currant, mango, tomato, etc. as shown in in Table 1.

Table 1 Fruit and vegetable by-products and their valuable target compounds

Fruit/vegetable	By-product	Target Ingredients
Mandarin	Peel	Narirutin Essential oil (limonene)
Orange	Peel	Hesperidin, essential oil and cellulose
Mango	peel	Vitamins, polyphenols, enzymes and dietary fibre
Tomato	Peel	Carotenoids (lycopene, lutein, and β-carotene (vitamin A)
Lemon	By-product	Pectin
Apple	Pomace	Pectin

Peach	Pomace	Pectin
Kiwi	Pomace	Dietary fibre
Pear	Pomace	Dietary fibre
Grape	Pomace	Dietary fibre
Carrot	Pomace	Carotenoids (some being vitamin A)
Black currant	Seeds residue after oil extraction	phenols
Tomato	Seeds	Lycopene, dietary fibre
Mango	Seed kernels	Phenolic compounds
Apricot	Kernel	Protein
Cauliflower	Floret and curd	pectin
Broccoli	Leaves or stalks	Vitamin C, flavonoids

Source of the table: Galanakis (2015).

Valuable ingredient from these by-products include, dietary fibre, pectin, vitamin C, vitamin A (by means of carotenoids like β-carotene, which through enzymatic reactions is partially turned to vitamin A in vivo by most animals) and lycopene (the carotenoid that gives tomato its unique colour).

Phenolic compounds (acids), flavonoids, and polyphenols are other bioactive compounds found in fruit and vegetable by-products. These are compounds acting as antioxidants in the human body, which prevent from cell damage and aging. They could also be used as natural antioxidants to replace the synthetic (chemical) antioxidants used to preserve different foods e.g. oils.

4.2.1.1. Utilization of apple pomace

Apple pomace, the major by-product of apple cider and juice processing industries represents 25% of the original fruit mass. Apple pomace is rich in carbohydrates, pectin, crude fibre and minerals (11). There are several purposes of apple pomace utilization, including apple pomace as food product, as fuel, for pectin extraction and as cattle feed. In this context (this section) apple pomace is used as food product.

4.2.1.1.1. Apple pomace as food product

One of the approaches made to utilize apple pomace as a food product is making jam and sauce out of it. Another way is to make citric acid from the apple pomace. Pomace *papad*, a form of high value low volume product has also been made from apple pomace (11). A powder prepared from apple pomace has also been utilized in the confectionary industry. Replacement of apple pomace powder for soy meal in two types of mixed toffees has been successful without causing any vegetative effects on their quality.

4.2.2. Brewer’s spent grain (BSG)

Generation of waste and by-products takes place at each step of the beverage life cycle. During beverage production a number of by-products are generated, which are often beneficially reused. Bagasse, pomace, spent grains, spilled products and wastewater are among these by-products.

For example, the spent grain from beer production and the peels from orange juice are generally sold as cattle feed.

Brewers spent grain (BSG) can be incorporated into several human diets such as breads and snacks, particularly where there is need to boost the fibre contents. This may provide a number of advantages, since dietary fibres have been reported to contribute to the prevention of certain diseases including cancer, gastrointestinal disorders, diabetics and coronary heart disease (12). When 30% of BSG was incorporated into wheat flour for the production of high-fibre enriched bread, content of fibre was increased from 2.3 to 11.5%. The degree of softening and loaf volume were, however, lowered than control containing only wheat flour(12, 13).

4.2.2.1 BSG and its commercial significance

The residual solid fraction left during beer production is known as spent grain. By composition, it comprises lignocellulosic (lignin and cellulose) materials of about 17% cellulose, 28% non-cellulosic polysaccharides (complex sugars from sources other than cellulose) and 28% lignin (8). Figure 1 shows chemical composition of BSG as reported in the literature.

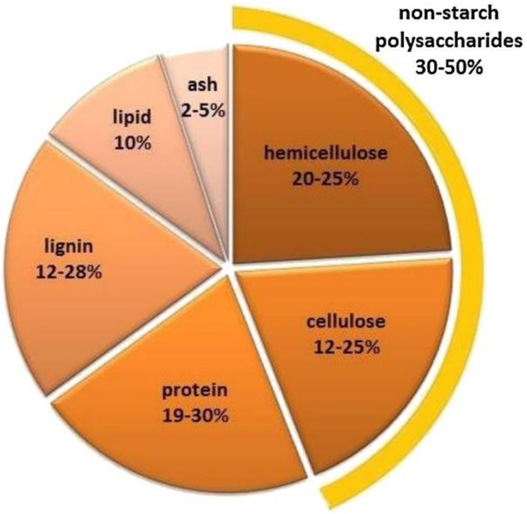


Figure 5.This figure was adapted from Lynch, Steffen (14)

BSG represents around 31% of the original malt weight. For its high content in polysaccharides (complex sugars that after breakdown finally become simple sugars like glucose) and associated proteins and minerals, BSG is a source of high biotechnological value, which could be used in various ways including.

i. Substrate for cultivation of microorganisms: e.g. mushrooms, the single cell protein
ii. Substrate for enzyme (reaction accelerators): production of e.g. xylanase, a class of enzymes which degrade the linear polysaccharide/complex sugars
iii. Additive or carrier in brewing: e.g. reuse of spent grain as anti-foaming agent or as alternative for yeast immobilization
iv. Source of added value products: e.g. after break down of complex sugars in spent grain into their basic units (like glucose) and then the use of them as food grade-chemicals, as energy or in microbial fermentation.
v. Animal feed: this is the predominant application of brewers spent grain, mainly for cattle for its high content of fibre and protein
vi. Bioenergy production: this could be done either by direct combustion or by fermentation to produce biogas.

4.2.2.2 BSG Preservation and Storage Techniques

Stability is a big issue in BSG and that is because of its high water content (77% to 81%), although different portions of the grain contain different moisture levels.

For its high water, protein and sugar contents which are ideal atmosphere for microbial growth, BSG is considered unstable material and deteriorates quickly. Thus, drying is considered the most effective method to reduce storage and transportation costs.

Some brewing companies are now using special plants to perform a 2-step drying process.

Step one uses a pressing technique to reduce the moisture level to 65% or below, and step two uses a drying-up technique to further reduce water content to below 10%.

This is a traditional method and it uses drum rotary dryers, an energy-intensive technique.

Three methods, namely freezing, freeze drying and oven drying was compared, and it was found that the use of freeze drying and oven drying reduced the product volume without changing its nutritional and chemical profiles.

Freezing was considered to be not economical method, with a large volume required for storage.

Oven drying technique, with temperatures higher than 60°C had also some limitations, leading to flavour deterioration and brow discoloration.

Membrane filter press is another new technique proposed. With this technique, BSG is thoroughly mixed in water, filtered at a pressure of 45 to 75psi, and washed with water at 65°C. The mixture is then filtered using nylon membrane and vacuum dried to minimize water levels up to 20% to 30% and then air drying for 2 days decreased moisture content to 10%, without microbial growth following the air drying (15).

4.2.2.3 BSG buttermilk biscuits, snakes and crackers

In a recent study BSG was combined into baked snacks (crispy-slices)(16). The nutritional, sensory and aromatic properties were then investigated. Wheat flour replacement of 10, 15, and 25% with spent grain was carried out. Snacks containing 10% BSG showed high crispiness index but unfavourable texture. Addition of BSG also altered the odour profile of the snacks, however, sensory results indicated that BSG at level of 10% were highly acceptable and emphasized the potential use of BSG as a baking ingredient (16).

The impact of 5% and 25% BSG in wheat flour when preparing cookies was also investigated. The results indicated increased fibre content with increasing BSG content. Due to the high fibre and antioxidants, the BSG-containing cookies also provided various human health benefits.

Brooklyn Brewshop, have already baked biscuits made from BSG with buttermilk, probably adding buttermilk to minimize the bitter taste (figure 2).

Figure 6 biscuit made from spent grain with buttermilk

This same shop managed to make some other cookie recipes all from BSG including macarons, thin mint cookies, chocolate almond biscotti, coconut pecan cookies, graham crackers, ruglelach and madeleines and spent grain cheddar crackers.

4.2.2.4 BSG Bread

These below Youtube Videos, illustrate how spent grain could be utilized for bread making

1) https://www.youtube.com/watch?v=chR33moKfiY

2) https://www.youtube.com/watch?v=QbTCvp2UIRE

3) https://www.youtube.com/watch?v=53zIjkMSgfU

4.2.2.5 BSG Sausages

In a recent study, smoked sausages with BSG plus mushrooms were prepared. Sensory studies of different formulations from mixture of smoked sausages, BSG and mushrooms were carried through. Formulations preferred by the sensory panellists were then selected and stored for shelf life analysis (17). Among all formulations, smoked sausages with mixture of 3% BSG and 8% mushrooms was the most appreciated by the panellists.

BSG was also used in low-fat high-fibre meat products.

4.2.2.6 BSG for Tarhana preparations

On the preparation of Tarhana, BSG was utilized to act as fermented wheat flour or yogurt product, which are necessary for Tarhana production. Milled BSG created satisfactory soup properties in Tarhana preparation. However lower sensory properties which could be compensated for by the increased fibre content in the end product was noted.

4.2.2.7 BSG for fibre rich pasta

A recent study by Cappa and Alamprese (18), valorised BSG in the production of a fibre enriched fresh egg pasta. Egg white powder was included in the preparation to improve pasta structure.

Results showed that BSG addition significantly lowered average break strain of the pasta compared to a standard formulation produced without fibre.

The addition of egg white powder also enhanced mechanical properties of cooked pasta because of the tighter protein network developed by egg albumin.

Researchers suggested that BSG with egg white powder can be successfully utilized in the production of fresh egg pasta, which is a source of fibre, therefore, contributing to a higher sustainability of brewing process.

4.2.2.8 BSG for cheap commercial protein

BSG was also utilized for protein preparation. A more recent study (19), utilized BSG through the preparation of protein co-precipitates with soybean flour to produce cheap commercial food grade protein with great nutritional, physical and functional properties.

Several ways that BSG could be utilized as food products was reviewed (14), and shown in Table 2.

Food	Processing/form of incorporated BSG (or Component)	Proportion BSG incorporated (% w/w)	Main finding (s)
Cookies	**Oven dried at various temperatures, milled and fractionated into specific flour components**	**10, 20, 30, 40**	**Cookies prepared with 20% sieved BSG (dried, 45C) had increased in certain nutrients (Protein by 55%, Lysine by 90% and Fibre by 220%) compared to control.**
Extruded snack (chickpea based)	Extruded	10, 20, 25, 30	Increased fibre and protein content. Phytic acid increased with BSG inclusion.
Bread (wheat), baker's yeast, kefir, *Lactobacillus casei* immobilised on BSG	Untreated, (autoclaving followed by microorganism immobilisation)	6, 8 and 10 BSG-yeast/BSG-kefir, 25, 35, 50 BSG-kefir (sourdough), 50 BSG-*Lb. casei*(sourdough)	Lower specific volume than yeast leavened control bread Sourdough breads had 4-day increased shelf-life Higher number and concentration of volatile compounds in sourdough compared with yeast-dough breads Sourdough had higher moisture retention during baking, lower rates of staling, maintained freshness for longer
Frankfurters (sausages)	Milled and sieved to various fractions	1, 3, 5 (fat substituted)	Dietary fibre and water holding capacity increased with increasing additions of BSG The textural parameters except springiness reduced because of the amount of BSG and the low level of fat
Bread	Flour produced by: extrusion and milling – untreated (Celluclast BG and Pentopan Mono BG added to dough) Extrusion and milling – treated with Celluclast BG and Pentopan Mono BG during extrusion	12	Enzymatic treated BSG in extruder – no effect on the characteristics of bread Untreated BSG with enzymes added to the dough – better texture and volume compared with control (e.g. reduced hardness)
Baked snacks (crispy-slices)	Flour	10, 15, 25	BSG addition increased the fibre and the protein content of the samples Addition of >10% BSG affected the texture – high levels of BSG led to a closed, compact structure BSG altered the odour profile in the snacks, compounds present in high levels in the BSG flour were observed in high levels in the BSG-containing snacks

Table 2 Application of BSG or constituent components in food products

	Use of 10% BSG resulted in snacks with similar texture and structure as the control and was accepted by panellists

This table was adapted from Lynch, Steffen (14)

4.2.3 Utilization of dairy processing waste/streams

Recently we have isolated and characterised functional and nutritional phospholipids (a class of lipids that are a major component of all cell membranes, which help two phases, for example, water and fat to mix and hence, the term emulsification) from underutilised dairy co-streams.

4.2.3.1 Composition of milk

The fat in milk (about 4% on a mass basis) is contained in tiny droplets (milk fat globules) a few microns, i.e. a thousandth of a millimetre, in diameter. They are covered by lipids derived from the secretory cells of mammary glands; these polar (able to mix with water) lipids include phospholipids and sphingolipids (similar to phospholipids but occur chiefly in the cell membranes of the brain and nervous tissue), which due to their chemistry, have the ability to stabilise fats/oils in water. When milk is processed into butter or cheese the water-rich waste steams contain milk fat with the attendant polar lipids.

Research into isolated milk polar lipids have suggested that they have important functional, nutritional and health benefits. These include attributes as natural emulsifiers, and as ingredients for cardiovascular (heart) health, cancer suppression and cholesterol reduction. The aim of the project was to test the hypothesis that 'waste' streams generated during butter oil production contain industrially relevant quantities of milk polar lipids.

Results suggested that polar lipids were present in all the samples provided by the industrial partner, including: phosphatidylcholine (PC); phosphatidylethanolamine (PE); phosphatidylinositol (PI); phosphatidylserine (PS); and sphingomyelin (SM). Since these polar lipids are reported to have specific functional properties at relatively low concentrations, the results from the project justify further work to recover these lipids from the waste streams of a butter-oil manufacturing site.

4.2.4 Food applications of oil crops by-products

Oil seed by-products such as, stems, pods, leaves, broken grains, hulls and cakes could be utilized not only for animal feed but also for human food preparations. For instance, hemp seed oil press-cake has already been used to increase the nutritional profile of gluten-free crackers (20)

4.2.4.1 Issues in oil crops by-products

- Safety: care should be given for the method of the extraction. Certain extraction methods using organic solvents like hexane might leave traces of the solvent still remaining in the by-products, which is not safe.
- Ant nutrients (digestion problem): Certain ant nutrients (e.g. tannins, phytic acid, saponins etc.) may limit nutrient conversion and utilization of these by-products for human consumption.

4.3.4.1. Possible solutions

One way to overcome safety issue caused by the organic solvents is to extract oil using mechanical methods like oil pressing. This is a traditional and simple method, however, the overall oil yield (output) in relation to the input might be inefficient (in case oil production is also important for the specific processing industry)

Another way is more sophisticated approach known as "supercritical fluid extraction" using CO2 as solvent instead of organic solvents. The CO2 is cheap but the supercritical instruments might be not cost-effective for certain enterprises.

For the antinutrients, fractionation of, for example, hemp flour by sieving to obtain the clearly differentiated fractions was found to be useful (21) .

4.2.5 Meat waste

The steps to stabilize, meat waste/by-products such as blood, fat, stomach, tendons, membranes, liver, heart, skin, bone, lung, feathers and hair include washing, mincing, rendering, smoking, slicing or soaking. By recovering any high value functional components (protein, lipids, proteoglycans etc.) from these by products may provide increased market opportunities for the meat sector. Examples of current uses of animal waste include:

Liver: Braised, broiled/grilled, fried, patty and sausage

Heart: Braised, cooked, luncheon, meat, patty, loaf

Skin: Gelatin

Blood: black pudding, sausages

Bone: Gelatin, soup, jellied products

Lung: Blood preparation, pet food

Feathers and hair: Feather or hair meal

These by-products have secured markets in some countries, but quite often low-value markets.

Example of utilized high added value products from meat industry include:

- high value protein with low ash, fat and cholesterol from **heart**
- Myofibrillar (type in the animal protein family) concentrates from **heart** as texturizing agents
- Purified protein as a food ingredient from **blood**
- Drug delivery materials from **skin**
- New kind of sausages from **banes**
- Possibility of replacement of ostrich hip to the non-functioning human hip (**bones**).
- Protein concentrates with good functional properties from **lungs**
- Culture media, separation membranes from **feathers/hair**

4.3 Food waste utilization for further functional food ingredients

Several food ingredients can be recovered from food waste. Some of these ingredients include sugars, proteins, yeast, vinegar, citric acid, pectin, peptides, collagen, gelatine, fatty acid, phenolic compounds etc. All these ingredients are very important in the food industry and food businesses.

4.3.1 Stale bread utilization

Stale bread can be utilized in several ways to produce valuable ingredients such production of glucose, protein and yeast.

4.3.1.1Production of glucose

A known amount of stale bread (e.g. 2400 gram) is mixed with a known volume of water (e.g. 2000 litre) in a thermostatic tank. Carbohydrate (starch) digesting enzymes such as alpha-amylase is then added for liquefaction (to form liquid flow) process at around 70˚C for 3 hours at pH 5.2, followed by saccharification (sugar production) using amyloglucosidase (sugar converting enzyme) at 60 ˚C over a period of 16 hours. During this step almost 80% of the starch is expected to be hydrolysed (broken and released). Assuming that of the starting bread 1680 kg are starch, 1493 kg glucose is obtained.

4.3.1.2. Production of protein

To recover protein, the suspension was hydrolysed by a protease (protein bonds breaking agents) enzymes, at 45, pH ˚C 5.2 over 21 hours, and 70% of the protein was recovered, then protease was inactivated by heating at 100 ˚C for 30 min. After this, the insoluble solids (mainly fibres) was separated by a decantation (separation of mixtures) step.

4.3.1.3. Production of yeast

Aerobic and anaerobic fermentation *using Lactobacillus delbruckii* was used to ferment the hydrolysed suspension for 24 hours during, which the pH decreased to 4.0. The fermentation process yielded 7.6 kg of dry yeast from the aerobic fermentation and 3.2 kg from the anaerobic one.

4.3.2 Production of vinegar from cooked rice, vegetables, meat and eggs

Commercial production of vinegar using biofilm reactors as a bioconversion technology has been exercised for many years(22). Using yeast and bacteria (acetic acid bacteria) Yang et al (23), produced vinegar from food waste containing a collection of cooked rice, vegetables, meat and eggs, which was obtained from local businesses.

4.3.3 Production of citric acid from breweries' spent grain

Citric acid is the most important acid used in food industries. It is chiefly produced from lemon and lime juices production. Alternatively, using fungus (*Aspergillus niger*) with BSG resulted in production of citric acid of about 19 g/L, representing a yield of 78.5% (24)

4.3.4 Production of pectin from apple pomace

Because of its applications in many food products, pectin is a very important ingredient in the food industry. One of the main applications of pectin is its use as gelling agent in jams and jellies, but also utilized as a thickener, texturizer, emulsifier and stabilizer in the food industry. Pomace, the major by-product from apple juice and cider industry is a good source of pectin and other nutritionally important ingredients. Miceli-Garcia (25) extract pectin from apple pomace and used as a wall material component for the encapsulation of alpha-tocopherol acetate (vitamin E) to extent the shelf life of the product.

4.3.5. Production of protein from fish washing water

Surimi (imitation crab) waste water (2.3% protein), for instance, contains myofibrillar (contractible muscle fibres) protein obtained from fish flesh due to extensive water washing. Oral feeding of peptides (a group of peptides form the protein) extracted from sales of sea bream indicated a decrease in blood pressure in laboratory rats (26).

4.3.6. Production of peptides from fish wastes

Peptides from fish wastes have been used to form new biofilms, which could be used as edible food coating and able to extend the shelf-life of food products (27, 28).

4.3.7 Production of collagen from fish skin

Collagen obtained from fish skin has numerous applications in cosmetic industry and medicine, and could act as alternative to mammalian collagen.

4.3.8 Production of gelatine

The low gelling strength and temperature as well as, good swelling capacity characterized in fish skin gelatine allows them to be used in capsules of controlled drug (29)

4.3.9. Production of fatty acids from fish wastes

The health benefits of oils and fatty acids from fish and seafood by-products such as head, intestine and liver (30), is generally attributed to the omega-3 type fatty acids it contains. Linolenic (ALA, 18:3 omega-3), eicosapentaenoic (EPA, 20:5n-3), and docosahexaenoic acids (DHA, 22:6 n-3) are the main omega-3 poly unsaturated fatty acids in fish and seafood by-products.

4.3.10 Production of natural pigments from fish wastes

The colour of many fish species is due to the presence of carotenoids. Natural carotenoids can be used as supplements, pigments or as a source of vitamin A. Astaxanthin is the predominant carotenoid of many marine fish species (e.g. Salmon) and it is a powerful antioxidant, with anticancer and photo-protective effect (31).

4.3.11 Coffee waste as a source for natural colorants

Restrictions on the use of synthetic colorants due to safety issues resulted in significant increase in the interest in natural colorants. During processing the colour of coffee husks is rapidly degraded by the action of enzymes and oxidizing agents (e.g. oxygen). Thus large quantities of natural colorants are wasted in the process, which could be utilized as natural antioxidants.

4.4 Food waste utilization- turn food waste into feed for animals

Food wastes such as, surpluses of bakery and confectionaries, wastes from breweries (spent grains) and dairy industries (whey) including other food industry wastes are generally used for animal feed. Examples of other industries whose food waste/ by-products are fed to animals include sugar, coffee and fruits and vegetables processing industries.

4.4.1 Utilization of apple pomace for cattle feed

Utilization of apple pomace as cattle feed is a well-known method applied throughout ages. Overall quality of cattle feed from apple pomace was found to be greater when compared to a control feed (a more routinely used feed for cattle as standard feed). Results showed that when 39% of apple pomace was replaced with control feed, cattle body weight was better compared to the control. It was also observed that apple pomace fed cattle showed increased protein content but decreased lactose content in their milk. The feed cost per kg milk production was higher with apple pomace feeding but the gross income (total milk cost minus total feed cost) was higher with apple pomace feeding.

4.4.2 Utilization of coffee waste for animal feed

Large volumes of coffee processing by-products such coffee pulp and husk, are generated. From each tone of commercial coffee produced using dry processing treatment, 1 tone of husk is wasted. Coffee spent-ground, the residue obtained during the processing of raw coffee powder to prepare "instant coffee" is another waste from coffee. Provided that anti nutritional factors are removed, coffee pulp/husk could be used as an animal nutrient/feed supplement.

4.4.3 Utilization of funky foods for fish feeding

In a collaborative project between EU and Indian partners (with the name NAMASTE), funky foods made from fruit by products have been utilized. From this project 15 types of carp and ornamental fish feed has been formulated.

4.4.4 Feeding food waste to insects to feed animals for protein

The product, MagMeal, by the South African firm, AgriProtein is a protein substitute for fishmeal currently used in aquaculture. The firm has recently opened headquarters in London and came up with an animal feed ingredient prepared from fly larvae reared on food waste. The firm, which won the inaugural BBC food Chain Global Champion Award, claims that the product is a natural and sustainable alternative that will never run out "as long as humans produce waste".

AgriProtein invests fly farm businesses, currently growing in a number of countries with a supply of 100 billion aquafeed market to create feed for poultry, pigs and pet food. For details, one may visit the home page of the firm http://agriprotein.com/. The figure (6) illustrates the process of protein production from food waste fed to insects.

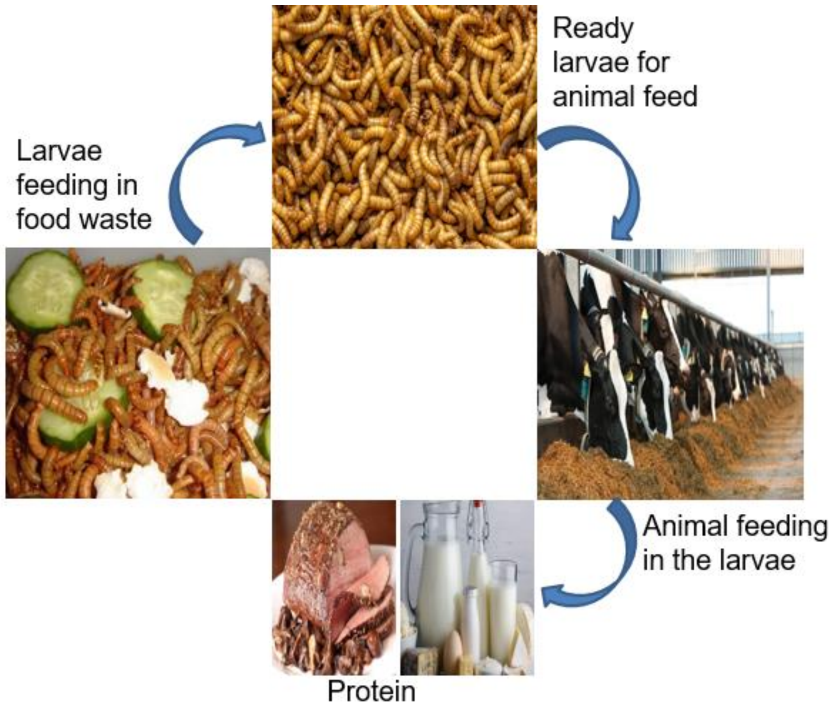


Figure 7 Rearing insects using food waste to feed animals for protein

4.5 Food waste utilization- turn food waste into packaging materials

There are two distinct categories of packaging materials, which are rigid such as glass, jars, cans, wooden boxes and some plastic boxes. The other category, which is generally flexible includes, plastic films, vegetables fibres, foils, and paper. Plastic materials are one of the mainly used materials for food packaging. Typical materials in which these plastics comprise as their basic units include Polyethylene (PE), High Density Polyethylene (HDP), Polyethylene terephthalate (PET), Polyvinyl chloride (PVC), Polystyrene (PS) and Poly Carbonate (PC).

Food waste utilization for packaging comes under the umbrella of biodegradable packaging, however, there are two types of biodegradable materials, which are biodegradable polymers and biodegradable biopolymers. The former (polymers) are synthetic polymers which either have certain degrees of inherent biodegradability (e.g. polycaprolactone, polyhydroxybutyrate and vinyl alcohol) or chemically modified plastics to assist biodegradation. The later (biopolymers), are naturally occurring material such as cellulose (consists of long chain simple sugars like glucose), polysaccharides (long chain sugars or complex sugars such as, glucose, galactose, arabinose etc.) and proteins (e.g. biofilms, which could be used as edible food coating and able to extend the shelf-life of food products from peptides originally obtained from fish waste). This below Figure (7) represents food waste that could be used as biopolymers for packaging.

Figure 8 Turning food waste to food packaging materials, source: http://nirvanacph.com/2017/07/material-monday-food-packaging-compostable-disposables/

An example of food waste turned into food packaging materials is bagasse, a sugar cane processing by-product. Major by-products of sugar cane include cane tops, bagasse, filter muds, and molasses. In this case, bagasse is the material which is suitable for food packaging.

The fibrous residue of the cane stalk left after crushing and extraction of juice is known as Bagasse. By composition, fibre (including ash) represents 48%, moisture 50% and soluble solids 2.0%. The fibre comprises mainly of cellulose (27%), pentosans (30%), lignin (20%) and ash (3%). Apart from food packaging, there are a number of other ways that bagasse could be utilized such as, charcoal production, electricity generation, production of particle board, paper, chemicals (e.g. furfural and methane)(32).

A number of UK companies are producing food packaging materials from food waste, mostly plant based (e.g. from bagasse). Some of these companies are manufactures and others are retailers (below links):

i. Biopac: http://www.biopac.co.uk/
ii. Comp bio: http://www.comp-bio.co.uk/
iii. VaioPak Group Limited: http://www.vaiopak.co.uk
iv. Vegware: https://www.vegware.com/
v. KCC : http://www.k-c-c.co.uk/
vi. Packwood: http://packnwood.co.uk/
vii. Trinity Food Packaging Ltd: http://www.trinityfoodpackaging.co.uk/

Products produced from the food wastes (sugar cane bagasse, wheat straw, potato peels, corn etc.) include cups (for hot or cold drinks), take away containers, plates, bowls and trays, and cutlery (Figure 8).

Figure 9 Containers, bags and cutleries made from bagasse

4.5.1 Bio-plastics

EU-funded project (BIO-BOARD) has developed an innovative solution that ensures that the packaging is both easily biodegradable and produced in a sustainable way. Researchers in this project have developed biomaterials to replace polyethylene coatings made from little-used or used by-products of food processing industry, such whey from cheese-making and potato juice from starch production.

An Israel based company (TIPA) which recently landed in the UK, also involves in developing biodegradable films from plant based materials, food waste included. The company claims that its films are fully compostable, with similar good quality packaging properties as fossil fuel based plastics, in terms of, shelf life and durability, transparency, printability, and flexibility. Their marketing statement reads: "TIPA biodegradable plastic decomposes like orange peel when thrown away" and as in the figure (9).

Figure 10 Composability of bioplastics developed by TIPA

4.6 Food waste utilization- turn food waste into biofuel/bioenergy

A number of UK and international companies /businesses produce bio-fuel/bioenergy from food waste such as bagasse, coffee ground, fruit pomace, dairy waste water and brewery's waste water.

4.6.1. Bagasse for bio-fuel/bioenergy

Traditionally countries such as India and Sudan, for instance, produce cooking fuel from Bagasse after pelleting**.** See how to make these pellets out of Bagasse (https://www.youtube.com/watch?v=SIxTrJAkvDQ). However, generation of electricity from bagasse is the more straightforward solution. This solution attracted a number of cane producing countries such Australia, Brazil, Hawaii, Reunion Island, and Mauritius. Using a modern equipment, about 450kWh can now be produced from a tonne of mill-ran bagasse. Various types of bagasse boilers could be selected from this link https://www.alibaba.com/showroom/bagasse-boiler.html.

4.6.1.1. Production of methane from Bagasse

Methane (CH_4) and carbon dioxide are the main gaseous products of the anaerobic methane fermentation of waste and cellulosic materials. Theoretically 1 kg of cellulose would produce 415 litres of methane, but in practice the process is less efficient with a complex three-stage reaction operating in cascade and not always easy to manage.

Cellulose is, normally, easily digested by bacteria. However when it is combined with lignin, as in bagasse, it is degraded only with great difficulty. Hence, a biogas digester in the sugar industry should be planned to operate mainly on distillery stillage or feedlot effluents with a small addition of surplus pith, and not on bagasse as the only or main raw material.

4.6.1.2. Production of ethanol from Bagasse

Ethanol can be produced from various food waste (bio-waste) materials, particularly those that are rich in carbohydrates through fermentation process. For instance, in one case, a mashed potatoes, sweet corn and white bread left overs were used to produce ethanol, and a high concentration of ethanol (144g/L) was obtained(33).

Ethanol is an excellent transportation fuel and blends of it with gasoline provides oxygen for fuel, resulting in a more complete combustion with a low atmospheric photochemical reactivity and consequently cleaner environment.

4.6.2. Apple pomace as bio-fuel

After drying, the apple pomace can be used as fuel for steam generation in processing plants, which will help to reduce not only the cost of the energy by means of reduction in fossil fuel but also reduces the waste disposal costs.

4.6.3. Coffee grounds waste for bio-fuel/bioenergy

Coffee husks and hulls could be used as a potential raw material for bio-ethanol or biodiesel production as they contain high concentrations of carbohydrates.

Bio- bean (http://www.bio-bean.com) is a UK company based in London and is the first in the world industrialising the process of recycling waste coffee grounds to produce biofuels.

In collaboration with the existing energy and waste infrastructure, the company collects spent coffee grounds from coffee factories and coffee shops and then recycles them into sustainable and valuable products to displace traditional fuels.

4.6.3.1. Where Bio-bean obtains the coffee waste

The company has recently contracted with Costa Coffee to send their coffee waste to Bio-bean. Currently Bio-bean collects 3000 tonnes of waste coffee grounds a year over 800 Costa locations across UK.

Previously Costa used to send its waste coffee to anaerobic digesters. After sending the coffee waste to Bio-bean, Costa produces 30% less emissions than anaerobic digestion, which led to the prevention of 360 tonnes of CO2e from entering the atmosphere per year. This is equivalent to planting a forest the size of 95 football pitches.

Other businesses that Bio-bean has contracted with and collected their coffee ground wastes include Network Rail, Vacherin, Petersham Nurseries, Kahaila Café and Eversheds Sutherland.

4.6.3.2. What Products does Bio-bean produce from coffee waste?

Some of the products that bio-bean produces from the waste of coffee grounds, which was developed into commercial applications are coffee logs (briquettes), coffee pellets and biodiesel.

4.6.4. Dairy waste water

The below diagram (Figure 10) is hybrid of microorganisms together with anaerobic digestion from H2AD Lindhurst company, which cleans up the waste effluents using the microorganisms or as the company calls "the power of microbes", and at the same time generates bioenergy in the form of biogas and fertilisers.

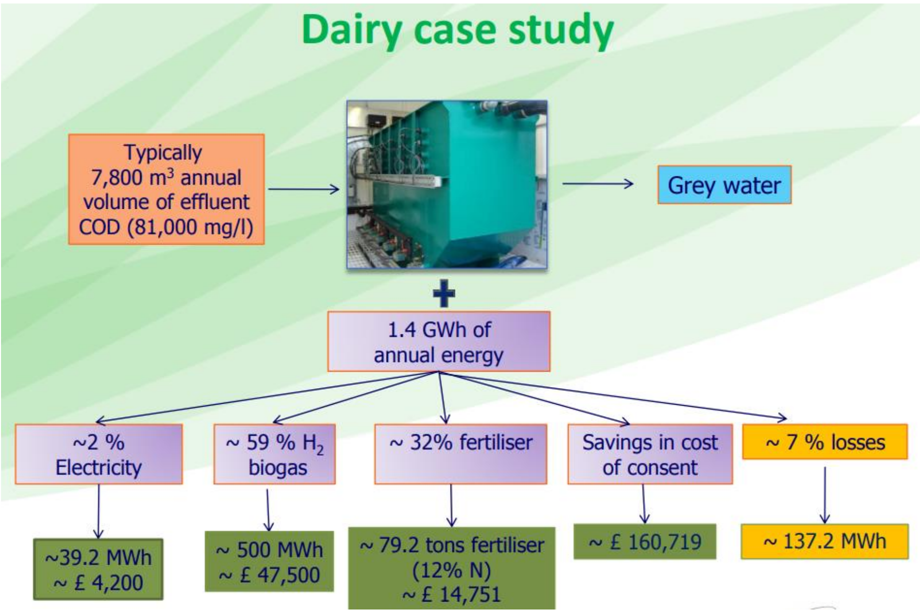


Figure 11 Diagram of how dairy waste could be utilized using H2AD Sourced from Lindhurst Innovation Engineers

http://www.nottingham.ac.uk/etc/pdfs/EUSEW2012/Lindhurst.pdf

4.6.5. Brewers' waste water

The composition of brewing effluent can fluctuate significantly as it depends on various processes that take place within the brewery, however, the amount of wastewater produced depends on the water consumption during process. In general, water consumption per volume of produced beer is ~4.7 L (water)/L (beer). However, it should be noted that waste water to beer ratio is often 1.2L/L less. This is because part of the water is disposed of with by-product and lost by evaporation(34).

Organic compounds in brewery effluent are generally easily biodegradable and mainly comprised of sugars, soluble starch, ethanol, volatile compounds (e.g. fatty acids) leading to low biological oxygen demand (BOD) and chemical oxygen demand (COD) ratio of about 0.6 to 0.7.

The effluent solids consists of spent grain, kieselguhr, waste yeast, and "hot" trub. The pH levels depend on the amount and type of chemicals used at the clean in place (CIP) units such as caustic soda, phosphoric acid and nitric acid. Nitrogen (N2) and phosphorous levels are mainly determined by the handling of raw material and the amount of spent yeast present in the CIP unit.

Brewers' waste water treatment and cost in the UK depends on the location of the certain production line. If the brewery is in the middle of a city, there is a higher chance of merging your effluent into the municipal water system, and if pre-treated slightly, local authorities might not have a problem with it, consequently paying lower charges. However, if a certain brewery business locates in a countryside, the cost for their waste water treatment might go higher, as this requires construction of own drainage system .

4.6.5.1. Brewers' waste water utilization

Craft brewers end up with an average of 3 litres of waste water per 1 litre of beer produced. Despite this volume of waste water is low compared to large brewery average of 7 litres of waste water per 1 litre of beer produced, it is still taxable to local water treatment facilities and can lead to environmental issues unless treated properly.

Requirements on waste water treatments depends on the business size, waste water flow and freight. While small businesses may only remove solids, large brewers must usually reduce their chemical oxygen demand (COD) and biochemical oxygen demand (BOD) freights as well.

One simple solution for smaller craft breweries may be sending wastewater to empty fermentation tank so that solids can settle before the wastewater is pumped out to the sewer. However, if it is economically feasible (i.e. the technology required and cost), excellent treated waste water can be reused as process, for example, for washing empty bottles etc.

Suez water UK (https://www.suezwater.co.uk) is a UK company dealing with industrial services and solutions towards wastewater. Another more specific to brewers' wastewater is Huber Solutions (http://www.huber.co.uk), a waste management company offering full range of equipment for various scales of businesses.

4.6.5.2. Anaerobic digestion (AD) brewers' waste treatment

One approach to produce effluent clean enough to enter a water treatment plant is the use of microbes in a closed system, which means it is treated without oxygen or anaerobic digestion (AD). Basically, microbes consume the organic waste and turn it into biogas (methane) and carbon dioxide (CO2). The CO2 can be released into the atmosphere safely, and the methane can be used to generate power for the brewery.

4.6.6. Farm waste and animal fat as biofuel for airplanes

Trying to reduce air pollution, United Airlines is using a biofuel mix from traditional jet fuel, agricultural waste and animal fats. Details could be accessed from this link http://blogs.discovermagazine.com/scienceandfood/2015/09/10/jet-fuel-food-waste/#.Wckim8iGPcs .

4.7 Food waste utilization- turn food waste into compost

4.7.1 Coffee husks for composting

Despite the issues (presence of toxic phenolic compounds) in direct land disposal of coffee by-products, they are traditionally used as organic compost. It was reported that coffee waste can be an alternative fertilizer with soil improving properties for certain type of soils like sandy soils in certain humid tropical environments (35).

4.7.1.1 Coffee husks for cultivation of mushrooms

Coffee husks could be used for mushrooms cultivation. Fungal species (mushrooms) resulted in increase in the protein content and decrease in fibre content of coffee husk. Therefore, it was proposed that after cultivation, the residue could be used for feeding to ruminants (cow sheep etc.) because several toxic compounds like caffeine was decreased by the fungal species and protein increased up to 9.62% (36). In general, several types of food wastes could be utilized for soil fertilization. In Figure 11, food waste is cycled for compost, which finally yields food for human.

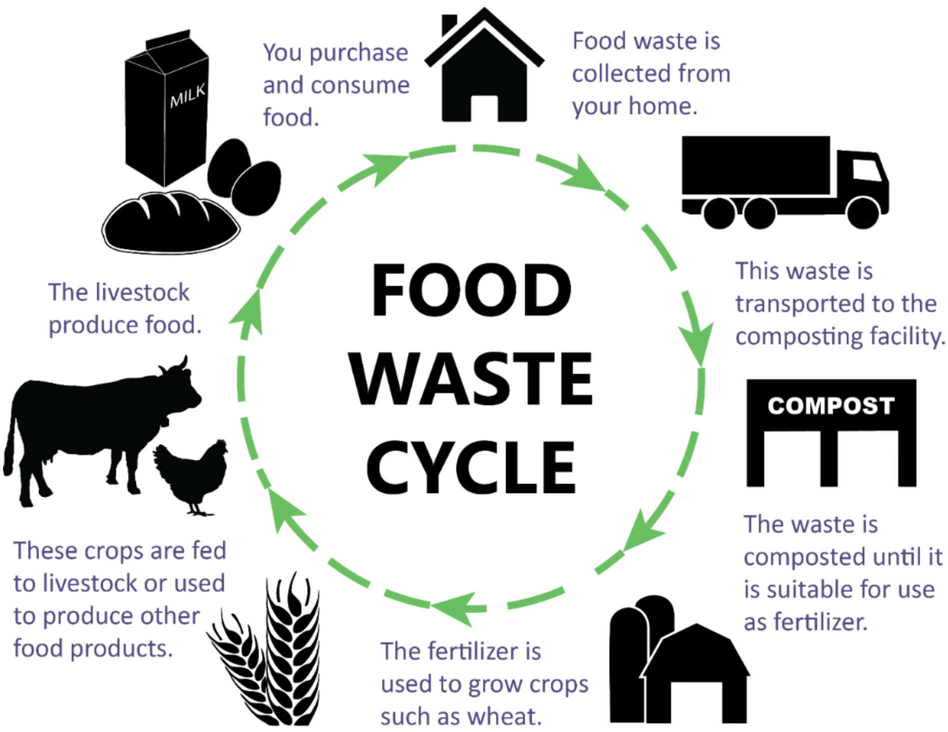


Figure 12 Food waste cycle, Source: Environment. (2017, Nov.15) http://www.salmonarm.ca/index.aspx?NID=356&PREVIEW=YES

4.8 Food waste utilization- turn food waste into miscellaneous uses

In the above sections, food waste was used as new food products, new functional food ingredients, as feed for animals, as packaging materials, as biofuel/bio-energy and as soil fertilizers, in this section, however, food waste usage for other applications such as particle board, paper, cosmetics, building materials etc. is presented.

4.8.1 Bagasse as particle board

Shell laminates Pvt.Ltd is an Indian company involved in this business. Particle boards are one of the well proven technology made from bagasse, which may compete with plywood and fibreboards. Its main issue is the cost (high) of imported synthetic resin used as binding materials for bagasse fibres. The optimal thickness (15 mm) is another issue limiting its outdoor uses and making its main market to inner partitions and furniture.

A Germany firm, Portland cement has replaced the urea formaldehyde resins, enabling this cement-bonded particle board to be used for exterior walls, roofing, etc., which increases its market appeal.

4.8.2 Bagasse as a paper

GreenLine Paper Company is an Indian company producing paper from Bagasse

(https://www.greenlinepaper.com/bagasse-products.html).

Wrapping and magazine paper with good quality can be produced from bagasse as raw material. In order to produce newsprint made from bagasse, a fair percentage of waste paper may be mixed.

4.8.3 Oil crops by-products as cosmetics

These include using proteins from oil seed by-products for cosmetic and pharmaceutical industries.

Biopolymers e.g. proteins, polysaccharides (sugars), lipids or their combinations recovered from oil seed and pulse as wastages could be used for the preparation of biodegradable films (e.g. soya protein is the superior in this regard)

4.8.4 Spent grains as building material

The use of spent grains to increase the porosity in brick has been proposed. In fact, some laboratory experiments supported that the addition of sawdust, commonly used in the brick-making process to increase porosity, can be replaced with spent grains.

4.9 Key Notes

As discussed in this chapter and shown in Figure 12, food/drink waste could be utilized in a number of different approaches.

An SME could also utilize its waste not only by producing new products but also by reusing it (recycling the food/drink waste) as in Figure 12. For instance, brewer's empty bottles could be reused by means of promising incentives for any customer who commits to return their empty bottle. Similarly egg packaging trays could also be recycled.

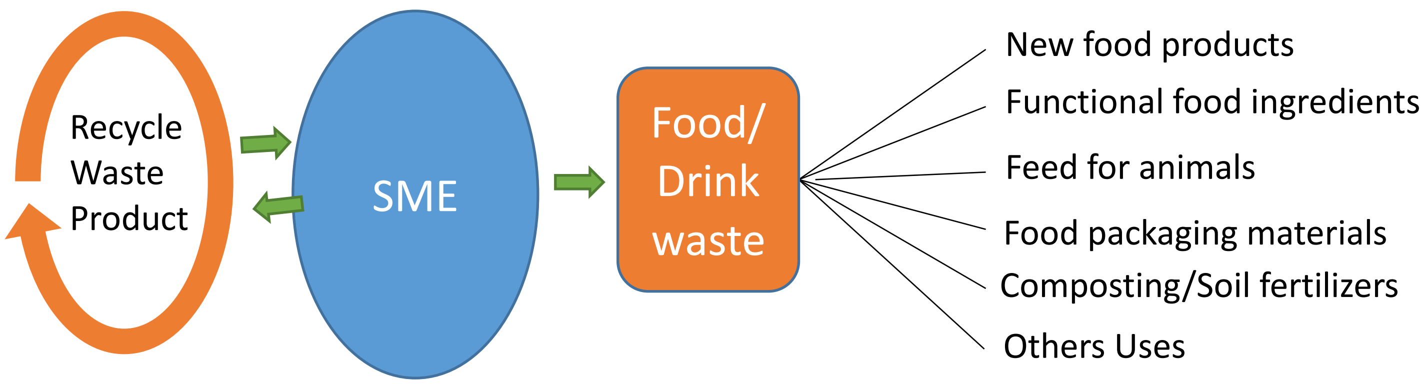


Figure 13 several approached of food/drink waste utilization

Chapter 5. Regulations on food waste

5.1. Regulations on food wastes/ food by-products

The systematic reuse of waste and by-products is of great significance for sustainable utilization of natural resources including food and drinks. However, this requires to comply with the regulations of general food waste disposal and production of ingredients that will not negatively affect consumers (mainly risk of human health).

5.1. European Union

In the field of waste management the European Commission (EC 2008, 199) has formulated instrument known as “The Thematic Strategy on the Prevention and Recycling of waste”.

The act obligates each member state to handle waste without posting a negative impact on human health or the environment.

UK waste management legislation and policies were developed based on “The EU Waste Framework Directive” and associated directives on specific waste.

Uk’s waste policy is reflected in the Waste Strategy for England 2007 by the Department for Environment, Food and Rural Affairs (DEFRA).

Due to waste regulations food waste disposal causes huge expenses during each step in the supply chain. However, if reduction or reprocessing of food waste to create value added products is plausible, production costs may be compensated.

5.1.1. Animal by-product regulations 2005 (No.2347 Animals, England)

These regulations update the Animal By-product Regulations 2003. Details of these regulation can be accessed from this link.

(http://www.legislation.gov.uk/uksi/2005/2347/contents/made)

5.1.1.1. Regulations on insect based nutrients

New EU regulations issued since July 1 2017 allow the use of insect-based nutrients in aquafeed (EU N^{O} 2017/893). This was also widely permitted in other parties of the world, some consuming insects themselves already. Figure 6 demonstrates EU legal opportunities of which type of food waste to feed insects and for which animal, to produce which type of nutrient? Some companies like MagMeal (chapter 4) produced AgroProtein from insects reared with food waste.

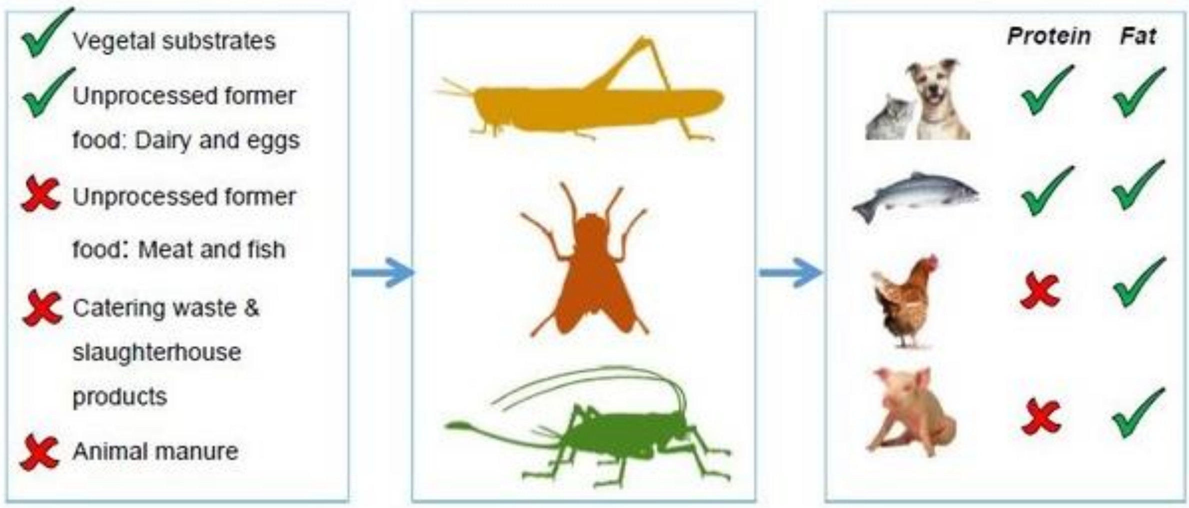


Figure 14 EU legal opportunities for the use of insect processed animal protein (sourced from http://www.ipiff.org/our-positions)

As in the Figure (6), it is permitted to feed vegetable and unprocessed former food wastes to insects as animal feed stocks. However, insects fed with food wastes from meat and fish, slaughterhouse or animal manure, is only permitted for certain type of animals and for fat production only but not for protein.

Chapter 6. Food/drink waste product/services

6.1. Food/drink waste services

Several waste recycling services dealing with food and drink waste exist in the region of Nottingham/Nottinghamshire and Derby/Derbyshire. Waste Cycle (https://www.wastecycle.co.uk/) based in Nottingham is one that can provide a full food waste segregated collection service.

Similar service to that of Waste Cycle is being offered by Bio Dynamic UK (http://www.biodynamicuk.com/index.html), a recycling company with the focus on renewable energy.

The food waste that Waste Cycle and Bio Dynamic UK collect is directed to either a fully permitted in-vessel composting or anaerobic digestion facility, where it is used to produce a soil fertilizer product, as well as recover energy as shown in Figure 10.

Business Waste (https://www.businesswaste.co.uk/food-waste/) is also among the food waste management companies in Nottingham, promising you to save up to 20% of your waste disposal costs.

In addition, Suez (http://suez.co.uk/#home), a UK and global waste recycling company, offers food waste collection services, which according to their claims, helps SMEs avoid rising costs of landfill tax, as well as reduce business' negative impact on the environment. In 2016, Suez recycling and recovery materials in the UK alone reached ~8 million tonnes, from which about 1.1 million megawatt hours of electricity was generated, with around 134 thousand tonnes of compost produced.

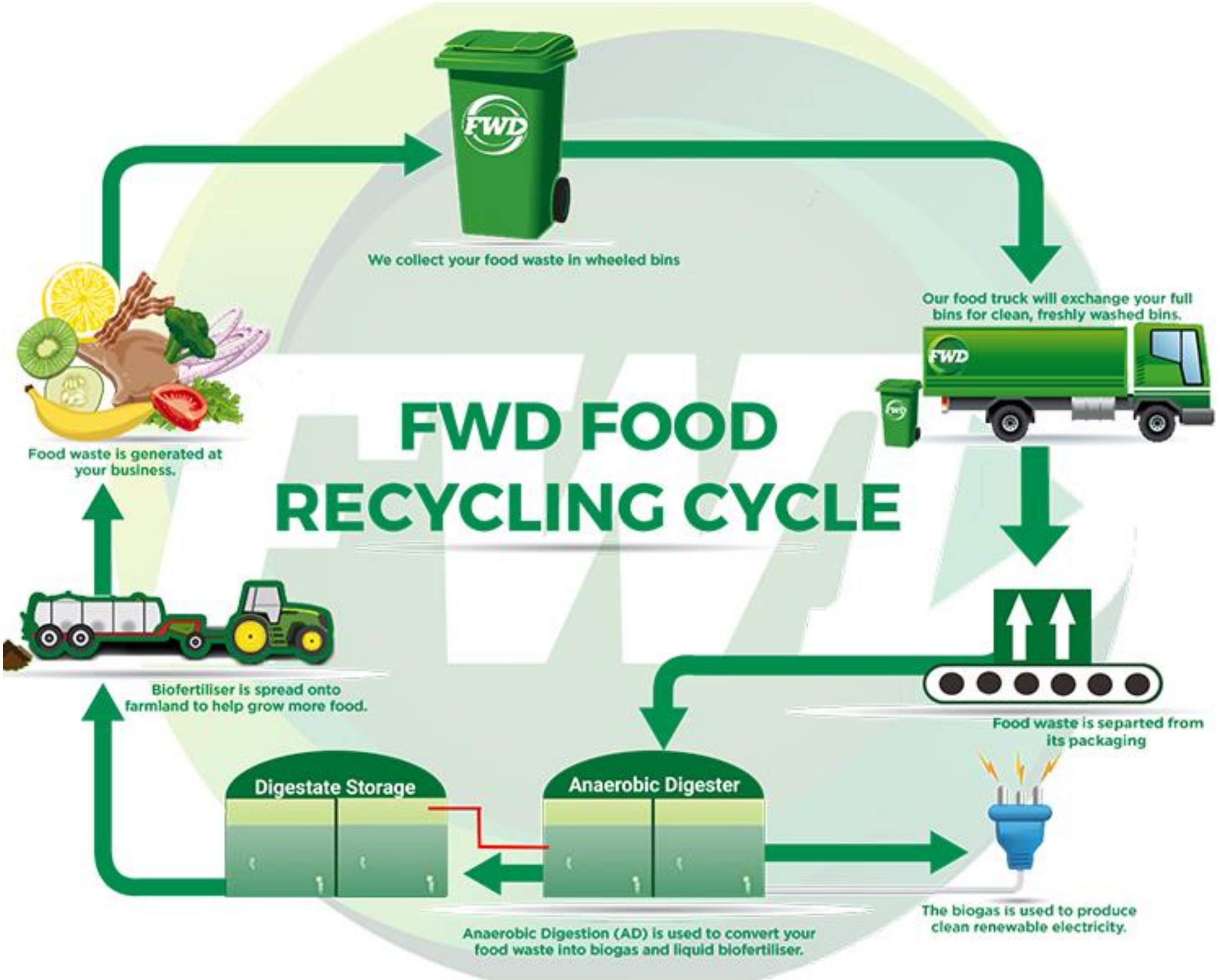


Figure 15 food waste diversion, source:

https://www.linkedin.com/biz/10993202/feed?start=10&v2=true

Service companies collecting food waste also exist in Derby, and Ward (https://www.ward.com/waste-management-derby/) is an example. This is what Ward would say about their food waste service "At Ward we recycle 100% of the food waste we collect".

Plastic Recycling Nottingham, although not specific for food/drink waste recycle, they do collect soft and hard materials such as pallet wrap, drums and buckets. One of the good sides of this company is that customers may cut down on the number of waste collections, thus saving money; on top of that, this company pays brilliant prices for customer waste plastic.

Chapter 7. Case studies

7.1. Utilization of waste banana

Apart from wastes from processing food industries, food wastes can occur at any stage in the supply chain, thus waste could be recovered from local supermarkets and/or mini-markets (although wastes from retail stage / household etc. is not the main purpose for this study).

Nagori B. Mayank (MSc student in food Science, University of Nottingham) has collected waste banana from e.g. supermarkets, and dried to make biscuits. In the UK, shoppers waste 1.4 million bananas every day at a cost of £80 million a year (37) . With respect to the undesirable loads of banana left-overs in the market, such project is not only profitable from entrepreneurship point of view but also from sustainability prospective.

7.2. Utilization of fruits/vegetable pomace

An MSc project carried out by Mss Oumadevi Rangasamy and Dr Olayide Oladokun, the project supervisor, Food Science, (University of Nottingham), was undertaken to evaluate the potential of vegetable pomace, a waste by-product after a process to manufacture soup. Two drying methods was employed. Chemical and nutritional analysis was subsequently evaluated. Results demonstrated that pomace was rich in dietary fibres, polyphenols and fatty acids. Since the project is still under confidentiality restrictions, further details of these results cannot be disclosed at the moment.

In a different collaborative project (with the name NAMASTE) between EU and Indian partners, funky foods made from fruit by products have been utilized. The project has developed and assessed procedures to obtain some bioactive molecules and ingredients. From this project, jam, biscuits and health drinks has already been formulated. According to Fabio Fava, the project's EU scientific coordinator, snack rolls are also on the menu in the near future (https://phys.org/news/2013-04-funky-food-fruit-by-products.html).

7.3. Collaborative food waste project between three universities

EPSRC funded projects investigate food waste from plant sources and has been named Re-SAUCE. The grant details online are:

http://gow.epsrc.ac.uk/NGBOViewGrant.aspx?GrantRef=EP/P008771/1.

Three universities are collaborating in this project. They are University of Nottingham, University of York (project lead) and Loughborough University. The basic aim here at Nottingham, is to investigate the extraction of food ingredients from four sources (considered as food waste): pea-vine, out of spec citrus fruit, potato peels and brewery straw. Current work is looking at stabilising the nutrient rich chloroplast fraction from the pea-vine which is a seasonal agricultural residue (Nottingham), Protein extraction from potato peels (York) and pectin extraction using microwaves from citrus fruits (York).

7.4. Surplus bread for beer

Toast Ale (http://www.toastale.com/), is an SME with the intention to combat local food waste and according to their figures 44% of bread produced in the UK is never eaten. They produce their beer from surplus bread obtained from local food manufacturers, and it is now distributed globally, starting with Iceland and USA. In the UK Toast Ale brewed and sold 60,000 bottles in its first 12 months.

7.5. Surplus fruit for "fruit crispy"

Sparefruit (http://www.sparefruit.com/) is another SME that utilizes surplus fruits, mainly apples and pears by slicing them whole and then slow air-drying the fruits. The firm argues that they had rescued large quantities of fresh fruits that would otherwise gone to waste.

7.6. Reduction of food waste by PEPSICO

PEPSICO employs its Resource Conservation Program (ReCon) to identify and eliminate waste generations sources and to conserve raw materials. The company claims that in 2015, 94% of its total waste generated was utilized; only nearly 6% were disposed of using traditional methods like landfill. PEPSICO believes that there is an opportunity to utilize food waste both from its own operations and collaborating companies across the entire value chain.

Waste products that PEPSICO turned into resources include left-over peelings from its potato chip production, which the company developed to produce a new fertilizer, named "Naturalis".

Another example is oat hulls, a by-product of oat processing, which the company converted to biomass for renewable energy production at different parties of its sites. Dietary fibre, livestock feed, bedding and fuel markets was also made from oat hulls.

7.7. Reduction of drink waste by Britvic Soft Drinks

British Soft Drinks Association (BSDA) has collaborated with Britvic Soft Drinks on a joint project to reduce drink waste (the amount of ingredient and product waste being sent to sewer and to land injection in the brewing and soft drink industry). Workshops on waste reduction have been held at Britvic and from these workshops, the company identified that improvements in operator awareness could lead to significant savings in ingredient waste, particularly syrup. The company thus manages to achieve the following savings:

- ✓ 156 tonnes of syrup saved from effluent per year (780m3 waste product equivalent)
- ✓ £117,000 per year due to reduction in syrup waste
- ✓ £1400 per year water and effluent cost savings

7.8. Reduction of oils waste by Olleco

Olleco (https://www.olleco.co.uk/), a renewable energy business at Liverpool collects used cooking oils, fats and food waste from 50,000 catering and hospitality businesses. The waste food is then converted into renewable energy and heat and used oils are transformed into high quality fuel. Details of this information can be found in this link:

https://www.theguardian.com/sustainable-business/2015/apr/30/olleco-closes-the-loop-on-commercial-food-waste.

7.9. Brewers Spent Grains utilized for beer yeast production

Researchers from Nanyang Technological University (NTU) led by Prof. Williams Chen, have managed to develop a process that utilizes 85% of brewery's waste reused, turning spent grain into beer yeast. Traditionally, grains such as barley or hops are fermented by yeast; and then sugars, proteins and other nutrients from these grains are recovered, leaving behind plant fibres like lignin. Lignin is a tough and mostly unstable in food production. It is in this step where NTU employs food-grade microorganisms to convert the spent grains into basic nutrients that can be easily consumed by yeast, With this finding, researchers believe that brewers are likely to save a considerable amount of money i.e. nearly 85% of their waste can now be turned into valuable products, which will reduce brewer's waste and production cost while becoming more self-sustainable.

Appendices

Appendix 1

Household Food Waste

Waste Stream	Financial (p.a.)	Million tonnes (p.a.)	Environmental impact	Notes
TOTAL Household Food & Drink		7.0 Mt		Consumers throw away 7.0 Mt per year of food & drink – the majority of which (4.2 Mt) was avoidable (Source: WRAP). 1/5th is truly unavoidable (bones, cores and peelings) (Source: WRAP). Household food waste is almost half (47%) of the total UK food waste (~15Mt) (Source: WRAP).
Avoidable food & drink	£12.5 bn	4.2 Mt	17 Mt CO_2e	4.2 Mt is equivalent to filling ca. 8,400 Olympic sized swimming pools (Source: WRAP). Producing, storing and getting products to our homes uses a lot of energy. If we stopped wasting avoidable food and drink it would save ca. 17 Mt $CO_2eq.$ – equivalent to the emissions from one quarter of private car journeys made in the UK (Source: WRAP). Most discarded food reaches landfill sites where it emits methane, a powerful greenhouse gas 25 times more powerful than CO_2 (Source: IPCC http://www.ipcc.ch/publications_and_data/publications_and_data_reports.shtml#1 £470 - Average UK household spend on food that could have been eaten but is thrown away (Source: WRAP). £700 - Average UK household with children spend on food that could have been eaten but is thrown away. The average family could save almost £60 a month (Source: WRAP).
Reasons for disposal (avoidable)	£5.6 bn	2.0 Mt		Food and drink that is thrown away untouched or opened/started but not finished (e.g. whole apples, yoghurts, half loaves of bread, unused slices of bacon etc.)
Possibly avoidable		1.2 Mt		Food that some but not all people would eat (e.g. bread crusts, potato skins).
Unavoidable		1.6 Mt		Elements of food and drink that are not suitable for consumption (e.g. egg shells, bones, banana skins, tea-bags).
Examples				Examples of avoidable household food we throw away p.a. (Source: WRAP). Fresh fruit and vegetables: £2.6bn / 1,200,000 t. Bakery: £860 m / 450,000 t. Home-made and pre-prepared meals:

	£2.1 bn / 440,000 t. Dairy and eggs. Includes milk thrown away from the fridge and leftovers from serving too much (e.g. breakfast cereals): £780 m / 420,000 t. £290m worth of milk is thrown away and over 90% of this is in amounts of 50g or more = about quarter of a glass each time. Examples of avoidable household drink we throw away p.a. (Source: WRAP). • £270 m of wine. • £200 m of carbonated soft drinks. • £150 m of fruit juices and smoothies.

Data in this table is adapted from WRAP.

Appendix 2

Hospitality and Food Service Sector

Waste Stream	Financial (p.a.)	Million tonnes (p.a.)	Env. impact	Notes
Total waste arising		2.87 Mt		The total amount of waste, including food, packaging and other 'non-food' waste, produced each year at HaFS outlets is 2.87 million tonnes, of which 46% is recycled, sent to Anaerobic Digestion (AD) or composted. There are nine major HaFS subsectors as defined by Horizons: staff catering, healthcare, education, services, restaurants, Quick Service Restaurants (QSRs), pubs, hotels and leisure. In addition to food and packaging waste, 'other' wastes amount to a total 0.66 million tonnes, and include kitchen towels, disposable cups, newspapers and office paper.
Food Waste	£2.5 bn	0.92 Mt	3.6 Mt CO_2eq.	The amount of food that is wasted each year in the UK is equivalent to 1.3 billion meals, or one in six of the 8 billion meals served each year. On average 21% of food waste arises from spoilage; 45% from food preparation and 34% from consumer plates. The total cost of food being wasted in the UK HaFS industry for 2011 is estimated at over £2.5 billion; three subsectors (restaurants, pubs and hotels) account for 54% of this financial cost

Avoidable food waste		0.68 Mt	2.7 Mt	75% of food waste in HaFS is avoidable. 40% of all food waste is associated with 'carbohydrate foods', including: potato and potato products (21%); bread and bakery (12%); and pasta/rice (7%).
Unavoidable Food Waste		0.24 Mt	0.9 Mt	A quarter of all food waste that is unavoidable mainly consists of fruit and vegetable peelings.
Packaging				An estimated 1.3 million tonnes of packaging is used by UK HaFS outlets each year, including packaging around food, drink, cleaning products and other HaFS supplies. Of this, 61% is glass packaging, used mainly in pubs, restaurants and hotels. Of the 1.3 million tonnes of packaging, 66% is recycled. Greenhouse gas impacts shown are the potential savings associated with recycling all readily recyclable packaging and other wastes currently disposed of to landfill.

Data in this table is adapted from WRAP.

Appendix 3

Manufacturing and Retail Sector

Waste Stream	Financial (p.a.)	Million tonnes (p.a.)	Env. impact	Notes
Total waste arising		2.87 Mt		The total amount of waste, including food, packaging and other 'non-food' waste, produced each year at HaFS outlets is 2.87 million tonnes, of which 46% is recycled, sent to Anaerobic Digestion (AD) or composted. There are nine major HaFS subsectors as defined by Horizons: staff catering, healthcare, education, services, restaurants, Quick Service Restaurants (QSRs), pubs, hotels and leisure. In addition to food and packaging waste, 'other' wastes amount to a total 0.66 million tonnes, and include kitchen

				towels, disposable cups, newspapers and office paper.
Food Waste	£2.5 bn	0.92 Mt	3.6 Mt CO2eq.	The amount of food that is wasted each year in the UK is equivalent to 1.3 billion meals, or one in six of the 8 billion meals served each year. On average 21% of food waste arises from spoilage; 45% from food preparation and 34% from consumer plates. The total cost of food being wasted in the UK HaFS industry for 2011 is estimated at over £2.5 billion; three subsectors (restaurants, pubs and hotels) account for 54% of this financial cost.
Avoidable food waste		0.68 Mt	2.7 Mt CO2eq.	75% of food waste in HaFS is avoidable. 40% of all food waste is associated with 'carbohydrate foods', including: potato and potato products (21%); bread and bakery (12%); and pasta/rice (7%).
Unavoidable Food Waste		0.24 Mt	0.9 Mt CO2eq.	A quarter of all food waste that is unavoidable mainly consists of fruit and vegetable peelings.
Packaging		1.3 Mt	0.4 Mt CO2eq.	An estimated 1.3 million tonnes of packaging is used by UK HaFS outlets each year, including packaging around food, drink, cleaning products and other HaFS supplies. Of this, 61% is glass packaging, used mainly in pubs, restaurants and hotels. Of the 1.3 million tonnes of packaging, 66% is recycled. Greenhouse gas impacts shown are the potential savings associated with recycling all readily recyclable packaging and other wastes currently disposed of to landfill.

Data in this table is adapted from WRAP.

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