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Analytical methods for waste minimisation in the convenience food industry

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ABSTRACT

Waste creation in some sectors of the food industry is substantial, and while much of the used material is non-hazardous and biodegradable, it is often poorly dealt with and simply sent to landfill mixed with other types of waste. In this context, overproduction wastes were found in a number of cases to account for 20–40% of the material wastes generated by convenience food manufacturers (such as ready-meals and sandwiches), often simply just to meet the challenging demands placed on the manufacturer due to the short order reaction time provided by the supermarkets. Identifying specific classes of waste helps to minimise their creation, through consideration of what the materials constitute and why they were generated. This paper aims to provide means by which food industry wastes can be identified, and demonstrate these mechanisms through a practical example. The research reported in this paper investigated the various categories of waste and generated three analytical methods for the support of waste minimisation activities by food manufacturers. The waste classifications and analyses are intended to complement existing waste minimisation approaches and are described through consideration of a case study convenience food manufacturer that realised significant financial savings through waste measurement, analysis and reduction.

1. Introduction

Over the past decades industrial and economic growth has been largely at the expense of the environment and, as a result, strictly defined limits regarding the acceptable use of resources are now in place (Byrne and Glover, 2002). Food manufacturers and retailers produce and handle a wide range of wastes, some of which are common to all other industrial sectors such as waste water and packaging waste. According to the UK Government's new Food Industry Sustainability Strategy (FISS), the food industry faces three particular challenges with regard to waste: packaging, processing wastes, and their influence over household waste (DEFRA 2005). Current food manufacturing practices have often been developed based on a culture where product losses are inherent to the processes and products will typically yield considerably below the amount of raw material used. This is due to the physical transformation effect of cooking processes in conjunction with a number of other issues, and as such waste measurement and minimisation have not been considered as rigorously as other engineering disciplines. In addition, the environmental impacts of food wastes have been given little consideration due to the fact that very few dangerous chemicals and pollutants are used in food manufacture. In fact most of food production wastes may be used for land treatment – with certain production wastes being rich in potassium, phosphorus, and nitrogen which can be beneficial to replenish soil nutrients, provided such waste treatment is carefully monitored and managed (Mattsson and Sonesson, 2003). There is much legislation and much research has been completed in considering the wider implications of waste creation (such as the use of packaging) and environmental impacts of food manufacture (such as energy and water consumption). However, there is notably less support for the improvement of production efficiencies at an operational level and the reduction of overproduction wastes, which are found to be generated in substantial quantities, and of being disposed in an inefficient manner, mainly to landfill.

This paper aims to provide a consistent theme for the consideration of waste in food manufacture, and to define a number of analytical methods for the minimisation of waste in convenience foods. The initial section of the paper provides an overview of trends in waste generation and management as well as a review of the waste problem in convenience food manufacture. The major sections detail a waste model to identify the generic waste types in convenience food manufacture, together with three waste analysis methods which are developed to monitor and minimise waste generation in food sector.

2. Trends in waste generation and management

Waste generation in the European Union is currently estimated at about 1.3 billion tonnes per year, approximately 3.5 tonnes per capita per year. This includes waste from manufacturing (338 million tonnes), mining and quarrying (377 million tonnes),

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the construction sector (286 million tonnes), municipal solid waste (182 million tonnes) and hazardous waste (27 million tonnes) (EC, 2003). In general, waste generation in the EU is increasing at rates comparable to economic growth. For example, both GDP and municipal solid waste grew by 19% between 1995 and 2003, while these upward trends in waste generation are expected to continue (EC, 2005).

According to the recently published Waste Directive 2006/12/EC (2006), waste should only be landfilled when the use of a better waste treatment option is not possible, while the European thematic strategy on recycling of waste clearly stated that "the long-term goal is to become a recycling society that seeks to avoid waste and uses waste as a resource" (EC, 2005). However, in many countries landfilling still is the most common practice of waste treatment. Based on the latest EU figures, municipal waste is disposed of through landfilling (49%), recycling and composting (33%) and incineration (18%) (EC, 2005). To achieve this vision for minimisation of waste sent to landfill, the European Commission has set up a waste management hierarchy based on the environmental impact of various types of waste. According to this hierarchy, reduction of waste should be the top priority of waste management solutions. Reduction of waste aims to reduce the generation of waste at source through efficient use of materials, better design and reduced operational costs (Monkhouse and Farmer, 2003). The second preferred option is to reuse products and parts/components with minimal processing for the same purpose for which they were conceived in the first place. Recycling is the third preferred option, where used/scrap materials are reprocessed in order to recover value from waste. When waste is being recycled, the value extracted from raw materials should be maximised while the energy needed for recycling should be less than that for extracting, refinement and preparation of the virgin materials. Energy recovery from waste is a process by which energy contained in the waste is extracted in the form of heat or electricity, which can be then used as a power source for various applications. Techniques currently used to recover energy from waste are varied and include incineration, anaerobic digestion, gasification and pyrolysis (McLanaghan, 2002). Finally, disposal of waste in landfills is considered as the worst waste management option, although in many countries this is the most common form of waste treatment.

3. Review of the convenience food industry and its waste problem

The convenience food industry manufactures a wide range of products, ranging from snacks to entire meal replacements. During the last decade, the convenience food sector has grown steadily in the UK to account for around 35% of the total consumer spending on food (Mintel, 2005). This growth of the UK spending on convenience food has been attributed to changing consumer time pressures (Warde, 1999), increasing health concerns (Shiu et al., 2004) and added value for consumers (Hollingsworth, 2001). Levels of waste are particularly pronounced in this sector of the food industry, which typically experiences volatile demand and products with short shelf-life. Many of such products are manufactured for the specific brands of a retailer to very short order lead-times, thus manufacturers have in the past actively overestimated demand to ensure orders are met, at the expense of creating large volumes of overproduction wastes. These wastes are inefficiently dealt with, with large volumes of material (which have been processed at a cost to the manufacturer) are being sent to landfill along with other factory wastes (Bates and Phillips, 1999).

The standard practice of dumping waste in landfills has led to soil, surface and groundwater contamination. Biodegradable waste accounts for approximately 55% of the overall food processing waste (Biffaward, 2004). However, biodegradable materials when landfilled produce methane (CH_4), a powerful greenhouse gas that contributes to the phenomenon of global warming (Gilberg et al., 2005). Furthermore, landfill space is becoming extremely limited; in Germany in the early 1990s, for example, there were over 8000 landfill sites in use, while the number of currently operating landfill sites is below 300 (Hempen, 2005). In addition, the EU Landfill Directive 99/31/EC (1999) clearly promote the diversion of waste from landfills towards products and materials recycling using a variety of measures. The landfill restrictions introduced by article 5 of this directive are very important, in particular the reduction in the amount of biodegradable waste going to landfill, which must be reduced to 35% of 1995 figures by 2014.

The UK landfill allowances and trading scheme regulations (LATS), introduced in 2004, determine the percentage of certain waste types that are regarded as biodegradable municipal waste. These biodegradable fraction ranges from food, paper and vegetable oils (potentially 100% biodegradable) to furniture and textiles (50% biodegradable) to batteries, glass and metal waste (0% biodegradable) (LATS, 2004). Furthermore, since June 1, 2005, German landfills only accept biodegradable municipal waste that has been either incinerated or undergone mechanical and biological treatment. In Austria strict limits on the landfilling of organic wastes has also been introduced (Hempen, 2005). Although the EU landfill directive and the LATS restrictions are focusing on municipal waste, challenges on the way the food processing industry deals with its industrial biodegradable waste are expected. These legislative requirements together with an increase consumer demands for waste minimisation highlight the need for careful consideration of waste creation practices in the food sector (Aiking and de Boer, 2004). The remaining sections of the paper present a waste model along with a number of analysis methods to support food manufacturers in reducing the environmental impacts of their waste.

4. Waste model for food sector

The waste model is developed to visualise the waste generated by convenience food manufacturers and to serve as the starting point for realisation of a framework for waste minimisation. The model has been created based on information collected/obtained through a comprehensive programme of industrial visits and interviews (Darlington, 2006). IDEF0 representations have been utilised to generate the waste model as they are easy to comprehend and their hierarchical approach enables systems and processes to be modelled in many levels of detail (Dorador and Young, 2000). The developed model focuses on the physical flow through the various stages of food manufacture and supply, as depicted in Fig. 1, with inputs (raw materials) and outputs (wastes) for each stage being identified separately. These classifications of waste are described in further detail below.

4.1. Bulk wastes

Bulk wastes are associated with the preparation of ingredients and may include inedible parts of the ingredient, such as stems, leaves, bones, excess animal fat etc., along with contaminated materials or ingredients, such as outer layers of vegetables that are spoiled and even soil or debris on the ingredient that is removed by washing or mechanical means. The costs of managing these wastes are low, the mechanisms by which they are collected being their primary expense. Provided they are disposed of responsibly, they present little environmental hazard.

4.2. Waste water

Water is used in large quantities in food processing, predominantly in the preparation, cleaning and cooking stages of the prod-

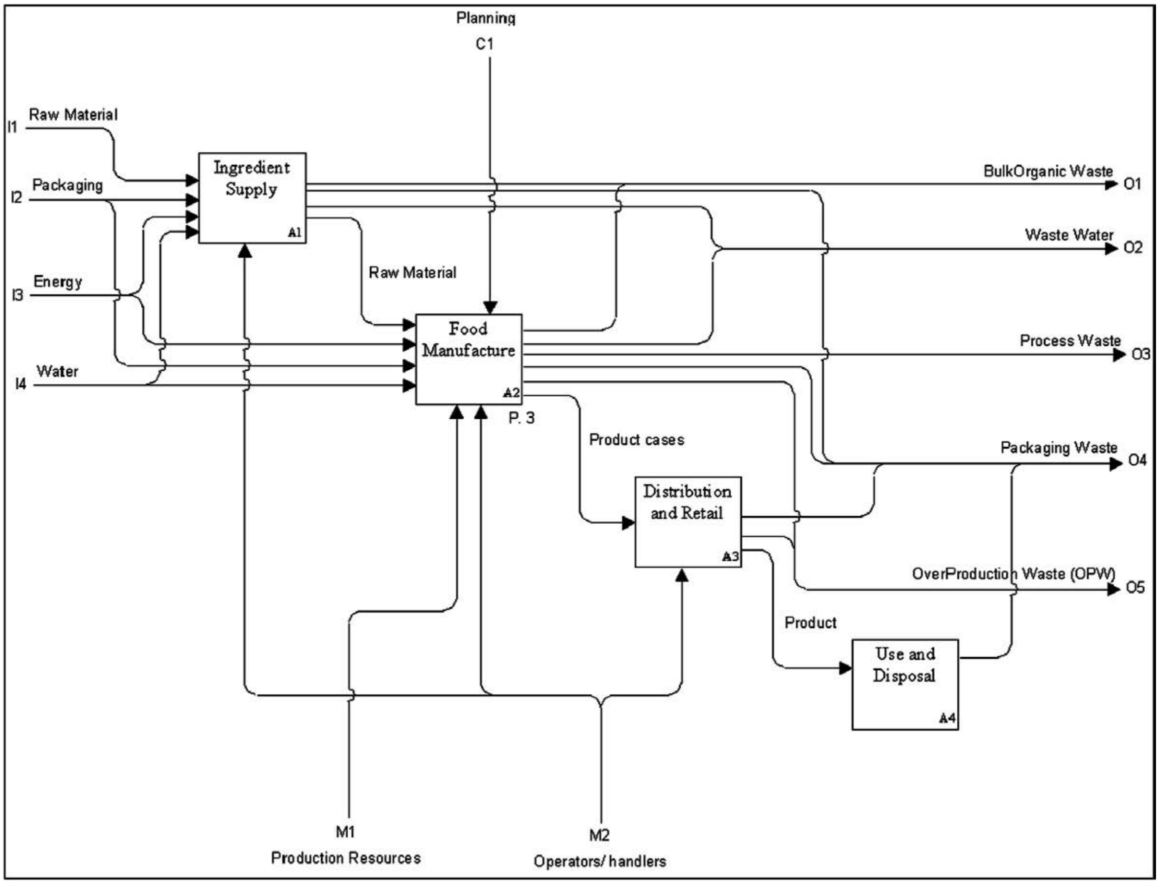

Fig. 1. IDEF0 representation of the waste model through life cycle.

uct life cycle. The waste water as described in this context is the water reclaimed at the end of the process either as a carrier for dirt and contamination or as a by-product from the cooking or processing operations. In some cases it may be possible to recycle the water after filtration, for example in Sous-vide manufacturing where the product is not in contact with the water throughout processing (Ghazala, 1998). However, in most applications the bulkiest debris are filtered out from the waste water and the remaining contaminated water is disposed of to the drain or groundwater.

4.3. Processing wastes

Processing wastes as considered here may be due to a number of different sources, and may be further described as being due to poor housekeeping procedures, inherent process losses or poor conformity. Spillages, damages and contamination of product may be caused by operator neglect, poor handling procedures, forming equipment making improper seals on packs, etc. By-product wastes are materials that are created by the manufacturing process, such as juices or animal fats, which are removed and disposed to give the desired product quality or consistency. Finally, waste due to poor conformity may be created at any time for any ingredient or product failing to adequately conform to specifications, quality, appearance, flavour, aroma etc.

4.4. Packaging wastes

Packaging is widespread in the food industry to prevent contamination or spoilage of foods that are often packaged to protect them from their immediate environment. Packaging can vary from large paper-based sacks for bulk ingredients, to various plastic bags, sheets and pouches depending on the product and application. The material properties and specific nature of the packaging are typically engineered for each application, though unfortunately they are all often disposed together in a manner similar to commercial waste disposal.

4.5. Overproduction wastes (OPW)

Overproduction wastes constitute significant cost to the company as materials and resources in manufacturing are wasted given that the finished (prepared) product no-longer has an end customer. OPW may be used to describe batches of ingredients that have been prepared before order confirmation and cannot be re-directed before expiry. In such cases the ingredients will typically be scrapped to commercial waste and send to landfill as many own-label manufacturers cannot re-direct the product to different customers in keeping with their contractual agreements with the retailers. The authors contend that the generation of OPW is the most unsustainable practice in the food industry as significant resources such water, energy and raw material are wasted and therefore a structured approach to reduce such waste needs to be investigated.3

5. A methodology for waste analysis in the convenience food industry

In most food manufacturing applications, the source and amount of waste generated at various stage of production are not closely monitored. Furthermore, many manufacturers do not have any record of the cost of managing and treating their waste.

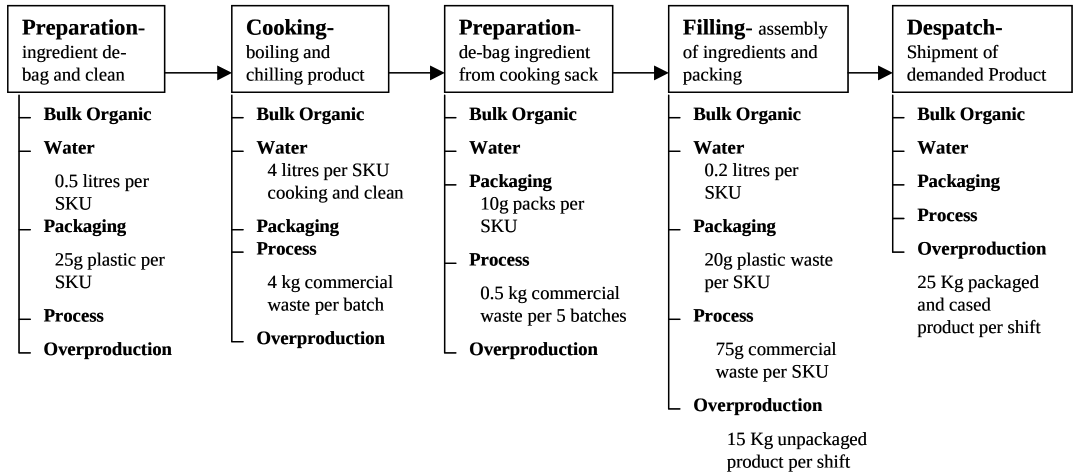

Fig. 2. Example of waste inventory diagram for a convenience food manufacturer.

Such treatment of waste can be very costly to the business and may require significant investment in operating technologies, processes and equipment. Hence, there is a requirement to prioritise the range of the waste types that a particular manufacturer needs to consider at any time. In addition, the minimisation of waste in the food sector requires a structured approach to identify the source of waste, monitor its generation and develop bespoke solutions for their elimination and minimisation. Hence, this research has investigated a waste analysis methodology tailored to the specific requirements of food manufacturing which consists of:

(1) Waste inventory analysis to highlight and monitor the sources of waste throughout the production processes,
(2) Cost and environmental impact analysis to perform a cost analysis and to prioritise the importance of cost management,
(3) Reduce–recycle–disposal analysis to highlight a detailed step-by-step solution for reducing, reusing and recycling and safe disposal of the waste.

These waste analysis methods are further discussed and demonstrated with aid of a case study. The company selected as a case study is referred to in this paper as company X, which was established in 1985 and manufactures chilled prepared meals for sale through one of the largest UK food retailers. The production facility is based in the UK and is staffed by around 1000 personnel, operating a challenging 24 h a day, 7 days per week. The main production facility is split over three floors, each of which manufactures a different family of products. Company X currently manufactures 130 of the retailer's own label products, 80 of which are described as core lines, having greater demand accordingly. The manufacturing lead-times of products vary considerably, from a few hours for very simple products to several days for products requiring long cook and/or marinated cycles. The retailer demands a minimum shelf-life on receipt of 75%, whereby a product with 10 days shelf-life must be received by the retailer with 7.5 (rounded to 8) days remaining life before the expiry date. The above mentioned waste analysis methods are applied in the case of this manufacturer to identify and minimise various types of waste as outlined below.

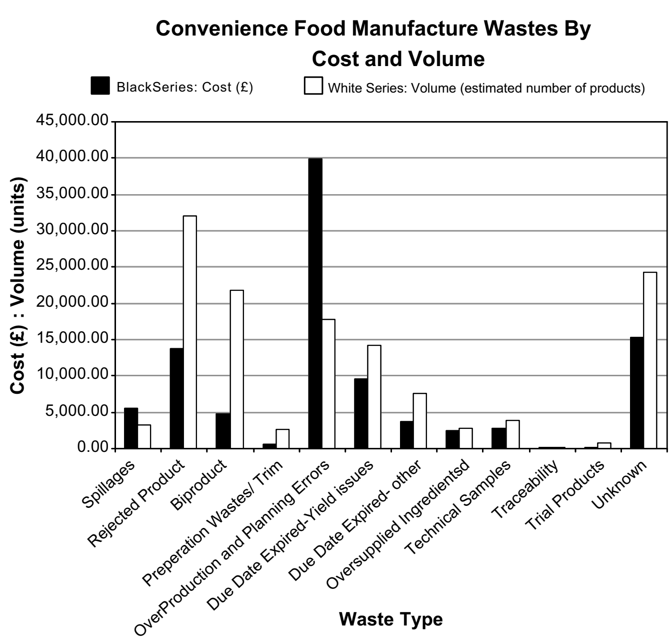

Fig. 3. Production wastes for convenience food manufacturer, over one month period.

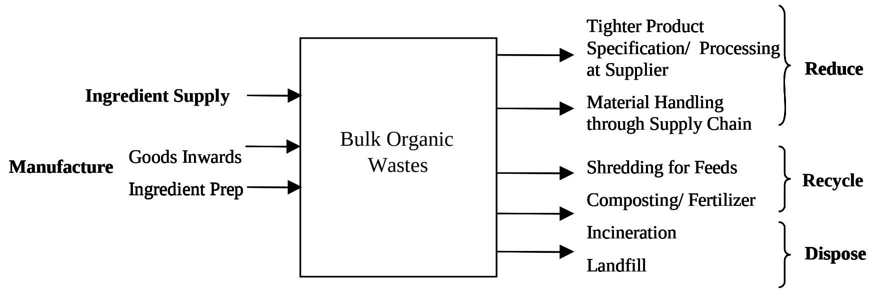

Fig. 4. The RRD diagram for bulk organic waste.

5.1. Waste inventory analysis

The aim of a 'waste inventory analysis' is to effectively summarise and highlight the data relating to each form of waste at the various stages throughout manufacture, which aids in identifying means by which waste creation may be reduced. Summarising the sources of waste through production is achieved through creation of a waste inventory diagram (see Fig. 2), which details the data available relating to wastes created at each stage using the previously mentioned five categories in the waste model, namely, bulk waste, waste water, processing waste, packaging waste and overproduction waste. Little rigidity is required in the type/format of data collected provided the measurements are consistent and evenly taken, as the inventory serves to indicate only rough-cut volumes of waste created at the various stages of production. Reduction in the amount of wastes in some cases requires significant changes to the way in which current production processes are undertaken, with investment or redesign necessary in many cases. For the case study manufacturer, OPW was recorded as a weight of wasted material for each production shift, while other waste measures were recorded against the number of stock keeping units (SKU) produced, from which weights of waste can be calculated. The waste inventory diagram (illustrated in Fig. 2) highlighted the extent of OPW creation, in addition to isolating the majority of water wastes being attributable to the cooking stage of production. The application of this analysis clearly identified the OPW as the major source of environmental and economic concern.

5.2. Cost versus environmental impact analysis

Waste may be measured as a financial loss to the manufacturer, and as such may be an economic driver for change. It may also be accounted by a physical measure of weight or volume with associated environmental implications for landfill and disposal. Whilst it is intuitive that the weight of waste is the simplest and quickest measure to obtain through use of scales in the production environment, in practice manufacturers may prefer to collect information relating to the costs of materials that are being disposed, and as such 'costing data' have been found to be more readily available than weights and volumes of waste created. In order to further demonstrate this difference between the cost and volume of wastes, a 'cost versus environmental impact analysis' has been developed and conducted as depicted in Fig. 3, which shows the compositions of wastes created during one month's production at company X, along with estimated costs. This cost versus volume graph illustrates the relationship between cost to the manufacturer and volume of waste material created. In company X, the overproduction wastes accounted for a considerable proportion of the total cost of all waste generated, while only contributing approximately 14% of the volume of waste created. However, it should be noted that this limited volume of OPW still represents a significant environmental impact, as huge amounts of other resources (including energy, water and ingredients) have been consumed to produce the final product. Hence, the minimisation of OPW was highlighted as a priority for the case study company.

5.3. Reduce–recycle–disposal analysis

This waste analysis method has been designed and proposed as a method of simultaneously considering three activities – reduce, recycle and disposal – for each of the waste classifications identified in the waste model. This approach is based on the commonly adopted waste hierarchy in which the reduction of the sources of wastes is followed by the recycling of materials where possible in order to minimise the amount of waste that must be disposed (Strategy Unit, 2002). The primary focus of the 'Reduce–recycle–disposal (RRD) analysis' is to minimise the creation of any waste and thus to improve its impact on the environment. This include lessening the volumes of wastes created through more accurate or efficient supply and manufacture operations and ideally, where possible, eliminating the wastes entirely. It should be noted that the current disposal practice in company X for most of the solid waste streams was the common industrial approach of sending the wastes to landfill. In most cases, the incineration of wastes is preferred over landfilling, provided the calorific content of the waste is such that some energy can be reclaimed from the wastes.

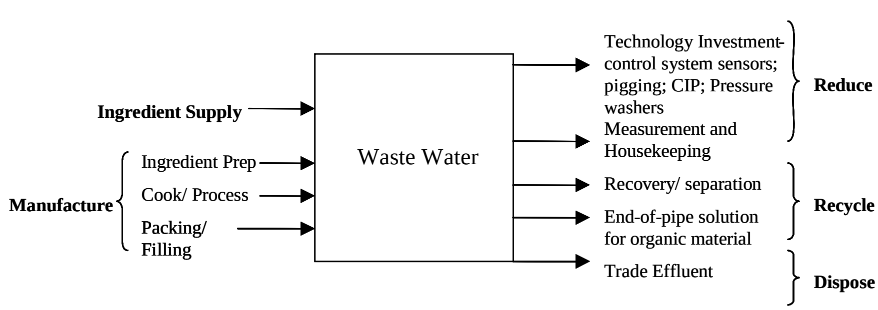

Fig. 5. The RRD diagram for waste water.

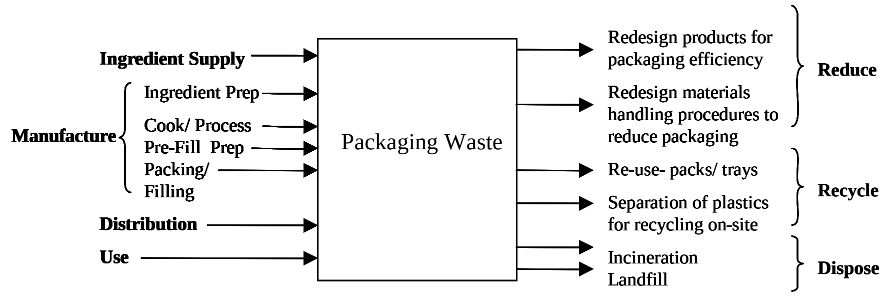

Fig. 6. The RRD diagram for packaging waste.

The RRD diagrams shown in Figs. 4–8 were generated for the case study manufacturer to support improvement activities with regard to each type of waste. Bulk organic wastes (BOW) are somewhat inevitable when processing foods that are harvested along with inedible parts. The organic nature of these wastes, however, means that they can have useful application in other areas such as composting or in some cases using them as feed for livestock. The opportunities for reduction of BOW come from earlier processing of the raw materials – removing husks, shells, bones, leaves etc. at the supplier, as shown in Fig. 4. This has the effect of reducing the amount of material handled and transported through the supply chain, and in many cases this will be closer to the point of recycling of BOW as fertilizer or feed. The means by which such improvements can be implemented include tighter product specification by manufacturers, and appropriate re-location of equipment and preparatory processes from the manufacturer site to the suppliers in the supply network.

Waste water has considerable implications for industry and there is a great deal of support available for manufacturers, particularly food industry manufacturers, in undertaking environmental projects to reduce the amounts of water required by industry. Capital is available through government agencies (such as Envirowise in the UK) to offset the cost of investment in new technology to reduce water wastes, and such technology covers the monitoring and control of water usage through flow monitors, for example, automated systems such as cleaning in place (CIP) and pigging equipment (where crushed ice is used to clear pipe work for changeovers in place of large volumes of water). As indicated in Fig. 5, straightforward housekeeping measures considerably reduce the consumption of water, and many example initiatives and case projects have been documented through government agencies. The possibility to reclaim and recycle the water in some cases requires considerable investment, and will not be feasible for many companies requiring fresh and clean water in their food production. However, the end-of-pipe solutions that remove much of the BOW from waste water alleviate additional burden on re-processing plants that treat the trade effluent.

When considering packaging waste, manufacturing organisations also benefit from considerable support and financial incentives from government agencies to instigate improvement projects to reduce the amount of packaging inherent to the products. Reduction of packaging associated with a particular product requires redesign of either the packaging itself or the accompanying handling procedures, as shown in Fig. 6. The most common methods by which these improvements may be made come in the form of elimination of the need for intermediary packaging, and double packaging of products and components. Separation of plastics from general wastes in manufacturing facilities will significantly ease the subsequent processing of recyclable materials from the general waste streams, increasing the cost efficiency of such operations.

Process wastes are all sourced directly to manufacturing activities, as indicated in Fig. 7, and may be best improved by modifications to handling methods that aim to reduce incidences of product being accidentally lost in production by process inefficiency. More costly investment in processing machinery will yield better improvements still, though the economic cost savings balanced against the environmental benefits will vary greatly for various products and processes.

Finally, overproduction wastes are created late in the production sequence as demand fluctuates. The reduction of such wastes are typically greatest by having accurate forecasts upon which manufacture could be based and where possible by changes to lead-times to enable products to be manufactured to order, as indicated in Fig. 8. Improved planning flexibility will result in faster turnaround of production plans, which again will reduce the volumes of OPW created. Furthermore in the case of the company X, it was feasible to reuse the OPW through the re-direction of ingredients to alternative products to follow demand and offloading of finished products to alternative customers (Darlington and Rahimifard, 2007).

These RRD waste analysis diagrams provided a systematic approach for waste minimisation in company X, which, as stated, used to send a substantial amount of waste directly to the landfill.

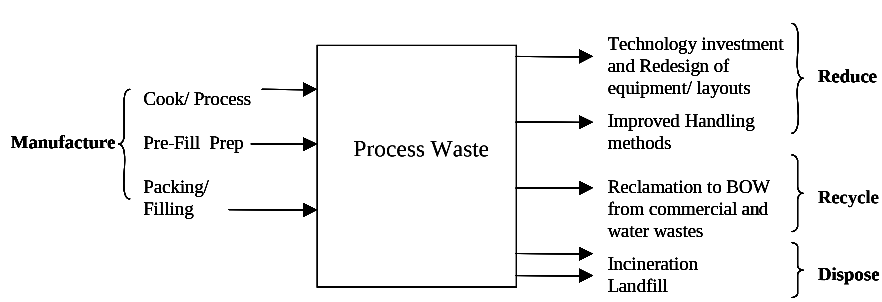

Fig. 7. The RRD diagram for process waste.

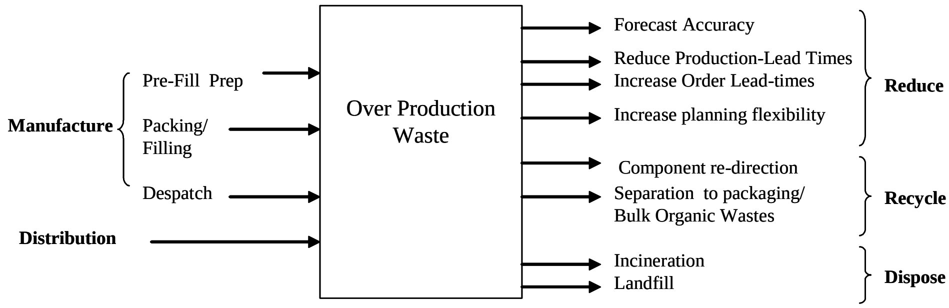

Fig. 8. The RRD diagram for overproduction waste.

Furthermore, the hierarchal nature of the RRD analysis encourages the case study company to adopt a proactive approach to waste management with emphasis on reduction, reuse, and recycle as opposed to disposal. The authors propose that the information contained in these RRD diagrams needs to be amalgamated within a "waste manual" for each company to provide a single comprehensive source of instructions for waste minimisation and management within a food manufacturing company.

6. Some observations related to waste minimisation in company X

By far the most marked improvement in company X's operations came through the reduction of manufacturing wastes, where substantial financial savings were realised. The implementation of a scheme of waste measurement was driven throughout the factory and resulted in significant cost reductions as shown in Fig. 9, which shows data from the beginning of the waste measurement and reduction. However, the continuous trend for reduction of waste costs was affected on two occasions, as represented by spikes (1) and (2) in Fig. 9. Spike (1) represents wastes associated with Christmas, during which the company traditionally experiences unpredictable demand; the amount of wastes has been in excess of the value shown in Fig. 9 in previous years. Spike (2) in Fig. 9 shows waste costs associated with the withdrawal of products and ingredients contaminated with 'Sudan 1' in February 2005, when around £15,000 per week of waste cost is estimated to have been directly caused by the withdrawal.

These waste reduction improvements were initially driven by the monitoring of the costs of the wastes being created, the better use of the MRP system and with preventative measures targeted at waste minimisation as highlighted through the application of the waste analysis methodology. Cultural issues relating to the collection of data were difficult to overcome; however, the constant monitoring of production wastes led quickly to considerable reductions of weekly waste costs from £35,000–40,000 per week to around £15,000–£20,000 per week.

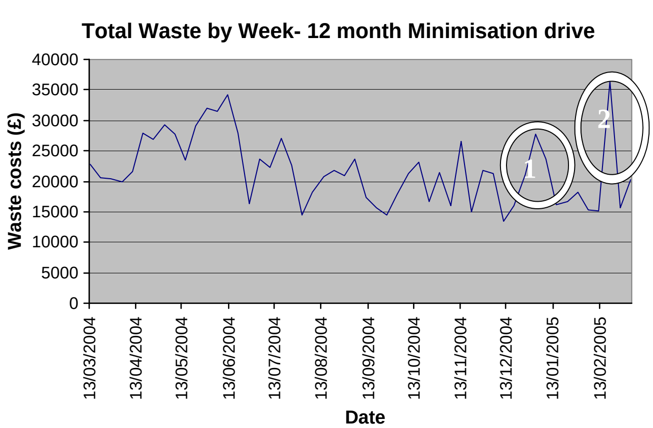

Fig. 9. Total waste costs for company X (calculated weekly over the 12 months).

7. Conclusions

The vast majority of waste created within the food industry is non-hazardous. As such, in this sector, only those wastes of highest priority to the wider community have received wider attention to drive improvements, namely the quantities of water consumed throughout production and the volumes of packaging wastes created by end customers. However, the authors contend that the range and types of wastes identified by this research have economic implications in addition to the environmental impact through the volume of material released to landfill. The amount of such wastes may be significantly reduced through an effective waste management approach, primarily through a significant 'culture shift' in an entrenched sector where process inherent wastes and the 'use' of overproduction to meet unrealistic demand are commonplace. This point was underscored by the case study company that experienced considerable challenges in incorporating new responsibilities for operators to simply record instances of waste. The primary consideration of this research was the minimisation of overproduction waste, which was found to contribute not only to the volume of wastes produced but also substantially to costs of wastes, which made the results from this research of considerable interest to collaborating industrial partners. It was also observed that a number of simple and low cost measures such as the separation of wastes (mainly sorting of bulk organic wastes from packaging wastes) at source during production can also lead to considerable minimisation of waste which can only be disposed of by landfilling.

In conclusion, when considering food manufacturing in a broader sense, it is the authors' belief that at present a consistent structured approach to waste minimisation throughout the food supply chain is lacking, which provided the impetus for the development of the waste model and waste analysis methodology described in this paper. Although many local initiatives are in place, it is argued that there is a need to develop industry-wide policies together with supporting business drivers to ensure truly sustainable food manufacturing in future.

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