Economic sustainability of food supply chains: life cycle costs and value added in the confectionary and frozen desserts sectors

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Abstract
The confectionary and frozen desserts sectors are important parts of the food industry but have received relatively little attention from a life cycle cost perspective. Thus, the purpose of the current study is to evaluate the life cycle costs (LCC) and value added (VA) in these sectors in the UK, focusing on four major product categories: biscuits, cakes (ambient and frozen), chocolates and ice cream. In total, 18 products are considered along their life cycles, including the raw materials, manufacturing, packaging, distribution, retail, consumption and waste management stages. The results suggest that cakes have the highest LCC (£1.52–2.64/kg) and the biscuits the lowest (£0.72–0.91/kg). The LCC of chocolates and ice cream fall within a similar range (£1.16–1.46/kg and £1.03–1.30/kg, respectively). Divergent trends are noted between LCC and VA: for instance, ‘premium’ ice creams have only 18% higher costs than their ‘regular’ counterparts, but a four-fold higher VA. For all the products, raw materials contribute most to the costs (43%–95%), followed by packaging (1%–29%) and manufacturing (1%–14%). The annual LCC at the sectoral level are estimated at £3.455 billion, to which biscuits contribute 42%. The share of chocolates and cakes is 24% and 19%, respectively, with ice cream contributing the remaining 15%. By contrast, chocolates contribute more than 50% of the total sectoral VA, which is five-fold higher than that of ice cream. The study also demonstrates how LCC can be used to evaluate the eco-efficiency of products and sectors. With respect to global warming potential, whole cakes are the most eco-efficient and vanilla regular ice cream the least efficient products. Overall, the confectionary sector is nearly 60% more eco-efficient than the frozen desserts sector. These results can be used for benchmarking and to drive innovation towards more economically-sustainable and eco-efficient confectionary and frozen desserts supply chains.

Keywords: Biscuits; Cakes; Chocolates; Ice cream; Economic assessment; Eco-efficiency.

| Nomenclature | Description |
|--------------|-------------|
| $C_{CL(CO)}$ | cost of washing the dishes at consumer |
| $C_{CO}$     | costs associated with product consumption |
| $C_{OC}$     | costs of operating distribution centre |
| $C_{EOL}$    | costs of post-consumer waste management |
| $C_{MA}$     | costs of product manufacturing |
| $C_{PA(CO)}$ | cost of consumer shopping bag |
| $C_{PA}$     | costs of packaging |
| $C_{RE}$     | costs associated with the retail |
| $C_{RM}$     | costs of raw materials (ingredients) |
| $C_{ST(CO)}$ | cost of refrigerated storage at consumer |
| $C_{TR(CG)}$ | transport costs from cradle to grave |
| $C_{TR(CMA)}$| transport costs from cradle to manufacturer |
| $C_{TR(MA(RE)}$| transport costs from manufacturer to retailer |
| $C_{TR(RE(CO)}$| transport costs from retailer to consumer’s home |
| $LCC_{COG}$  | total life cycle costs of a product from cradle to grave |
| $LCC_{MA}$   | manufacturer’s life cycle costs |
| $LCC_{RE}$   | retailer’s life cycle costs |
| $P$          | product selling price |
| $S$          | savings (system credits) related to end-of-life waste management |
| VA           | value added |
1 Introduction

The food sector is an important part of the global economy and a significant contributor to costs of living. In developing countries, it accounts for 38.6% of household expenditure (World Bank, 2010). In developed countries, this share is lower but still substantial. For example, in Japan, 23% of household income is spent on food, in the US 14% and in the UK 11% (FAO, 2015). However, despite its importance, relatively little work exists within the scientific literature related to the life cycle economic sustainability in the food sector. Only a handful of studies have assessed the costs of food products or specific sub-sectors across their entire life cycle. For instance, Schmidt Rivera & Azapagic (2014) analysed the life cycle costs (LCC) of chilled and frozen ready-made meals in comparison with their home-made equivalents. Other studies include that by Settani et al. (2010) who considered the LCC of pasta and by Nguyen et al. (2012) who evaluated the cost of environmental impacts of meat production. Furthermore, Sonye-Mengual et al. (2018) reported the LCC of fresh vegetables at the consumption point. A similar approach was also adopted by Laso et al. (2018) in the evaluation of fresh anchovies.

Aside from the above studies, no other life cycle costing work related to food products is available in the literature. Specifically, there is a notable lack of studies of confectionary, ice cream and other frozen desserts, despite the omnipresence and popularity of these products worldwide. The current study seeks to fill this research gap by estimating LCC and value added (VA) of the production and consumption of confectionary and frozen desserts. The study is based in the UK, which is the second highest consumer of these products in Europe after Germany (Statista, 2018a; 2018b). Four major product categories are considered within these two sectors – biscuits, chocolates, cakes (ambient and frozen) and ice cream – focusing on the leading products identified through a market analysis. In addition to LCC and VA, their eco-efficiency is also considered based on their life cycle global warming potential and the LCC. The analysis is carried out at the product and sectoral levels and is aimed at manufacturers and consumers. This is detailed in the next section, together with the methods used in the study. Although the study focuses on UK market conditions, the methods described below are generic and can be applied to estimating the LCC and VA of these sectors in other countries.

2 Methods

The methodology applied in this work comprises the following steps:
1. market analysis of the confectionary and frozen desserts sectors to select market-leading products to be considered;
2. LCC, VA and eco-efficiency estimation at the product and sectoral levels; and
3. sensitivity and uncertainty analysis to ensure the robustness of the results.

These are described in turn below.

2.1 Market analysis and selection of products

The confectionary and frozen desserts sectors are very diverse and can be divided in many different sub-sectors and product categories. In this work, the focus is on the aforementioned four major product categories consumed widely worldwide, including in the UK. Each product category is also very diverse and considering the whole range of products is not feasible. Therefore, to focus the study, a market analysis has been carried out to identify and select products with the highest market share. These are listed in Table 1, which also shows the annual sales by value of the four product categories selected for consideration.

As indicated in Table 1, the annual UK sales of biscuits amount to £2.608 billion (Key Note 2015a), with a total volume sold estimated in this study at 1.7 Mt/yr; for the estimates, see Table S1a in the Supplementary Information (SI). Fig. 1a shows that the greatest market share by volume is occupied by low fat & sugar biscuits (23.5%), followed by crackers (13.9%), semi-sweet (10.8%) and chocolate cream biscuits (10.8%). Therefore, these have been selected for consideration in this study. In addition, vanilla cream sandwich and chocolate-coated biscuits are also considered (8% each). The remaining 25.1% of the sales...
volume are other biscuits involving a great variety of products with small individual contributions (Key Note 2015a). Hence, they are not considered at the product level but are included in the assessment at the sectoral level.

The cakes sector is worth £1.646 billion per year, of which ambient storage cakes are valued at £1.37 billion (Key Note, 2015a) and frozen cakes at £0.272 billion (Key Note, 2015c). An estimated total 360 Mt of cakes are consumed annually in the UK (Table S1b in the SI). As indicated in Fig. 1b, the leading product types by volume are apple pies (50.4%), cheesecake (17.6%); cake slices (12.6%), whole cakes (11.7%) and cupcakes (7.7%). Therefore, these have been chosen for evaluation, assuming that apple pies represent all pies and Victoria sponge all cakes. Strawberry cheesecake is presumed representative of all other types of cheesecake while vanilla flavoured cake slices with sugar icing represent all types of cake slice.

Table 1 Market-leading products in the biscuits, cakes, chocolates and ice creams sectors.

| Biscuits (£2.608 billion/yr) | Cakes (£1.646 billion/yr) | Chocolates (£4.344 billion/yr) | Ice cream (£1.133 billion/yr) |
|-------------------------------|-------------------------|--------------------------------|-------------------------------|
| Crackers                      | Whole cakes             | Moulded chocolate              | Vanilla regular               |
| Low fat/sugar                 | Cake slices             | Chocolate countlines            | Vanilla premium               |
| Semi-sweet                    | Pies                    | Chocolates in bags              | Chocolate regular             |
| Chocolate-coated              | Cupcakes                |                                | Chocolate premium             |
| Chocolate cream               | Cheesecake              |                                |                               |
| Vanilla cream                 |                         |                                |                               |

*Total annual sales by sector (Key Note, 2015a; Key Note, 2015b&c).

Fig. 1 Market share by volume of leading products in the biscuits, cakes, chocolates and ice cream sectors [Estimates based on data for annual share of different products by value sourced from the literature as follows: Biscuits & cakes: Key Note (2015a); Chocolates: Key Note (2015b); Frozen desserts (including ice cream): Key Note (2015c). For details, see Table S1 in the SI. CC: Chocolate-coated biscuits].
The chocolates sector is the market leader by value among the four sectors considered, with an estimated £4.344 billion/yr (Key Note, 2015b). As indicated in Fig. 1c, the leading products by volume are chocolate countlines (47.6%), chocolates in bags (24.7%), moulded chocolates (17.7%) and other chocolate confectionaries (9.9%) (Konstantas et al., 2018). For these estimates, see Table S1c in the SI. Hence, these products have been selected for further consideration.

Finally, the ice cream market has annual sales of £1.133 billion (Key Note, 2015c). Vanilla and chocolate ice cream are the leading flavours, occupying nearly 36% of the total market volume, with around 18% each (see Fig. 1d and Table S1d). The other ice cream products are wrapped ‘impulse’ ice cream and multipacks (Key Note, 2015c). The latter refers to individual wrapped impulse products sold together.

2.2 Life cycle costing, value added and eco-efficiency

The methodology for life cycle costing adopted in this study is that based on Hunkeler et al. (2008). The value-added and eco-efficiency estimates are based on LCC as described in more detail further below. Prior to that, the next section gives an overview of the goal and scope of the study.

2.2.1 Goal and scope of the study

The goals of the study are:

i. to estimate total LCC and VA in the life cycle of biscuits, cakes, chocolate and ice cream at the product level, based on a basket of 18 individual market-leading products (Table 1);
ii. to estimate costs of these products to different stakeholders: manufacturers, retailers and consumers;
iii. to identify the economic hotspots in the life cycles of these products;
iv. to evaluate the annual LCC and VA at the sectoral level based on the annual consumption of confectionary products and frozen desserts in the UK; and
v. to determine the eco-efficiency at the product and sectoral levels.

To achieve these goals, two functional units are defined, as follows:

- 1 kg of product consumed at home (study goals i-iii); and
- annual consumption of each product in the UK (study goal iv).

The system boundary spans cradle to grave, comprising production of raw materials and products, their packaging, distribution, retail, consumption, end-of-life waste management and all life cycle transport steps. This is depicted in Fig. 2, which also shows the system boundaries used to estimate the costs to manufacturers, retailers and consumers.

![Fig. 2 Life cycle stages considered for life cycle costing and the system boundaries for the costs to manufacturers, retailers and consumers [TR: transport].](image-url)
2.2.2 Estimation of life cycle costs and value added

The total life cycle costs of individual products have been calculated as follows:

\[ LCC_{CtG} = C_{RM} + C_{MA} + C_{PA} + C_{DC} + C_{RE} + C_{CO} + C_{EOL} + C_{TR(CtG)} - S \]  

(1)

where:
- \( LCC_{CtG} \): total life cycle costs of a product from cradle to grave
- \( C_{RM} \): costs of raw materials (ingredients)
- \( C_{MA} \): costs of product manufacturing
- \( C_{PA} \): costs of packaging
- \( C_{DC} \): costs of operating distribution centre
- \( C_{RE} \): costs associated with the retail
- \( C_{CO} \): costs associated with product consumption
- \( C_{EOL} \): costs of post-consumer waste management
- \( C_{TR(CtG)} \): transport costs from cradle to grave
- \( S \): savings (system credits) related to end-of-life waste management (recycling and energy recovery).

Considering costs to different stakeholders, the manufacturer’s life cycle costs comprise costs of raw materials, manufacturing, packaging and all transport up to the manufacturing facility, as illustrated in Fig. 2 and defined by eqn. (2):

\[ LCC_{MA} = C_{RM} + C_{MA} + C_{PA} + C_{TR(CtMA)} \]  

(2)

where:
- \( LCC_{MA} \): manufacturer’s life cycle costs
- \( C_{TR(CtMA)} \): transport costs from cradle to manufacturer.

Costs to the retailer incorporate the manufacturer’s costs, costs of operating distribution centres and retail space as well as transport costs from the manufacturing gate to the retailer (Fig. 2):

\[ LCC_{RE} = C_{MA} + C_{DC} + C_{RE} + C_{TR(MAIRE)} \]  

(3)

where:
- \( LCC_{RE} \): retailer’s life cycle costs
- \( C_{TR(MAIRE)} \): transport costs from manufacturer to retailer.

Finally, from the consumer’s perspective, life cycle costs include the retailer’s costs, costs of transport to purchase the product and a (plastic) shopping bag, as well as the cost of electricity for refrigerated storage and energy and water for cleaning the dishes:

\[ LCC_{CO} = C_{RE} + C_{TR(REICO)} + C_{PA(CO)} + C_{ST(CO)} + C_{CL(CO)} \]  

(4)

where:
- \( C_{TR(REICO)} \): transport costs from retailer to consumer’s home
- \( C_{PA(CO)} \): cost of consumer shopping bag (allocated to the functional unit on volume basis)
- \( C_{ST(CO)} \): cost of refrigerated storage at consumer (ice cream and frozen cakes)
- \( C_{CL(CO)} \): cost of cleaning the dishes.

In addition to LCC, VA has also been estimated at both the product and sectoral levels. VA is defined as the sales price minus the costs of goods sold (Sutherland & Canwell, 2004), reflecting the increase in economic value due to the production of the final goods. Therefore, the VA is calculated considering the life cycle costs incurred up to the retail point where the product is sold, as follows:

\[ VA = P - LCC_{RE} \]  

(5)

where:
- \( VA \): value added
2.2.3 Estimation of eco-efficiency
Following the definition by the World Business Council for Sustainable Development (Lehni, 2000), the eco-efficiency can be estimated as a ratio of an environmental impact to the economic value of a product or service. LCC can be used as an indicator of a product system value (ISO, 2012) as any cost variation alters the economic value added and consequently the corresponding system value. Different environmental impacts can be considered for the estimation of eco-efficiency. Here, global warming potential is selected as one of the key impacts of interest to manufacturers, policy makers and consumers. Therefore, the eco-efficiency is estimated as a ratio of GWP and LCC, both at the product and sectoral levels, with the lower values representing a higher efficiency. The GWP values for the products and sectors have been sourced from Konstantas (2018), Konstantas et al. (2018) and Konstantas et al. (2019). These have been estimated based on the same system boundary as for the LCC and are summarised in Table 2 and Table 3, respectively.

Table 2 Global warming potential (GWP) of confectionary products and frozen desserts (Konstantas, 2018, Konstantas et al., 2018, Konstantas et al., 2019)

| Product                | GWP (kg CO₂ eq./kg) |
|------------------------|---------------------|
| **Biscuits**           |                     |
| Crackers               | 1.31                |
| Low fat/sugar          | 1.27                |
| Semi-sweet             | 1.28                |
| Chocolate coated       | 1.81                |
| Vanilla cream          | 1.29                |
| Chocolate cream        | 1.36                |
| **Cakes**              |                     |
| Whole cakes            | 2.04                |
| Cake slices            | 1.78                |
| Pies                   | 1.58                |
| Cupcakes               | 2.18                |
| Cheesecakes            | 4.83                |
| **Chocolates**         |                     |
| Moulded chocolate      | 3.39                |
| Chocolate countlines   | 2.91                |
| Chocolates in bags     | 4.15                |
| **Ice cream**          |                     |
| Vanilla regular        | 3.75                |
| Chocolate regular      | 3.66                |
| Vanilla premium        | 3.94                |
| Chocolate premium      | 3.91                |

Table 3 Global warming potential (GWP) of the confectionaries and frozen sectors based on the annual consumption in the UK (Konstantas, 2018)

| Sub-sectors and sectors | GWP (kt CO₂ eq./yr) |
|-------------------------|---------------------|
| Biscuits sub-sector     | 2573                |
| Cakes sub-sector        | 820                 |
| Chocolates sub-sector   | 2176                |
| Ice cream sub-sector    | 1573                |
| Confectionary sector    | 5263                |
| Frozen desserts sector  | 1879                |
Table 4 Cost data along the life cycle of the products considered in the study

| Life cycle stage                      | Cost (£/unit) | Source                                      |
|---------------------------------------|---------------|---------------------------------------------|
| **Raw materials (ingredients)**       |               |                                             |
| Acetic acid                           | 0.46 (£/kg)   | ICIS (2015)                                 |
| Apples                                | 0.61 (£/kg)   | Office for National Statistics UK (2015)    |
| Butter                                | 1.94 (£/kg)   | DEFRA (2015)                                |
| Citric acid                           | 0.79 (£/kg)   | ICIS (2015)                                 |
| Cocoa butter                          | 2.11 (£/kg)   | Niagara – Atlantic (2015)                   |
| Cocoa liquor                          | 2.65 (£/kg)   | Niagara Atlantic Industries (2015)          |
| Cocoa powder                          | 2.85 (£/kg)   | Niagara Atlantic Industries (2015)          |
| Eggs pasteurised                      | 5.99 (£/kg)   | Bulk Powders (2015)                         |
| Egg-yolk pasteurised                  | 10.95 (£/kg)  | Fine Food Specialist (2015)                 |
| Flour white                           | 0.94 (£/kg)   | Marriage’s Master Millers (2015)            |
| Flour wholmeal                        | 1 (£/kg)      | Marriage’s Master Millers (2015)            |
| Fructose – glucose                    | 3 (£/kg)      | RealFoods (2015)                            |
| Glycerine (vegetable)                 | 2.4 (£/kg)    | Darrant Chemicals (2015)                    |
| Milk cream                            | 0.98 (£/kg)   | DairyCO (2015)                              |
| Milk powder                           | 2.19 (£/kg)   | Index Mundi (2015)                          |
| Palm kernel oil                       | 0.595 (£/kg)  | Index Mundi (2015)                          |
| Palm oil                              | 0.37 (£/kg)   | Index Mundi (2015)                          |
| Raw milk                              | 0.24 (£/kg)   | DairyCo (2015)                              |
| Salt                                  | 0.13 (£/kg)   | Credit Chem Group (2015)                    |
| Soda                                  | 0.33 (£/kg)   | ICIS (2015)                                 |
| Soft cheese                           | 2.28 (£/kg)   | DEFRA (2015)                                |
| Sorbic acid                           | 79.19 (£/kg)  | ICIS (2015)                                 |
| Starch                                | 1.12 (£/kg)   | RealFoods (2015)                            |
| Strawberries                          | 2.26 (£/kg)   | Office for National Statistics UK (2015)    |
| Sugar                                 | 0.37 (£/kg)   | Index Mundi (2015)                          |
| Vanilla extract                       | 155 (£/kg)    | Vanilla Mart (2015)                         |
| Vanillin                              | 11.97 (£/kg)  | ICIS (2015)                                 |
| Whey powder                           | 1.064 (£/kg)  | Index Mundi (2015)                          |
| Yeast                                 | 9.36 (£/kg)   | RealFoods (2015)                            |
| **Manufacturing**                     |               |                                             |
| Electricity                           | 0.079 (£/kWh) | DECC (2015)                                 |
| Liquid ammonia                        | 0.33 (£/kg)   | Technicol Services (2015), ICIS (2015)      |
| Lubricant                             | 0.664 (£/kg)  | ICIS (2015)                                 |
| Natural gas                           | 0.019 (£/kWh) | DECC (2015)                                 |
| Nitric acid                           | 0.141 (£/kg)  | ICIS (2015)                                 |
| Sodium hydroxide                      | 0.416 (£/kg)  | ICIS (2015)                                 |
| Steam                                 | 0.034 (£/MJ)  | DECC (2015)                                 |
| Water                                 | 0.0016 (£/l)  | United Utilities (2015)                     |
| **Packaging**                         |               |                                             |
| Aluminium                             | 1.22 (£/kg)   | LME (2015)                                  |
| Corrugated board                      | 0.14 (£/kg)   | LetsRecycle (2015)                          |
| Folding box                           | 0.14 (£/kg)   | LetsRecycle (2015)                          |
| Low density polyethylene              | 1.57 (£/kg)   | Plastic Informat (2015)                     |
| Paper                                 | 0.14 (£/kg)   | LetsRecycle (2015)                          |
| Plastic bags (retailer price)         | 0.05 (£/piece)| UK retailers                                |
| Polypropylene                         | 1.69 (£/kg)   | Plastic Informat (2015)                     |
| **Distribution centre, retail and consumption** | |                                                       |
| Electricity                           | 0.079 (£/kWh) | DECC (2015)                                 |
| Water                                 | 0.0016 (£/l)  | United Utilities (2015)                     |
| Refrigerant (R134a)                   | 12.8 (£/kg)   | Schmidt & Azapagic (2014)                   |
| Electricity (domestic)                | 0.152 (£/kWh) | Ofgem (2015)                                |
| Detergent                            | 6.65 (£/kg)   | Tesco (2015)                                |
| **Transport**                         |               |                                             |
| Fuel for passenger car                | 1.208 (£/l)   | Global Petrol Prices (2014)                 |
| Transoceanic tanker                   | 0.0025 (£/km) | VTT (2010), Global Petrol Prices (2014)    |
| Transport (16 t lorry)                | 0.00003 (£/kg km) | DECC (2015), VTT (2010)                                      |
| **Waste management**                  |               |                                             |
| Wastewater treatment                  | 0.0013 (£/l)  | United Utilities (2015)                     |
| Landfilling                           | 0.1 (£/l)     | WRAP (2015)                                 |
| Energy recovery                       | 0.99 (£/kg)   | WRAP (2015)                                 |
| Recycling                             | 0.06 (£/kg)   | WRAP (2015)                                 |
| Organic waste                         | 0.046 (£/kg)  | WRAP (2015)                                 |

\[ ^a \] Refrigerant used for deep-freezing of ice cream. Frozen storage at manufacturer: 30 days (Konstantas et al., 2019).

\[ ^b \] Frozen storage of ice cream: 7 days at retailer and 30 days at consumer (Konstantas et al., 2019). Frozen storage of cheesecake: 30 days at distribution centre, 15 days at retailer and 5 days at consumer (Konstantas, 2018).

\[ ^c \] Average fuel consumption assumed at 10 l/100 km.
Life cycle cost data

Life cycle cost data for individual products have been collected from manufacturers, literature and other publicly available sources. These are summarised in Table 4, which lists costs of all flows and activities across the 18 products considered in the study, together with the data sources. A detailed breakdown of ingredients and costs by product can be found in Table S2 in the SI. Where possible, all cost data are representative of UK conditions in 2015. In the case of multi-function or multi-output systems, the costs have been allocated on an economic basis. The savings (system credits) correspond to the market prices of recycled materials (see Table S2).

To estimate the LCC and VA at the sectoral level, it has been necessary to define sales volumes and typical retail prices. Due to a lack of data on the sales volumes, these have been estimated based on the annual monetary value (Key Note 2015a-c). These values have been divided by the typical retail prices of each product in the UK at three major UK supermarkets (Tesco, 2015; Sainsbury’s, 2015; Morrison, 2015) to obtain an estimated sales volume for each product in mass terms (Table S1). The retail prices and the derived annual sales volumes are given in Table 5. In the case of different retail prices for the same product, the lowest price has been adopted. Thus, following a conservative approach, the highest possible sales volumes have been considered.

In the estimation of the sales volumes, it has been assumed that cupcakes, pies and cake slices have equal sales value as their individual share of the market is not known. In a similar fashion, semi-sweet and vanilla cream biscuits are also presumed to have the same sales values. The same assumption applies for chocolate-coated and chocolate cream biscuits as only the total sales of chocolate-containing biscuits are available but not their individual shares. For ice cream, the same sales of vanilla and chocolate flavour are considered. Any other products that could not be assigned to the existing product categories have been allocated to the ‘other’ category. Taking a conservative approach, their LCC are assumed to be equal to the highest cost to the retailer in each product category.

Table 5 Product sales prices and estimated annual sales volumes

| Category   | Products                  | Retail price [£/kg] | Sales value [£m/yr] | Sales volume [t/yr] |
|------------|---------------------------|---------------------|---------------------|---------------------|
| Biscuits   | Crackers                  | 1.3                 | 362                 | 278,462             |
|           | Low fat/sugar             | 1.5                 | 612                 | 409,000             |
|           | Semi-sweet                | 1.1                 | 281.5               | 255,909             |
|           | Chocolate coated          | 2                   | 208.5               | 104,250             |
|           | Vanilla cream             | 6.4                 | 281.5               | 43,984              |
|           | Chocolate cream           | 6.5                 | 208.5               | 32,077              |
|           | Other biscuit products a  | 1.1                 | 654                 | 594,545             |
|           | Total                     |                     |                     | 2608                |
|           | Cakes                     | 6.8                 | 287                 | 42,206              |
|           | Whole cakes               | 8                   | 362.3               | 45,288              |
|           | Cake slices               | 2                   | 362.3               | 181,150             |
|           | Pies                      | 13                  | 362.3               | 27,869              |
|           | Cupcakes                  | 4.3                 | 272                 | 63,256              |
|           | Cheesecakes               |                     |                     | 1646                |
|           | Total                     |                     |                     | 359,769             |
| Chocolates | Moulded chocolate         | 7.5                 | 845                 | 112,667             |
|           | Chocolate countlines      | 6                   | 1817                | 302,833             |
|           | Chocolates in bags        | 8.3                 | 1304                | 157,108             |
|           | Other chocolate products b| 6                   | 378                 | 63,000              |
|           | Total                     |                     |                     | 4344                |
|           | Ice cream                 |                     |                     | 635,608             |
|           | Vanilla regular           | 2                   | 55                  | 27,500              |
|           | Chocolate regular         | 2                   | 55                  | 27,500              |
|           | Vanilla premium           | 5                   | 221.5               | 44,300              |
|           | Chocolate premium         | 5                   | 221.5               | 44,300              |
|           | Other ice cream products c| 2.225               | 580                 | 260,674             |
|           | Total                     |                     |                     | 1133                |
|           |                           |                     |                     | 404,274             |

a Seasonal, savoury, children and special treats (Key Note 2015a) report.
b Seasonal products and novelties (Key Note, 2015b).
c Other than take-home ice creams (Key Note 2015c).
3 Results and discussion
This section first presents the LCC and VA estimates by product type, followed by sensitivity and uncertainty analyses. The latter part of the section discusses the LCC and VA estimates at the sectoral level.

3.1 Economic sustainability at the product level
Among the product categories considered, cakes are found to have the highest LCC, followed by ice cream, chocolates and finally biscuits (Fig. 3–Fig. 6). These findings are discussed below by product category.

3.1.1 Life cycle costs of biscuits
The total life cycle costs of biscuits and the contribution of different stages are shown in Fig. 3. The most costly product is crackers (£0.91/kg) while the vanilla cream biscuits are the least expensive (£0.72/kg). The costs of all other biscuits are within approximately 15% of each other. The raw materials have the highest contribution to the total costs, ranging between 79% and 86%. This is mainly due to flour, milk and cocoa powder, palm oil and sugar, with flour alone contributing on average 50% of the total (see Table S2). While the unit cost of flour is quite low (£0.94/kg), it makes up the majority of the mass of the biscuits which explains its high overall contribution to the total cost.

Manufacturing contributes 6%–7%, mainly due to energy consumption in the production process. This is followed by packaging with 4%–6%, except for crackers where it accounts for 11%. The latter is due to the use of more packaging material per mass of product compared to the other types of biscuit, leading to their highest overall LCC in this product category. The rest of the costs (3%–4%) are due to transport. Crediting the system for end-of-life packaging recycling and energy recovery reduces the costs by only 1%–3% (Table S3).

3.1.2 Life cycle costs of cakes
The results in Fig. 4 indicate that whole cakes are the most costly products (£2.64/kg) with a total LCC 42% higher than the lowest cost, estimated for pies (£1.52/kg).

More than any of the other product categories, cakes are dominated by the raw material costs, which account for 80%–94% of the total LCC. Pasteurised eggs, fructose/glucose sweetener, butter, flour, strawberry, milk powder and palm oil contribute most to the costs of ingredients (Table S3). Eggs are the biggest individual cost component, accounting for an average of 43% across the products. The only exception is cheesecake which does not include eggs, where milk powder and soft cheese together account for 53% of the total LCC.

The second most contributing stage is packaging, with noteworthy contributions to the costs of cupcakes (12.8%) and pies (7%). Cupcakes benefit from some cost savings (3%) due to a greater amount of energy recovered from the incinerated packaging, related to a higher amount of packaging used for these products.

3.1.3 Life cycle costs of chocolates
The LCC of chocolate products are presented in Fig. 5 which reveals that chocolates in bags are the most expensive product type (£1.46/kg), followed closely by moulded chocolates (£1.16/kg). By comparison, chocolate countlines cost £1.16/kg.

Raw materials again dominate the LCC, accounting for 89%–94% of the total, with milk powder, cocoa butter and liquor as well as sugar being the most relevant ingredients (see Table S2). Milk powder is the greatest single contributor, accounting for an average of 35% of the LCC. It can also be noted in Fig. 5 that the cost of packaging is over three times higher for chocolates in bags than for the moulded chocolates, despite their packaging materials being very similar. This is due to the bagged chocolates requiring more packaging per unit of product. However, in comparison with raw materials, packaging and other stages have
insignificant contributions to the LCC. Further details on the contribution analysis can be found in Table S3.

**Fig. 3** Life cycle costs (LCC) of biscuits [RM: raw materials; MA: manufacturing; PA: packaging; RE: retail; CO: consumption; EoL: end-of-life waste management; TR: transport; S: savings (system credit for EoL)].

**Fig. 4** Life cycle costs (LCC) of cakes [For the legend, see Fig. 3.].

**Fig. 5** Life cycle costs (LCC) of chocolates [For the legend, see Fig. 3.]
3.1.4 Life cycle costs of ice cream

As indicated in Fig. 6, chocolate premium ice cream has the highest LCC (£1.30/kg) while vanilla regular is the least costly (£1.03/kg). This difference is entirely attributable to the raw materials: premium chocolate ice cream contains egg yolk and cocoa, which are expensive ingredients (Table S2) and not used in the regular varieties. It also has a 27% higher amount of sugar compared to the vanilla regular product.

Across all four types of ice cream, production of raw materials is the most expensive life cycle stage (43%–55% of the total), mainly due to milk (30%–37%). Packaging is the next significant stage, with contributions ranging from 23%–29%, largely due to the polypropylene tub. Manufacturing is the third biggest contributor (11%–14%) with energy consumption accounting for 10%–13% of the total costs, the vast majority of which is related to electricity usage. The retail stage contributes 4%–5% of the total LCC, mostly caused by energy consumption for refrigeration. The contribution of the consumption stage is similar to retail (4%–6%), mainly due to energy consumed by the freezer and hot water used to wash the used dishes. Crediting the system for packaging recycling and energy recovery saves £0.020–0.022/kg ice cream, reducing the total LCC by 2%. For further details on the contribution of different life cycle stages to the costs, see Table S3.

3.1.5 Costs to different stakeholders and value added

The LCC to manufacturers, retailers and consumers are shown for each product in Fig. 7. These have been estimated using eqns. (2)–(4), based on the system boundaries outlined in Fig. 2. Fig. 7 also provides the VA by product type, obtained via eqn. (5), using the LCC discussed in the previous sections and the sales prices of the products in Table S2. Further details on the costs to different stakeholders and VA can be found in Table S4.

As can be inferred from Fig. 7, the costs to the biscuit manufacturers are 4.7%–7.3% lower than their respective total LCC. A similar difference is found for cakes (4%–8.5%), while for chocolates the differential is only 2%. By contrast, the costs of ice cream manufacture are 23%–30% lower than the total LCC, largely due to the additional refrigeration beyond the manufacturer's gate.

Costs to retailers are higher with respect to manufacturers’ costs on average by 1.5% for all product categories but the ice cream (7%); the latter is again due to refrigeration. Finally, costs to consumers relative to retailers are on average 20% higher for ice cream and, for the other products, they are greater by 1% to 6%.

The highest VA is found for the cupcakes, estimated at £11.28/kg (Fig. 7a). This is due to the low costs of ingredients and high retail price per kg relative to the other cake types. The next highest VA is for chocolates in bags with £6.84/kg and moulded chocolates with £6.11/kg.
They both command high retail prices (£8.3 and £7.5 per kg) and have low retailer’s LCC (£1.46 and £1.39/kg), hence the high VA. At the other end of the scale, the lowest VA, found for semi-sweet biscuits, is 30 times lower than that of the cupcakes. This type of biscuit has a low retail price (£1.10/kg) and, despite only a moderate retailer’s LCC (£0.75/kg), generates only £0.35/kg in VA. The other products with a relatively low VA are crackers (£0.44/kg) and pies (£0.55/kg). Among the biscuits, the highest VA is found for the vanilla and chocolate cream varieties (~£5.75/kg) and, among the ice cream, for the premium products (~£4/kg).

(a) Biscuits and cakes

(b) Chocolates and ice cream

**Fig. 7** Life cycle costs to different stakeholders and value added by product
3.1.6 Sensitivity analysis
Given the high contribution of raw materials across the products, and the packaging for ice cream, these two life cycle stages are the focus of the sensitivity analysis as discussed below. The effect on the LCC of energy consumption in the manufacturing, retail and use stages is explored.

3.1.6.1 Raw materials
Loss of raw materials in manufacturing can be highly variable. In the base case presented above, manufacturing losses have been assumed at 2%. In the sensitivity analysis, two cases are examined, one assuming 5% and another 10% losses of raw materials. The results are shown in Fig. 8, expressed relative to the base case costs.

If the manufacturing losses increase from 2% to 5%, the overall LCC increase by around 1% for ice cream and up to 3% for the remaining products. When losses are assumed to be 10%, the costs go up by 3%-4% for ice cream, 4%-8% for biscuits and 6%-8% for chocolates and cakes. Hence, a five-fold increase in raw material losses increases the overall LCC by only 3%-8%. Nevertheless, production losses have an obvious adverse effect on both the economic and environmental sustainability and should be minimised as much as possible.

3.1.6.2 Packaging losses in ice cream manufacturing
To examine how manufacturing losses in ice cream packaging influence the LCC, it is assumed that 5% and 10% of packaging is lost in manufacturing instead of 2% assumed in the base case. The results in Fig. 9 suggest very low influence of packaging losses on the total LCC. An increase in the packaging losses from 2% to 5% increases the LCC at most by 1.5%, while an increase to 10% changes the total by 3%. Therefore, the total costs are not sensitive to packaging wastage. However, generation of waste is undesirable and should be kept as low as possible.

3.1.6.3 Energy
The effect on the LCC of energy used in the manufacturing, retail and use stages is explored by varying the total energy consumption by ±20%. As Fig. 10 indicates, the relationship between energy and life cycle costing is stronger in the case of ice cream than for the other products. This is attributable to the refrigeration energy used in the life cycle of ice cream. However, the total LCC of ice cream only changes by ±3%. The LCC of the other products is altered by ±0.2-1.4%, with the latter referring to chocolate-coated biscuits. Nevertheless, despite this low variation in the overall LCC with energy consumption, the cost reductions are likely to be significant on an annual basis.
Fig. 8  The effect on the life cycle costs (LCC) of increasing raw materials losses in manufacturing relative to the base case losses (2%).

Fig. 9  The effect on the life cycle costs (LCC) of increasing packaging losses for ice cream relative to the base case losses (2%).
Fig. 10 The effect on the life cycle costs (LCC) of the variation in energy consumption in manufacturing and distribution.

3.1.7 Uncertainty analysis
In addition to the uncertainties explored in the sensitivity analysis, the uncertainty analysis also considers potential price changes across the life cycle. A variation of ±25% over a three-year period is considered to capture sizeable year-on-year price swings.

The uncertainty analysis has been carried out through Monte Carlo simulation using @RISK7 software (Palisade, 2017). A total of 20,000 iterations have been performed for each product using the PERT distribution for each distinct parameter and considering a 95% confidence interval. This type of distribution has been selected because it places equal emphasis on the minimum and maximum values in the range, which are normally less well-known than the most likely value.

The results in Fig. 11 and Table S5 reveal that the LCC could vary by ±12% (chocolates in bags and chocolate premium ice cream) to 19% (low fat/sugar biscuits). However, their ranking in terms of costs remains unchanged: cakes maintain their position as the most costly product category, followed by ice cream, chocolates and finally biscuits.

3.2 Economic sustainability at the sectoral level
This section presents the LCC and VA at the sectoral level, estimated using the LCC and VA of the individual products discussed in sections 3.1.1–3.1.4 and their annual sales volumes given in Table 5. The total LCC at the sectoral level are estimated at £3.455 billion/yr (Fig. 12 and Table S6). Biscuits contribute most to the total costs (41%) due to their high sales volumes (1.72 million t/yr). They are followed by chocolates, accounting for 23% of the total – although their sales volume is much lower (636 kt/yr), they have a higher average cost per kg (see previous sections). Cakes and ice cream contribute 19% and 15% to the total costs, respectively.
Fig. 11 Uncertainty analysis for the four product categories considered in the study [Parameters varied: raw material and packaging losses in manufacturing, energy consumption and costs across the life cycle of products].
The total VA per year is equivalent to £6.483 billion, of which chocolates account for 54% (Fig. 12 and Table S6). Within this product category, chocolate countlines generate the most value (£1.47 billion/yr) due to the combination of high sales volumes, high retail prices and relatively low costs (see section 3.1.5). Overall, chocolates have a five-fold higher VA than ice cream (which accounts for 11% of the total sectoral VA), three times higher than biscuits (19%) and more than three times greater than cakes (16%). Although ice cream creates the lowest total VA at the sectoral level, it is notable that the premium versions generate four times the value of their respective regular counterparts as they command a 150% higher retail price despite their similar costs per unit.

The above results are contextualised in Fig. 13 against the sales values (Key Note, 2015a-c) of the four product categories considered. As indicated in the figure, the annual LCC of biscuits contribute around 55% to their total sales value, with the rest representing the VA. The share of the LCC in the sales value of cakes is lower, estimated at 38%, and thus the contribution of VA to the total is somewhat higher than for biscuits. The split between the LCC and the VA for ice cream is similar to that of cakes, with the former accounting for 41% of the sales value and the VA for 59%.

**Fig. 12** Annual life cycle costs (LCC) and value added (VA) at the sectoral level.

**Fig. 13** Annual sales of products by value, showing contributions of the life cycle costs and value added to the total.
Chocolates, on the other hand, have a much lower LCC contribution (19%) than the other products; therefore, their VA is considerably higher (81%), making chocolates economically the most efficient sector.

The total sales value in these four sectors estimated in this work is £9.938 billion – this differs only by 2% from the value of £9.731 billion reported by Key Note (2015a-c), instilling further confidence in the results. Overall, the estimated LCC of £3.455 billion account for 35% of the total sales and VA the remaining 65%.

3.3 Eco-efficiency at the product and sectoral levels

To put the economic performance in context, this section considers eco-efficiency of the products and sectors relative to their environmental performance. As explained in Section 2.2.3, global warming potential is considered for these purposes.

The estimated eco-efficiencies of the different products considered in the study are illustrated in Fig. 14. As can be seen, whole cakes are the most eco-efficient product type with an eco-efficiency of 0.77 kg CO$_2$ eq./£, while vanilla regular ice cream has the lowest eco-efficiency of 3.64 kg CO$_2$ eq./£. The cakes are generally most eco-efficient: although they have high LCC, their GWP is relatively low, leading to a lower score and, therefore, higher eco-efficiency. The exception to this is cheesecake which is ranked 13th out of 18 products due to its high GWP – more than two times higher than that of whole cakes (Table 2).

Biscuits are the second most eco-efficient products with respect to GWP, with the crackers being the best and chocolate-coated biscuits the worst in this category (1.44 and 2.06 kg CO$_2$ eq./£, respectively). Chocolates are ranked third overall, with the eco-efficiency values in the range of 2.4 and 2.84 kg CO$_2$ eq./£. The ice cream is the least efficient product category due to the high GWP, leading to 2.5–4.7 times worse eco-efficiency than the cakes (3.01–3.64 kg CO$_2$ eq./£).

The above results are also reflected at the sectoral level, with the cakes sub-sector being the most eco-efficient at 1.3 kg CO$_2$ eq./£ and the ice cream the least efficient with 3.1 kg CO$_2$ eq./£ (Fig. 15). Biscuits and chocolates are ranked 2nd and 3rd, respectively. Overall, as indicated in Fig. 15, the confectionary sector is around 60% more eco-efficient than the frozen desserts sector (1.9 vs 3 kg CO$_2$ eq./£).

![Fig. 14 Product eco-efficiency with respect to the global warming potential (GWP) and life cycle costs (left) and the ranking of products based on their eco-efficiency (right). [The values on top of the bars in the graph on the right represent the eco-efficiency scores of the products obtained by dividing their respective GWP values by their life cycle costs (kg CO$_2$ eq./£). The lower the score, the higher the eco-efficiency.]](image-url)
4 Conclusions

This study has estimated life cycle costs and value added of biscuits, cakes, chocolates and ice cream, both at the level of individual products and for the whole sector. For the 18 product types assessed, the life cycle costs range from £0.72 to £2.64/kg, with vanilla cream biscuits having the lowest and whole cakes the highest costs.

In the biscuits category, crackers have the highest life cycle costs, followed by chocolate-coated; vanilla cream biscuits are the least costly. Raw materials are the main hotspot, with flour, milk and cocoa powder being the main contributors.

In the cakes sector, whole cakes have the highest costs. Like the other product categories, the majority of costs within the life cycle of cakes are related to raw materials.

Chocolates show a similar pattern in terms of the contribution analysis: raw materials production is by far the most costly stage, accounting for 89%–94% of the total life cycle costs. Milk powder, cocoa butter and liquor as well as sugar production are the most cost-relevant activities.

Within the ice cream sector, the premium versions have up to 18% higher life cycle costs than their regular counterparts, primarily because they contain egg yolk and more sugar. Chocolate premium ice cream has the highest overall costs. The majority of costs are due to raw materials, followed by manufacturing, packaging and retail. Within these, the key activities are milk production, energy consumption for ice cream refrigeration and packaging.

The estimated value added across the products ranges from £0.35/kg for semi-sweet biscuits to £11.28/kg for cupcakes. Chocolates in bags, moulded chocolates, cake slices and cream biscuits also have a high value added (£5.71-6.84/kg) which is four to six times higher than their overall costs. It is also notable that premium ice cream products create four times higher value added than their regular counterparts (~£4/kg vs ~£1/kg), despite a much smaller difference in their costs (18%).

The total annual life cycle costs in the four sectors considered are estimated at £3.455 billion, of which 42% is contributed by the biscuits due to their high sales volume. The total value added is nearly £6.5 billion per year, half of which is created by chocolates because of their high retail prices.

The study has also demonstrated how LCC can be used to evaluate the eco-efficiency of products and sectors. Using global warming potential as an environmental indicator, the results suggest that whole cakes are the most eco-efficient and vanilla regular ice cream the least efficient products. The same trend is found at the sectoral level, with cakes being the best and ice cream the worst sub-sectors for the eco-efficiency. Overall, the confectionary sector is around 60% more eco-efficient than the frozen desserts sector. However, these
results are based on one environmental indicator so the ranking of products and sectors could change if other life cycle impacts are also taken into account. This should be considered as part of future work. Multi-criteria decision analysis could be used to rank the products and sectors on their eco-efficiency.

The results of this study can be used for benchmarking of different products and to drive innovation towards economically-sustainable and eco-efficient confectionary and frozen desserts supply chains. They can also be used to stimulate closer collaboration between different players in the supply chain, helping to make more informed procurement and purchasing decisions. Although the focus here has been on the UK market, the methods developed are generic and can be applied to estimate life cycle costs, value added, and eco-efficiency of these sectors in other countries and regions.

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# Economic sustainability of food supply chains: life cycle costs and value added in the confectionary and frozen desserts sectors

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## Supporting information

**Table S1a.** Estimates of the volume of biscuits sold annually

| 1. Sales volume (Key Note 2015a) | 2. Biscuit categories – consumer perspective | 3. Biscuit categories – manufacturer perspective | 4. Alignment of consumer and manufacturer classification | 5. Assumptions | 6. Average market prices | 7. Estimated total sales volume |
|----------------------------------|---------------------------------------------|-----------------------------------------------|-----------------------------------------------|----------------|--------------------------|-----------------------------|
| Crackers: £362 million/yr         | Crackers                                    | Similar from both perspectives                 | Cracker: £1.3/kg                              | Crackers: 278,462 t |
| Healthier biscuits: £612 m/yr    | Healthy biscuits                            | Low fat/sugar                                  | Low fat/sugar: £1.5/kg                        | Low fat/sugar: 408,000 t |
| Chocolate biscuits: £417 m/yr    | Chocolate biscuits                          | Chocolate-coated/white chocolate              | Chocolate-coated: £2/kg                       | Chocolate-coated: 104,250 t |
| Everyday biscuits: £563 m/yr     | Everyday biscuits                           | Semi-sweet                                     | Semi-sweet: £1.1/kg                           | Semi-sweet: 255,909 t |
|                                  | Chocolate-coated                            | Equal share of vanilla cream and semi-sweet   | Chocolate-coated: £6.5/kg                     | Chocolate cream: 32,077 t |
|                                  | Chocolate cream sandwich                    |                                              |                                              |                                              |
|                                  | Vanilla cream sandwich                      | Equal share of vanilla cream and semi-sweet   | Vanilla cream: £6.4/kg                        | Vanilla cream: 43,984 t |
| Other types (seasonal, special, children’s, etc.): £563 m/yr | Other types | Other types                                    | Other: £1.1/kg                               | Other: 594,545 t |

Total: £2,608 m/yr
Table S1b. Estimates of the volume of cakes sold annually

| 1. Sales volume (Key Note 2015a & c) | 2. Assumptions | 3. Average market prices | 4. Estimated total sales volume |
|-------------------------------------|-----------------|--------------------------|---------------------------------|
| Whole cakes: £287 million/yr        | Assumed to be Victoria sponge cake | Whole cakes: £6.8/kg | Whole cakes: 42,206 t |
| Individual cakes: 1,087m/yr         | Equal share of slices, pies and cupcakes | Cake slices: £8/kg | Cake slices: 45,288 t |
| Cake slices: £362.3 m/yr            |                                | Pies: £2/kg | Pies: 181,150 t |
| Pies: £362.3 m/yr                  |                                | Cupcakes: £2/kg | Cupcakes: 27,869 t |
| Cupcakes: £362.3 m/yr              |                                | Cheesecake: £4.3/kg | Cheesecake: 63,256 t |
| Cheesecake: £272 m/yr              |                                |                          |                          |
| Total: 1,645.9 m/yr                |                                |                          |                          |

Table S1c. Estimates of the volume of chocolates sold annually

| 1. Sales volume (Key Note 2015b) | 2. Chocolates categories – consumer perspective | 3. Chocolate categories – manufacturer perspective | 4. Average market prices | 5. Estimated total sales volume |
|----------------------------------|-------------------------------------------------|---------------------------------------------------|--------------------------|--------------------------------|
| Moulded chocolates: £845 million/yr | Moulded chocolates | Moulded chocolates | Moulded: £7.5/kg | Moulded: 112,667 t |
| Chocolate countlines: £1,817 m/yr | Chocolate countlines | Chocolate countlines | Countlines: £6/kg | Countlines: 302,833 t |
| Chocolates in bag: £1,304 m/yr | Chocolates in bag | Chocolates in bag | In bag: £8.3/kg | In bag: 157,108 t |
| Other chocolates: £378 m/yr | Other chocolates | Other chocolates | Other: £6/kg | Other: 63,000 t |
| Total: 4,344 m/yr | | | | |

Table S1d. Estimates of the volume of ice cream sold annually

| 1. Sales volume (Key Note 2015c) | 2. Sales share in the take-home sector | 3. Product categories considered | 4. Assumptions | 5. Average market prices | 6. Estimated total sales volume |
|----------------------------------|----------------------------------------|---------------------------------|----------------|--------------------------|--------------------------------|
| Take-home ice cream: £899 million/yr | Regular ice cream 12.2% | Regular ice cream | Vanilla and chocolate occupy 100% of the regular and premium ice cream market in equal shares (no actual data available) | Regular: £2/kg | Vanilla regular: 27,500 t |
| Premium ice cream 49.3% | Premium ice cream | | Premium: £5/kg | Chocolate premium: 44,300 t |
| Wrapped impulse ice cream: £234 m/yr | Multipacks 38.5% | Other (wrapped impulse & multipacks) | Premium: £2.225/kg | Other ice cream: 260,674 t |
| Total: 1,133 m/yr | | | | |
## Table S2: Life cycle cost inventory for the 18 products considered in the study

| Crackers            | Activities                                      | Value per functional unit (1 kg of product) | Unit | Unit price (£) | Total cost (£) |
|---------------------|-------------------------------------------------|---------------------------------------------|------|---------------|----------------|
| Raw materials (RM)  | Flour white                                     | 0.653                                       | kg   | 0.936         | 0.611208       |
| RM                  | Palm oil                                        | 0.103                                       | kg   | 0.3698        | 0.0380894      |
| RM                  | Sugar                                           | 0.0115                                      | kg   | 0.37          | 0.004255       |
| RM                  | Ammonium bicarbonate                            | 0.0013                                      | kg   | 0.33          | 0.000429       |
| RM                  | Salt                                            | 0.0064                                      | kg   | 0.13          | 0.000832       |
| RM                  | Yeast                                           | 0.0064                                      | kg   | 9.36          | 0.059904       |
| RM                  | Water                                           | 0.28                                        | kg   | 0.0016        | 0.000448       |
| Transport (TR)      | Transport lorry (raw materials to manufacturer) | 184.48                                      | kg*km| 0.00003       | 0.0055344      |
| TR                  | Transport ship (raw materials to manufacturer)  | 1630                                        | kg*km| 5.00E-08      | 0.0000815      |
| Manufacturing (MA)  | Electricity                                     | 1.259                                       | MJ   | 0.022         | 0.027698       |
| MA                  | Gas                                             | 4.16                                        | MJ   | 0.0054        | 0.022464       |
| MA                  | Lubricants                                      | 0.00001                                    | kg   | 0.664         | 0.00000664     |
| MA                  | Wastewater                                      | 0.5                                         | L    | 0.0013        | 0.000656       |
| MA                  | Water                                           | 0.5                                         | L    | 0.0016        | 0.0008         |
| Packaging (PA)      | Polypropylene primary packaging                 | 0.0104                                      | kg   | 1.69          | 0.017576       |
| PA                  | Cardboard secondary packaging                   | 0.382                                       | kg   | 0.14          | 0.05348        |
| Distribution centre (DC) | Water                            | 0.00693                                      | L    | 0.0016        | 0.000011088    |
| DC                  | Transport lorry                                 | 150                                         | kg*km| 0.00003       | 0.0045         |
| DC                  | Electricity                                     | 0.00000205                                  | MJ   | 0.022         | 4.51E-08       |
| DC                  | Wastewater                                      | 0.00693                                    | L    | 0.0013        | 0.00000909     |
| DC                  | LDPE tertiary packaging                          | 0.00047                                    | kg*km| 1.57          | 0.0007379      |
| TR                  | Transport lorry                                 | 7.29                                        | kg*km| 0.00003       | 0.0002187      |
| PA                  | Plastic bags 1 bag weight 0.0075 kg and costs 5p| 0.0047                                      | kg   | 6.6           | 0.03102        |
| Retailer (RE)       | Water                                           | 2.09                                        | L    | 0.0016        | 0.003344       |
| RE                  | Electricity                                     | 0.000824                                   | MJ   | 0.022         | 0.000018128    |
| RE                  | Wastewater                                      | 2.09                                        | L    | 0.0013        | 0.002717       |
| RE                  | Waste to recycling (secondary packaging)         | 0.033043                                   | kg   | 0.06          | 0.00198258     |
| Savings (S)         | Recycled corrugated board savings               | -0.0297387                                  | kg   | 0.14          | -0.004163418   |
| RE                  | Waste to landfill (secondary packaging)          | 0.005157                                   | kg   | 0.1           | 0.0005157      |
| RE                  | Waste to energy (tertiary packaging)             | -0.03207654                                 | MJ   | 0.022         | -0.000705684   |
| RE                  | Waste to landfill (tertiary packaging)           | 0.00047                                   | kg   | 0.99          | 0.0004653      |
| S                   | Energy from thermal treatment                   | -0.0106596                                 | MJ   | 0.022         | -0.000234511   |
| TR                  | Passenger car                                   | 0.135                                       | km   | 0.12          | 0.0162         |
| Crackers       | Activities                                      | Value per functional unit (1 kg of product) | Unit   | Unit price (£) | Total cost (£) |
|----------------|------------------------------------------------|---------------------------------------------|--------|----------------|----------------|
| Consumer (CO)  | Waste to landfill [plastic bags]               | 0.002726                                    | kg     | 0.1            | 0.0002726      |
| CO             | Waste to thermal treatment (plastic bags)      | 0.001974                                    | kg     | 0.99           | 0.00195426     |
| S              | Energy from thermal treatment                  | -0.03624264                                 | MJ     | 0.022          | -0.000797338   |
| End of life (EOL) | Waste to thermal treatment (primary packaging) | 0.004368                                    | kg     | 0.99           | 0.00432432     |
| EOL            | Waste to landfill (primary packaging)          | 0.006032                                    | kg     | 0.1            | 0.0006032      |
| S              | Energy from thermal treatment                  | -0.08019648                                 | MJ     | 0.022          | -0.001764323   |
| Low fat/sugar  | Biscuits                                       |                                             |        |                |                |
| RM             | Flour white                                    | 0.658                                       | kg     | 0.936          | 0.615888       |
| RM             | Palm oil                                       | 0.057                                       | kg     | 0.3698         | 0.0210786      |
| RM             | Sugar                                          | 0.105                                       | kg     | 0.37           | 0.03885        |
| RM             | Ammonium bicarbonate                           | 0.01                                        | kg     | 0.33           | 0.0033         |
| RM             | Salt                                           | 0.006                                       | kg     | 0.13           | 0.00078        |
| RM             | Water                                          | 0.196                                       | L      | 0.0016         | 0.0003136      |
| TR             | Transport lorry [tkm] while price is in kg*km  | 163.7                                       | kg*km  | 0.00003        | 0.004911       |
| TR             | Transport ship                                 | 94                                          | kg*km  | 5.00E-08       | 0.000047       |
| MA             | Electricity                                    | 1.259                                       | MJ     | 0.022          | 0.027698       |
| MA             | Gas                                            | 4.16                                        | MJ     | 0.0054         | 0.022464       |
| MA             | Lubricants                                     | 0.00001                                     | kg     | 0.664          | 0.0000664      |
| MA             | Wastewater                                     | 0.5                                         | L      | 0.0013         | 0.000065       |
| MA             | Water                                          | 0.5                                         | L      | 0.0016         | 0.0008         |
| PA             | Polypropylene primary packaging                | 0.0107                                      | kg     | 1.69           | 0.018083       |
| PA             | Cardboard secondary packaging                  | 0.0382                                      | kg     | 0.14           | 0.005348       |
| TR             | Transport lorry                                | 7.34                                        | kg*km  | 0.00003        | 0.002202       |
| DC             | Water                                          | 0.00487                                     | L      | 0.0016         | 0.00007792     |
| TR             | Transport lorry (distribution centre to retailer)| 150                                         | kg*km  | 0.00003        | 0.0045         |
| DC             | Electricity                                    | 1.44E-06                                    | MJ     | 0.022          | 3.168E-08      |
| DC             | Wastewater                                     | 0.00487                                     | L      | 0.0013         | 0.00006331     |
| DC             | LDPE tertiary packaging                         | 0.00047                                     | kg     | 1.57           | 0.000739       |
| TR             | Transport, lorry                               | 50                                          | kg*km  | 0.00003        | 0.0015         |
| PA             | Plastic bags 1 bag weight 0.0075 kg and costs 5p| 0.00325                                     | kg     | 6.6            | 0.02145        |
| RE             | Water                                          | 1.46                                        | L      | 0.0016         | 0.002336       |
| Low fat/sugar biscuits | Activities                                                      | Value per functional unit (1 kg of product) | Unit  | Unit price (£) | Total cost (£) |
|------------------------|-----------------------------------------------------------------|--------------------------------------------|-------|----------------|----------------|
| RE                     | Electricity                                                     | 0.000576                                   | MJ    | 0.022          | 0.000012672    |
| RE                     | Wastewater                                                      | 1.46                                       | L     | 0.0013         | 0.001898       |
| RE                     | Waste to recycling (secondary packaging)                        | 0.033043                                   | kg    | 0.06           | 0.00198258     |
| RE                     | Waste to thermal treatment (secondary packaging)                | 0.005157                                   | kg    | 0.1            | 0.0005157      |
| S                      | Recycled corrugated board savings (secondary packaging)         | -0.0297387                                  | kg    | 0.14           | -0.004163418   |
| S                      | Energy from thermal treatment (secondary packaging)             | -0.20552746                                 | MJ    | 0.022          | -0.004521604   |
| RE                     | Waste to energy (secondary packaging)                           | 0.0001974                                  | kg    | 0.99           | 0.000195426    |
| RE                     | Waste to thermal treatment (secondary packaging)                | 0.00047                                    | kg    | 0.1            | 0.000047       |
| S                      | Energy from thermal treatment (secondary packaging)             | -0.0106596                                  | MJ    | 0.022          | -0.000234511   |
| TR                     | Passenger car                                                  | 0.135                                      | km    | 0.12           | 0.0162         |
| CO                     | Waste to landfill (plastic bags)                               | 0.001885                                   | kg    | 0.1            | 0.0001885      |
| CO                     | Waste to thermal treatment (plastic bags)                      | 0.001365                                   | kg    | 0.99           | 0.00135135     |
| S                      | Energy from thermal treatment (plastic bags)                   | -0.0250614                                  | MJ    | 0.022          | -0.000551351   |
| EOL                    | Waste to thermal treatment (primary packaging)                  | 0.004494                                   | kg    | 0.99           | 0.00444906     |
| EOL                    | Waste to landfill (primary packaging)                          | 0.006206                                   | kg    | 0.1            | 0.0006206      |
| S                      | Energy from thermal treatment (primary packaging)              | -0.08250984                                 | MJ    | 0.022          | -0.001815216   |
| Semi-sweet Biscuits    | Activities                                                      | Value per functional unit (1 kg of product) | Unit  | Unit price (£) | Total cost (£) |
| RM                     | Flour white                                                    | 0.588                                      | kg    | 0.936          | 0.550368       |
| RM                     | Palm oil                                                       | 0.117                                      | kg    | 0.3698         | 0.0432666      |
| RM                     | Sugar                                                          | 0.161                                      | kg    | 0.37           | 0.05957        |
| RM                     | Ammonium bicarbonate                                           | 0.0008                                    | kg    | 0.33           | 0.000264       |
| RM                     | Salt                                                           | 0.006                                      | kg    | 0.13           | 0.00078        |
| RM                     | Water                                                          | 0.136                                      | L     | 0.0016         | 0.0002176      |
| TR                     | Transport lorry (raw materials to manufacturer)                | 179.3                                      | kg*km | 0.00003        | 0.0005379      |
| TR                     | Transport ship (raw materials to manufacturer)                 | 1860                                       | kg*km | 5.00E-08       | 0.0000093      |
| MA                     | Electricity                                                    | 1.259                                      | MJ    | 0.022          | 0.027698       |
| MA                     | Gas                                                            | 4.16                                       | MJ    | 0.0054         | 0.022464       |
| MA                     | Lubricants                                                     | 0.00001                                   | kg    | 0.664          | 0.00000664     |
| MA                     | Wastewater                                                     | 0.5                                        | L     | 0.0013         | 0.000065       |
| MA                     | Water                                                          | 0.5                                        | L     | 0.0016         | 0.00008        |
| PA                     | Polypropylene primary packaging                                 | 0.0107                                     | kg    | 1.69           | 0.018083       |
| Semi-sweet Biscuits | Activities                                           | Value per functional unit (1 kg of product) | Unit       | Unit price (£) | Total cost (£) |
|---------------------|-----------------------------------------------------|--------------------------------------------|------------|----------------|----------------|
| PA                  | Cardboard secondary packaging                        | 0.0382                                     | kg         | 0.14           | 0.003548       |
| TR                  | Transport, lorry (packaging to manufacturer)         | 7.34                                       | kg*km      | 0.00003        | 0.0002202      |
| DC                  | Water                                                | 0.00487                                   | L          | 0.0016         | 0.000007792    |
| TR                  | Transport lorry (manufacturer to distribution centre)| 0.0705                                    | kg*km      | 0.00003        | 0.000002115    |
| DC                  | Electricity                                          | 0.00000144                                | MJ         | 0.22           | 3.16E-08       |
| DC                  | Water                                                | 0.00487                                   | L          | 0.0013         | 0.000006331    |
| TR                  | Transport lorry (packaging to distribution centre)   | 0.0325                                     | kg         | 6.6            | 0.02145        |
| PA                  | Plastic bags (1 bag weighs 7.5 g and costs 5p)       | 0.003576                                  | MJ         | 0.022          | 0.00012672     |
| RE                  | Water                                                | 1.46                                      | L          | 0.0016         | 0.0002336      |
| RE                  | Electricity                                          | 0.000576                                  | MJ         | 0.022          | 0.000012672    |
| RE                  | Wastewater                                           | 1.46                                      | L          | 0.0013         | 0.0001898      |
| TR                  | Transport, lorry (distribution centre to retailer)   | 50                                        | kg*km      | 0.00003        | 0.0015         |
| RE                  | Waste to recycling (secondary packaging)             | 0.033043                                  | kg         | 0.06           | 0.00198258     |
| S                   | Recycled corrugated board savings                    | -0.0297387                                | kg         | 0.14           | -0.004163418   |
| RE                  | Waste to landfill (secondary packaging)              | 0.005157                                  | kg         | 0.1            | 0.0005157      |
| S                   | Energy from thermal treatment (secondary packaging)  | -0.03207654                               | MJ         | 0.022          | -0.000705684   |
| RE                  | Waste to energy (primary packaging)                  | 0.00047                                   | kg         | 0.99           | 0.0004653      |
| S                   | Energy from thermal treatment (tertiary packaging)   | -0.0106596                                | MJ         | 0.022          | -0.000234511   |
| TR                  | Passenger car                                        | 0.135                                     | km         | 0.12           | 0.00162        |
| CO                  | Waste to landfill (plastic bags)                     | 0.001885                                  | kg         | 0.1            | 0.0001885      |
| CO                  | Waste to thermal treatment (plastic bags)            | 0.001365                                  | kg         | 0.99           | 0.0013515      |
| S                   | Energy from thermal treatment (plastic bags)         | -0.0250614                                | MJ         | 0.022          | -0.000551351   |
| EOL                 | Waste to thermal treatment (primary packaging)        | 0.004494                                  | kg         | 0.99           | 0.00444906     |
| EOL                 | Waste to landfill (primary packaging)                | 0.006206                                  | kg         | 0.1            | 0.0006206      |
| S                   | Energy from thermal treatment (primary packaging)     | -0.08250984                               | MJ         | 0.022          | -0.001815216   |

| Chocolate-coated biscuits | Activities                                           | Value per functional unit (1 kg of product) | Unit       | Unit price (£) | Total cost (£) |
|---------------------------|-----------------------------------------------------|--------------------------------------------|------------|----------------|----------------|
| RM                        | Flour white                                         | 0.3431                                     | kg         | 0.936          | 0.3211416      |
| RM                        | Flour wholemeal                                     | 0.0803                                     | kg         | 1              | 0.0803         |
| RM                        | Palm oil                                            | 0.146                                      | kg         | 0.3698         | 0.0539908      |
| RM                        | Sugar                                               | 0.1022                                     | kg         | 0.37           | 0.037814       |
| RM                        | Ammonium bicarbonate                                | 0.0146                                     | kg         | 0.33           | 0.004818       |
| Chocolate-coated biscuits | Activities                                      | Value per functional unit (1 kg of product) | Unit       | Unit price (£) | Total cost (£)   |
|---------------------------|------------------------------------------------|---------------------------------------------|------------|----------------|------------------|
| RM                        | Salt                                           | 0.0073                                      | kg         | 0.13           | 0.000949         |
| RM                        | Water                                          | 0.028032                                    | L          | 0.0016         | 4.48512E-05      |
| TR                        | Transport lorry (raw materials to manufacturer) | 162.06                                      | kg*km      | 0.000003       | 0.0048618        |
| TR                        | Transport ship (raw materials to manufacturer)  | 2314.1                                      | kg*km      | 0.000000005    | 0.000115705      |
| RM                        | Sugar                                          | 0.1242                                      | kg         | 0.3698         | 0.04592916       |
| RM                        | Cocoa powder                                    | 0.0135                                      | kg         | 2.8471         | 0.03843585       |
| RM                        | Palm kernel oil                                 | 0.0783                                      | kg         | 0.595          | 0.0465885        |
| RM                        | Milk powder                                     | 0.054                                       | kg         | 2.185          | 0.11799          |
| TR                        | Transport lorry (raw materials to manufacturer) | 56.7                                        | kg*km      | 0.000003       | 0.001701         |
| TR                        | Transport ship (raw materials to manufacturer)  | 99.63                                       | kg*km      | 0.000000005    | 4.9815E-06       |
| MA                        | Electricity                                     | 2.136                                       | MJ         | 0.022          | 0.046992         |
| MA                        | Gas                                            | 3.04                                        | MJ         | 0.0054         | 0.016416         |
| MA                        | Lubricants                                      | 0.0000073                                   | kg         | 0.664          | 4.8472E-06       |
| MA                        | Wastewater                                      | 0.365                                       | L          | 0.0013         | 0.0004745        |
| MA                        | Water                                           | 0.365                                       | L          | 0.0016         | 0.000584         |
| PA                        | Polypropylene primary packaging                 | 0.0081                                      | kg         | 1.69           | 0.013689         |
| PA                        | Cardboard secondary packaging                   | 0.0382                                      | kg         | 0.14           | 0.005348         |
| TR                        | Transport lorry (packaging to manufacturer)     | 6.95                                        | kg*km      | 0.000003       | 0.0002085        |
| DC                        | Water                                           | 0.00318                                     | L          | 0.0016         | 0.000005088      |
| TR                        | Transport lorry (manufacturer to distribution centre) | 150                                        | kg*km      | 0.000003       | 0.0045           |
| DC                        | Electricity                                     | 0.000000942                                 | MJ         | 0.022          | 2.0724E-08       |
| DC                        | Wastewater                                      | 0.00318                                     | L          | 0.0013         | 0.000004134      |
| DC                        | LDPE tertiary packaging                          | 0.00047                                     | kg         | 1.57           | 0.0007379        |
| TR                        | Transport lorry (packaging to distribution centre) | 0.0705                                      | kg*km      | 0.00003        | 0.00002115       |
| PA                        | Plastic bags 1 bag weight 0.0075 kg and costs 5p | 0.00213                                     | kg         | 6.6            | 0.014058         |
| RE                        | Water                                           | 0.955                                       | L          | 0.0016         | 0.001528         |
| RE                        | Electricity                                     | 0.000377                                    | MJ         | 0.022          | 0.000008294      |
| RE                        | Wastewater                                      | 0.955                                       | L          | 0.0013         | 0.0012415        |
| TR                        | Transport lorry (distribution centre to retailer) | 50                                         | kg*km      | 0.000003       | 0.0015           |
| RE                        | Waste to recycling (secondary packaging)         | 0.033043                                    | kg         | 0.06           | 0.00198258       |
| S                         | Recycled corrugated board savings               | -0.0297387                                  | MJ         | 0.14           | -0.004163418     |
| RE                        | Waste to landfill (secondary packaging)          | 0.005157                                    | kg         | 0.1            | 0.0005157        |
| RE                        | Waste to energy (tertiary packaging)             | -0.03207654                                 | kg         | 0.0793         | -0.00254367      |
| RE                        | Waste to landfill (tertiary packaging)           | 0.00047                                     | kg         | 0.99           | 0.0004653        |
| S                         | Energy from thermal treatment (tertiary packaging) | -0.0106596                                 | MJ         | 0.022          | -0.000234511     |
| TR                        | Consumer's car                                  | 0.135                                       | km         | 0.12           | 0.0162           |
| Activity Description                                      | Value per functional unit (1 kg of product) | Unit | Unit price (£) | Total cost (£) |
|----------------------------------------------------------|--------------------------------------------|------|----------------|----------------|
| Waste to landfill (plastic bags)                         | 0.0012354                                  | kg   | 0.1            | 0.00012354     |
| Waste to thermal treatment (plastic bags)                | 0.0008946                                  | kg   | 0.99           | 0.000885654    |
| Energy from thermal treatment (plastic bags)             | -0.016424856                               | MJ   | 0.022          | -0.000361347   |
| Waste to thermal treatment (primary packaging)           | 0.003402                                   | kg   | 0.99           | 0.00336798     |
| Waste to Landfill (primary packaging)                    | 0.004698                                   | kg   | 0.1            | 0.0004698      |
| Energy from thermal treatment (primary packaging)        | -0.06246072                                | MJ   | 0.022          | -0.001374136   |
| Flour white                                             | 0.38908                                    | kg   | 0.936          | 0.36417888     |
| Palm oil                                                 | 0.08591                                    | kg   | 0.3698         | 0.031769518    |
| Sugar                                                    | 0.15975                                    | kg   | 0.37           | 0.0591075      |
| Ammonium bicarbonate                                    | 0.00142                                    | kg   | 0.33           | 0.0004686      |
| Salt                                                     | 0.00142                                    | kg   | 0.13           | 0.0001846      |
| Cocoa powder                                            | 0.01775                                    | kg   | 2.8471         | 0.050536025    |
| Water                                                    | 0.042032                                   | L    | 0.0016         | 6.72512E-05    |
| Transport lorry (raw materials to manufacturer)         | 121.623                                    | kg*km| 0.00003        | 0.00364869     |
| Transport ship (raw materials to manufacturer)          | 1363.2                                     | kg*km| 5.00E-08       | 0.00006816     |
| Sugar                                                    | 0.1624                                     | kg   | 0.3698         | 0.06005552     |
| Cocoa powder                                            | 0.0145                                     | kg   | 2.8471         | 0.04128295     |
| Palm kernel oil                                          | 0.1102                                     | kg   | 0.595          | 0.065569       |
| Transport lorry (raw materials to manufacturer)         | 58                                         | kg   | 0.00003        | 0.00174        |
| Transport ship (raw materials to manufacturer)          | 1748.7                                     | kg   | 5.00E-08       | 0.000087435    |
| Electricity                                              | 1.2795                                     | MJ   | 0.022          | 0.028149       |
| Gas                                                      | 2.95                                       | MJ   | 0.0054         | 0.01593        |
| Lubricants                                               | 0.0000071                                  | kg   | 0.664          | 4.7144E-06     |
| Wastewater                                               | 0.355                                      | L    | 0.0013         | 0.0004615      |
| Water                                                    | 0.355                                      | L    | 0.0016         | 0.000568       |
| Polypropylene primary packaging                          | 0.00365                                    | kg   | 1.69           | 0.0061685      |
| Aluminium                                                | 0.00365                                    | kg   | 1.22           | 0.004453       |
| Cardboard secondary packaging                            | 0.0325                                     | kg   | 0.14           | 0.00455        |
| Transport lorry (packaging to manufacturer)              | 5.976                                      | kg*km| 0.00003        | 0.00017928     |
| Water                                                    | 0.00356                                    | L    | 0.0016         | 0.00005696     |
| Chocolate cream biscuits | Activities | Value per functional unit (1 kg of product) | Unit | Unit price (£) | Total cost (£) |
|--------------------------|------------|--------------------------------------------|------|---------------|---------------|
| TR                       | Transport lorry (manufacturer to distribution centre) | 150 kg*km | 0.00003 | 0.0045 |
| DC                       | Electricity | 0.00000105 MJ | 0.022 | 2.31E-08 |
| DC                       | Wastewater | 0.00356 L | 0.0013 | 0.000004628 |
| DC                       | LDPE tertiary packaging | 0.00047 kg | 1.57 | 0.0007379 |
| TR                       | Transport lorry (packaging to distribution centre) | 0.0705 kg*km | 0.00003 | 0.000002115 |
| PA                       | Plastic bags 1 bag weight 0.0075 kg and costs 5p | 0.00238 kg | 6.6 | 0.015708 |
| RE                       | Water | 1.07 L | 0.0016 | 0.001712 |
| RE                       | Electricity | 0.000421 MJ | 0.022 | 0.000009262 |
| RE                       | Wastewater | 1.07 L | 0.0013 | 0.001391 |
| TR                       | Transport lorry (distribution centre to retailer) | 0.135 km | 0.12 | 0.0162 |
| RE                       | Waste to recycling (secondary packaging) | 0.0281125 kg | 0.06 | 0.00168675 |
| S                        | Recycled corrugated board savings | -0.02530125 kg | 0.14 | -0.003542175 |
| RE                       | Waste to thermal treatment (secondary packaging) | 0.0043875 kg | 0.1 | 0.00043875 |
| S                        | Energy from thermal treatment (secondary packaging) | -0.02729025 MJ | 0.022 | -0.00060386 |
| RE                       | Waste to energy (tertiary packaging) | 0.00047 kg | 0.99 | 0.0004653 |
| S                        | Energy from thermal treatment (tertiary packaging) | -0.0106596 kg | 0.022 | -0.000234511 |
| TR                       | Consumer's car | 0.39547 kg | 0.936 | 0.37015992 |
| RM                       | Flour white | 0.14413 kg | 0.3698 | 0.053299274 |
| RM                       | Sugar | 0.12993 kg | 0.37 | 0.0480741 |
| RM                       | Ammonium bicarbonate | 0.00213 kg | 0.33 | 0.0007029 |
| RM                       | Salt | 0.00213 kg | 0.13 | 0.0002769 |
| RM                       | Water | 0.031879 L | 0.0016 | 5.10606E-05 |
| TR                       | Transport lorry (raw materials to manufacturer) | 152.082 kg*km | 0.00003 | 0.00456246 |
| Table S2 continued |
|---------------------|
| **Vanilla cream biscuits** | **Activities** | **Value per functional unit (1 kg of product)** | **Unit** | **Unit price (£)** | **Total cost (£)** |
| TR | Transport ship (raw materials to manufacturer) | 2286.2 | kg*km | 5.00E-08 | 0.00011431 |
| RM | Sugar | 0.19053 | kg | 0.3698 | 0.07045794 |
| RM | Vanilla flavour | 0.00058 | kg | 11.97 | 0.0069426 |
| RM | Palm oil | 0.08671 | kg | 0.3698 | 0.032065358 |
| RM | Milk powder | 0.01218 | kg | 2.185 | 0.0266133 |
| TR | Transport lorry (raw materials to manufacturer) | 2.436 | kg*km | 0.000003 | 0.00007308 |
| TR | Transport ship (raw materials to manufacturer) | 1374.6 | kg*km | 5.00E-08 | 0.00006873 |
| MA | Electricity | 1.2795 | MJ | 0.022 | 0.028149 |
| MA | Gas | 2.95 | MJ | 0.0054 | 0.01593 |
| MA | Lubricants | 0.0000071 | kg | 0.664 | 4.7144E-06 |
| MA | Wastewater | 0.355 | L | 0.0013 | 0.0004615 |
| MA | Water | 0.355 | L | 0.0016 | 0.000568 |
| PA | Polypropylene primary packaging | 0.00365 | kg | 1.69 | 0.0061685 |
| PA | Aluminium | 0.00365 | kg | 1.22 | 0.004453 |
| PA | Cardboard secondary packaging | 0.0325 | kg | 0.14 | 0.00455 |
| TR | Transport lorry (packaging to manufacturer) | 5.976 | kg*km | 0.000003 | 0.00017928 |
| DC | Water | 0.00356 | L | 0.0016 | 0.00005696 |
| TR | Transport lorry (manufacturer to distribution centre) | 150 | kg*km | 0.000003 | 0.00045 |
| DC | Electricity | 0.00000105 | MJ | 0.022 | 2.31E-08 |
| DC | Wastewater | 0.00356 | L | 0.0013 | 0.00004628 |
| DC | LDPE tertiary packaging | 0.00047 | kg | 1.57 | 0.0007379 |
| TR | Transport lorry (packaging to distribution centre) | 0.0705 | kg*km | 0.000003 | 0.00002115 |
| PA | Plastic bags 1 bag weight 0.0075 kg and costs 5p | 0.00238 | kg | 6.6 | 0.015708 |
| RE | Water | 1.07 | L | 0.0016 | 0.001712 |
| RE | Electricity | 0.000421 | MJ | 0.022 | 0.0009262 |
| RE | Wastewater | 1.07 | L | 0.0013 | 0.001391 |
| TR | Transport lorry (distribution centre to retailer) | 0.0281125 | kg | 0.06 | 0.00168675 |
| S | Recycled corrugated board savings | -0.02530125 | MJ | 0.14 | -0.003542175 |
| RE | Waste to thermal treatment (secondary packaging) | 0.0043875 | kg | 0.1 | 0.00043875 |
| S | Energy from thermal treatment (secondary packaging) | -0.02729025 | MJ | 0.022 | -0.00060386 |
| RE | Waste to energy (tertiary packaging) | 0.00047 | kg | 0.99 | 0.0004653 |
| S | Energy from thermal treatment (tertiary packaging) | -0.0106596 | MJ | 0.022 | -0.000234511 |
| Vanilla cream biscuits | Activities                             | Value per functional unit (1 kg of product) | Unit | Unit price (£) | Total cost (£) |
|------------------------|----------------------------------------|--------------------------------------------|------|---------------|---------------|
| TR                     | Consumer’s car                         | 0.135                                      | km   | 0.12          | 0.0162        |
| CO                     | Waste to landfill (plastic bags)       | 0.0013804                                  | kg   | 0.1           | 0.00013804    |
| CO                     | Waste to thermal treatment (plastic bags) | 0.0009996                                | kg   | 0.99          | 0.000989604   |
| S                      | Energy from thermal treatment (plastic bags) | -0.018352656                             | MJ   | 0.022         | 0.000403758   |
| EOL                    | Waste to thermal treatment (primary packaging) | 0.003066                                  | kg   | 0.99          | 0.00303534    |
| EOL                    | Waste to Landfill (primary packaging)   | 0.004234                                   | kg   | 0.1           | 0.0004234     |
| S                      | Energy from thermal treatment (primary packaging) | -0.018352656                             | MJ   | 0.022         | 0.000403758   |

| Whole cakes | Activities                             | Value per functional unit (1 kg of product) | Unit | Unit price (£) | Total cost (£) |
|-------------|----------------------------------------|--------------------------------------------|------|---------------|---------------|
| RM          | Strawberry                             | 0.15                                       | kg   | 2.26          | 0.339         |
| TR          | Transport lorry (raw materials to manufacturer) | 30                                        | kg*km | 0.00003       | 0.0009        |
| RM          | Vanilla flavour                        | 0.0027                                     | kg   | 11.97         | 0.032319      |
| RM          | Sugar                                  | 0.15606                                    | kg   | 0.37          | 0.0577422     |
| RM          | Butter                                 | 0.11124                                    | kg   | 1.9437        | 0.216217188   |
| TR          | Transport lorry (raw materials to manufacturer) | 22.788                                    | kg*km | 0.00003       | 0.00068364    |
| RM          | Flour white                            | 0.1392                                     | kg   | 0.936         | 0.1302912     |
| RM          | Palm oil                               | 0.0232                                     | kg   | 0.3698        | 0.00857936    |
| RM          | Sugar                                  | 0.116                                      | kg   | 0.37          | 0.04292       |
| RM          | Soda                                   | 0.0203                                     | kg   | 0.33          | 0.006699      |
| RM          | Salt                                   | 0.000928                                   | kg   | 0.13          | 0.00012064    |
| RM          | Starch                                 | 0.0174                                     | kg   | 1.12          | 0.019488      |
| RM          | Sorbic acid/sorbates                   | 0.001392                                   | kg   | 79.19         | 0.11023248    |
| RM          | Eggs pasteurised                       | 0.2436                                     | kg   | 5.99          | 1.459164      |
| RM          | Glycerine                              | 0.0174                                     | kg   | 2.4           | 0.04176       |
| RM          | Acetic acid                            | 0.0058                                     | kg   | 0.46          | 0.002668      |
| TR          | Transport lorry (raw materials to manufacturer) | 47.444                                    | kg*km | 0.00003       | 0.00142332    |
| TR          | Transport ship (raw materials to manufacturer) | 368.3                                     | kg*km | 5.00E-08      | 0.000018415   |
| MA          | Electricity                            | 0.5475                                     | MJ   | 0.022         | 0.012045      |
| MA          | Gas                                    | 0.543                                      | MJ   | 0.0054        | 0.0029322     |
| MA          | Steam                                  | 0.501                                      | MJ   | 0.034         | 0.017034      |
| MA          | Lubricants                             | 0.0000058                                  | kg   | 0.664         | 3.8512E-06    |
| Whole cakes | Activities | Value per functional unit (1 kg of product) | Unit | Unit price (£) | Total cost (£) |
|-------------|------------|---------------------------------------------|------|---------------|---------------|
| MA          | Wastewater | 0.29                                        | L    | 0.0013        | 0.000377      |
| MA          | Water      | 0.29                                        | L    | 0.0016        | 0.000464      |
| PA          | Polypropylene primary packaging | 0.006            | kg   | 1.69          | 0.01014       |
| PA          | Folding box | 0.087                                        | kg   | 0.14          | 0.01218       |
| PA          | Cardboard secondary packaging | 0.054                                        | kg   | 0.14          | 0.00756       |
| TR          | Transport lorry (packaging to manufacturer) | 22.1          | kg*km | 0.000003      | 0.000663      |
| DC          | Water      | 0.00636                                    | L    | 0.0016        | 0.00010176    |
| TR          | Transport lorry | 150                                      | kg*km | 0.000003      | 0.0045        |
| DC          | Electricity | 0.00000188                                | MJ   | 0.22          | 4.136E-08     |
| DC          | Wastewater | 0.00636                                    | L    | 0.0013        | 0.000008268   |
| DC          | LDPE tertiary packaging | 0.00047                                | kg   | 1.57          | 0.0007379     |
| TR          | Transport lorry (packaging to distribution centre) | 0.0705                      | kg*km | 0.000003      | 0.00002115    |
| RE          | Water      | 1.91                                        | L    | 0.0016        | 0.003056      |
| RE          | Electricity | 0.000753                                | MJ   | 0.22          | 0.00016566    |
| RE          | Wastewater | 1.91                                        | L    | 0.0013        | 0.002483      |
| RE          | Waste to recycling (secondary packaging) | 0.04671                    | kg   | 0.06          | 0.0028026     |
| S           | Recycled corrugated board savings | -0.042039                   | MJ   | 0.14          | -0.00588546   |
| RE          | Waste to landfill (secondary packaging) | 0.00729                        | kg   | 0.99          | 0.0072171     |
| RE          | Waste to energy (tertiary packaging) | -0.0453438                  | MJ   | 0.022         | -0.000997564  |
| RE          | Waste to landfill (tertiary packaging) | 0.00047                        | kg   | 0.99          | 0.0004653     |
| S           | Energy from thermal treatment | -0.0106596                  | MJ   | 0.022         | -0.000234511  |
| TR          | Transport lorry | 50                                      | kg*km | 0.000003      | 0.0015        |
| PA          | Plastic bags 1 bag weight 0.0075 kg and costs 5p | 0.0043                        | kg   | 6.6           | 0.02838       |
| TR          | Consumer's car | 0.135                                       | km   | 0.12          | 0.0162        |
| CO          | Waste to landfill (plastic bags) | 0.002494                    | kg   | 0.1           | 0.0002494     |
| CO          | Waste to thermal treatment (plastic bags) | 0.001806                  | kg   | 0.99          | 0.00178794    |
| S           | Energy from thermal treatment | -0.03315816                  | MJ   | 0.022         | -0.00072948   |
| CO          | Electricity | 0.0524                                    | MJ   | 0.022         | 0.0011528     |
| CO          | Detergent   | 0.0016                                    | kg   | 6.65          | 0.01064       |
| CO          | Water       | 0.187                                      | L    | 0.0016        | 0.0002992     |
| CO          | Wastewater  | 0.187                                      | L    | 0.0013        | 0.0002431     |
| EOL         | Waste to thermal treatment (primary packaging folding box) | 0.00696                   | kg   | 0.99          | 0.0068904     |
| EOL         | Waste to Landfill (primary packaging folding box) | 0.00783                    | kg   | 0.1           | 0.000783      |
### Whole cakes

| Activities                                                                 | Value per functional unit (1 kg of product) | Unit | Unit price (£) | Total cost (£) |
|---------------------------------------------------------------------------|---------------------------------------------|------|----------------|----------------|
| EOL Waster to recycling plant (primary packaging folding box)             | 0.07221                                     | kg   | 0.06           | 0.0043326      |
| S Recycled folding box savings                                           | -0.017226                                   | kg   | 0.14           | -0.00241164    |
| S Energy from thermal treatment                                          | -0.0324684                                  | MJ   | 0.022          | -0.000714305   |
| EOL Waste to thermal treatment (primary packaging, plastic)              | 0.00252                                     | kg   | 0.99           | 0.0024948      |
| EOL Waste to landfill (primary packaging, plastic)                       | 0.00348                                     | kg   | 0.1            | 0.000348       |
| EOL Energy from thermal treatment                                        | -0.0462672                                  | MJ   | 0.022          | -0.001017878   |
| S Bio-waste to composting plant                                          | 0.024                                       | kg   | 0.06           | 0.00144        |
| S Savings compost                                                        | -0.00144                                    | kg   | 0.125          | -0.00018       |
| EOL Bio-waste to landfill                                                | 0.176                                       | kg   | 0.1            | 0.0176         |

### Cake slices

| Activities                                                                 | Value per functional unit (1 kg of product) | Unit  | Unit price (£) | Total cost (£) |
|---------------------------------------------------------------------------|---------------------------------------------|-------|----------------|----------------|
| RM Sugar - icing                                                         | 0.23218                                     | kg    | 0.37           | 0.0859066      |
| RM Starch                                                                 | 0.00442                                     | kg    | 1.12           | 0.0049504      |
| RM Water                                                                  | 0.0234                                      | L     | 0.0016         | 0.00003744     |
| TR Transport lorry (raw materials to manufacturer)                       | 0.884                                       | kg*km | 0.00003        | 0.00002652     |
| RM Vanilla flavour                                                       | 0.0012                                      | kg    | 11.97          | 0.014364       |
| RM Sugar                                                                  | 0.06924                                     | kg    | 0.37           | 0.0256188      |
| RM Sugar                                                                  | 0.02472                                     | kg    | 1.9437         | 0.048048264    |
| RM Palm oil                                                               | 0.12772                                     | kg    | 0.3698         | 0.047230856    |
| TR Transport ship (raw materials to manufacturer)                        | 2027.4                                      | kg*km | 5.00E-08       | 0.00010137     |
| TR Transport lorry (raw materials to manufacturer)                       | 17.544                                      | kg*km | 0.00003        | 0.00052632     |
| RM Flour white                                                           | 0.1488                                      | kg    | 0.936          | 0.1392768      |
| RM Palm oil                                                              | 0.031                                       | kg    | 0.3698         | 0.0114638      |
| RM Sugar                                                                 | 0.1426                                      | kg    | 0.37           | 0.052762       |
| RM Soda                                                                  | 0.0186                                      | kg    | 0.33           | 0.006138       |
| RM Salt                                                                  | 0.003968                                    | kg    | 0.13           | 0.00051584     |
| RM Water                                                                 | 0.0279                                      | L     | 0.0016         | 0.00004464     |
| RM Fructose - glucose                                                    | 0.031                                       | kg    | 3              | 0.093          |
| RM Eggs pasteurised                                                      | 0.186                                       | kg    | 5.99           | 1.11414        |
| RM Glycerine                                                             | 0.0279                                      | kg    | 2.4            | 0.06696        |
| RM Acetic acid                                                           | 0.000744                                    | kg    | 0.46           | 0.00034224     |
| Cake slices | Activities | Value per functional unit (1 kg of product) | Unit | Unit price (£) | Total cost (£) |
|-------------|------------|-------------------------------------------|------|--------------|---------------|
| RM          | Sorbic acid | 0.001488 kg                               | kg   | 79.19        | 0.11783472    |
| TR          | Transport lorry (raw materials to manufacturer) | 93.62 kg*km                              | kg*km | 0.000003     | 0.0028086     |
| TR          | Transport ship (raw materials to manufacturer) | 491.66 kg*km                             | kg*km | 5.00E-08    | 0.00024583    |
| MA          | Electricity | 0.5522 MJ                                 | MJ   | 0.022        | 0.121484      |
| MA          | Gas         | 0.581 MJ                                  | MJ   | 0.0054       | 0.0031374     |
| Ma          | Steam       | 0.536 MJ                                  | MJ   | 0.034        | 0.018224      |
| MA          | Lubricants  | 0.000062 kg                               | kg   | 0.664        | 4.1168E-06    |
| MA          | Wastewater  | 0.31 L                                    | L    | 0.0013       | 0.000403      |
| MA          | Water       | 0.31 L                                    | L    | 0.0016       | 0.000496      |
| PA          | Polyethylene bottle | 0.0667 kg | 1.57 | 0.104719  |
| PA          | Polyethylene film | 0.00909 kg | 1.57 | 0.0142713 |
| PA          | Folding box | 0.0306 kg                                 | kg   | 0.14         | 0.004284      |
| PA          | Cardboard secondary packaging | 0.057 kg | 0.14 | 0.00798   |
| TR          | Transport lorry (packaging to manufacturer) | 24.5 kg*km                               | kg*km | 0.00003     | 0.000735      |
| DC          | Water       | 0.00796 L                                 | L    | 0.0016       | 0.000012736   |
| TR          | Transport lorry (packaging to distribution centre) | 0.0705 kg*km                          | kg*km | 0.000002    | 0.000002115   |
| DC          | Electricity | 0.00000235 MJ                             | MJ   | 0.022        | 5.17E-08      |
| DC          | Wastewater  | 0.00796 L                                 | L    | 0.0013       | 0.000010348   |
| DC          | LDPE tertiary packaging | 0.00047 kg | 1.57 | 0.000739 |
| TR          | Transport lorry (packaging to distribution centre) | 2.39 L | 0.0016 | 0.003824 |
| RE          | Water       | 2.39 L                                    | L    | 0.0013       | 0.003107      |
| RE          | Electricity | 0.000942 MJ                               | MJ   | 0.022        | 0.00020724    |
| RE          | Wastewater  | 2.39 L                                    | L    | 0.0013       | 0.0003107     |
| RE          | Waste to recycling (secondary packaging) | 0.049305 kg | 0.06 | 0.0029583 |
| S           | Recycled corrugated board savings | -0.0443745 kg | 0.14 | -0.00621243 |
| RE          | Waste to landfill (secondary packaging) | 0.007695 kg | 0.99 | 0.00761805 |
| RE          | Waste to energy (tertiary packaging) | -0.0478629 MJ | 0.22 | -0.001052984 |
| RE          | Waste to landfill (tertiary packaging) | 0.00047 kg | 0.99 | 0.0004653 |
| S           | Energy from thermal treatment | -0.0106596 MJ | 0.22 | -0.000234511 |
| TR          | Transport lorry (packaging to distribution centre) | -0.1016596 kg | 0.00003 | 0.0015 |
| PA          | Plastic bags 1 bag weight 0.0075 kg and costs 5p | 0.0054 kg | 6.6 | 0.03564 |
| TR          | Consumer’s car | 0.135 km | 0.12 | 0.0162 |
| Cake slices | Activities                                                                 | Value per functional unit (1 kg of product) | Unit   | Unit price (£) | Total cost (£) |
|------------|---------------------------------------------------------------------------|--------------------------------------------|--------|----------------|----------------|
|            |                                                                           |                                            |        |                |                |
| CO         | Waste to landfill (plastic bags)                                          | 0.003132 kg                               | kg     | 0.1            | 0.0003132     |
| CO         | Waste to thermal treatment (plastic bags)                                 | 0.002268 kg                               | kg     | 0.99           | 0.00224532    |
| S          | Energy from thermal treatment                                            | 0.04164048 MJ                             | MJ     | 0.022          | -0.000916091  |
| CO         | Electricity                                                               | 0.0393 MJ                                 | MJ     | 0.22           | 0.0008646     |
| CO         | Detergent                                                                 | 0.0016 kg                                 | kg     | 6.65           | 0.01064       |
| CO         | Water                                                                     | 0.14 L                                    | L      | 0.0016         | 0.000224      |
| CO         | Wastewater                                                                | 0.14 L                                    | L      | 0.0013         | 0.000182      |
| EOL        | Waste to thermal treatment (primary packaging folding box)                | 0.002448 kg                               | kg     | 0.99           | 0.00242352    |
| EOL        | Waste to Landfill (primary packaging folding box)                         | 0.002754 kg                               | kg     | 0.1            | 0.0002754     |
| EOL        | Waster to recycling plant (primary packaging folding box)                 | 0.025398 kg                               | kg     | 0.06           | 0.00152388    |
| S          | Recycled folding box savings                                             | -0.0060588 kg                             | kg     | 0.14           | -0.000848232  |
| S          | Energy from thermal treatment                                            | -0.01141992 MJ                            | MJ     | 0.022          | -0.00251238   |
| EOL        | Waste to thermal treatment (primary packaging, plastic)                   | 0.031836 kg                               | kg     | 0.99           | 0.03151764    |
| EOL        | Waste to landfill (primary packaging, plastic)                            | 0.043964 kg                               | kg     | 0.1            | 0.0043964     |
| S          | Energy from thermal treatment                                            | -0.58450896 MJ                            | MJ     | 0.022          | -0.012859197  |
| EOL        | Bio-waste to composting plant                                            | 0.024 kg                                  | kg     | 0.06           | 0.00144       |
| S          | Savings compost                                                           | -0.00144 kg                               | kg     | 0.125          | -0.00018      |
| EOL        | Bio-waste to landfill                                                     | 0.176 kg                                  | kg     | 0.1            | 0.0176        |
| Pies       | Activities                                                                |                                            |        |                |                |
| RM         | Sugar                                                                     | 0.042 kg                                  | kg     | 0.37           | 0.01554       |
| RM         | Water                                                                     | 0.084 kg                                  | kg     | 0.0016         | 0.0001344     |
| RM         | Apple                                                                     | 0.1008 kg                                 | kg     | 0.61           | 0.061488      |
| MA         | Electricity (pre-processing apple filling)                                | 0.042714 MJ                               | MJ     | 0.022          | 0.000939708   |
| MA         | Bio-waste to composting plant                                            | 0.0168 kg                                 | kg     | 0.06           | 0.001008      |
| S          | Compost                                                                   | -0.0084 kg                                | kg     | 0.125          | -0.00105      |
| TR         | Transport lorry (raw materials to manufacturer)                           | 20.16 kg*km                               | kg*km  | 0.00003        | 0.0006048     |
| RM         | Flour white                                                               | 0.35313 kg                                | kg     | 0.936          | 0.33052968    |
| RM         | Palm oil                                                                  | 0.24253 kg                                | kg     | 0.3698         | 0.089687594   |
| RM         | Sugar                                                                     | 0.05372 kg                                | kg     | 0.37           | 0.0198764     |
| Pies | Activities                                      | Value per functional unit (1 kg of product) | Unit       | Unit price (£) | Total cost (£) |
|------|-----------------------------------------------|-------------------------------------------|------------|---------------|----------------|
| RM   | Eggs pasteurised                              | 0.13746                                   | kg         | 5.99          | 0.8233854      |
| TR   | Transport lorry (raw materials to manufacturer) | 220.252                                   | kg*km      | 0.00003       | 0.00660756     |
| TR   | Transport ship (raw materials to manufacturer) | 3847.3                                    | kg*km      | 5.00E-08      | 0.000192365    |
| MA   | Electricity                                   | 0.826                                     | MJ         | 0.022         | 0.18172        |
| MA   | Gas                                           | 1.06                                      | MJ         | 0.0054        | 0.005724       |
| Ma   | Steam                                         | 0.986                                     | MJ         | 0.034         | 0.033524       |
| MA   | Lubricants                                    | 0.000079                                  | kg         | 0.664         | 5.2456E-06     |
| MA   | Wastewater                                    | 0.395                                     | L          | 0.0013        | 0.0005135      |
| MA   | Water                                         | 0.395                                     | L          | 0.0016        | 0.000632       |
| PA   | Aluminium                                     | 0.0136                                    | kg         | 1.22          | 0.016592       |
| PA   | Polyethylene bottle                           | 0.0246                                    | kg         | 1.57          | 0.038622       |
| PA   | Folding box                                   | 0.0832                                    | kg         | 0.14          | 0.011648       |
| PA   | Cardboard secondary packaging                 | 0.064                                     | kg         | 0.14          | 0.00896        |
| TR   | Transport lorry (packaging to manufacturer)   | 27.83                                     | kg*km      | 0.00003       | 0.0008349      |
| DC   | Water                                         | 0.00668                                   | L          | 0.0016        | 0.00010688     |
| TR   | Transport lorry (manufacturer to distribution centre) | 150                                       | kg*km      | 0.00003       | 0.0045         |
| DC   | Electricity                                   | 0.00000198                                | MJ         | 0.022         | 4.356E-08      |
| DC   | Wastewater                                    | 0.00668                                   | L          | 0.0013        | 0.000008684    |
| DC   | LDPE tertiary packaging                        | 0.00047                                   | kg         | 1.57          | 0.0007379      |
| TR   | Transport lorry (packaging to distribution centre) | 0.0705                                    | kg*km      | 0.00003       | 0.000002115    |
| RE   | Water                                         | 2                                         | L          | 0.0016        | 0.0032         |
| RE   | Electricity                                   | 0.000791                                  | MJ         | 0.022         | 0.00017402     |
| RE   | Wastewater                                    | 2                                         | L          | 0.0013        | 0.0026         |
| RE   | Waste to recycling (secondary packaging)       | 0.05536                                   | kg         | 0.06          | 0.003216       |
| S    | Recycled corrugated board savings             | -0.049824                                 | kg         | 0.14          | -0.00697536    |
| RE   | Waste to landfill (secondary packaging)        | 0.00864                                   | kg         | 0.99          | 0.0085536      |
| RE   | Waste to energy (tertiary packaging)           | 0.0537408                                 | kg         | 0.022         | 0.00182298     |
| RE   | Waste to landfill (tertiary packaging)         | 0.00047                                   | kg         | 0.99          | 0.0004653      |
| S    | Energy from thermal treatment                 | -0.0106596                                 | MJ         | 0.022         | -0.000234511   |
| TR   | Transport lorry                               | 50                                        | kg*km      | 0.00003       | 0.0015         |
| PA   | Plastic bags 1 bag weight 0.0075 kg and costs 5p | 0.0045                                   | kg         | 6.6           | 0.0297         |
| TR   | Consumer’s car                                | 0.135                                     | km         | 0.12          | 0.0162         |
| CO   | Waste to landfill (plastic bags)              | 0.00261                                   | kg         | 0.1           | 0.00261        |
### Table S2 continued

| Pies | Activities                                                                 | Value per functional unit (1 kg of product) | Unit       | Unit price (£) | Total cost (£) |
|------|-----------------------------------------------------------------------------|--------------------------------------------|------------|----------------|----------------|
| CO   | Waste to thermal treatment (plastic bags)                                   | 0.00189                                   | kg         | 0.99           | 0.0018711      |
| S    | Energy from thermal treatment                                              | -0.0347004                                | MJ         | 0.022          | -0.000763409   |
| CO   | Electricity                                                                | 0.0393                                    | MJ         | 0.022          | 0.0008646      |
| CO   | Detergent                                                                  | 0.0012                                    | kg         | 6.65           | 0.00798        |
| CO   | Water                                                                      | 0.14                                      | L          | 0.0016         | 0.000224       |
| CO   | Wastewater                                                                  | 0.14                                      | L          | 0.0013         | 0.000182       |
|      | Waste to thermal treatment (Primary packaging folding box)                  |                                           |            |                |                |
| EOL  | Waste to Landfill (primary packaging folding box)                           | 0.001088                                  | kg         | 0.99           | 0.00107712     |
| EOL  | Waste to recycling plant (primary packaging folding box)                    | 0.001224                                  | kg         | 0.1            | 0.0001224      |
| EOL  |                                                                             | 0.011288                                  | kg         | 0.06           | 0.00067728     |
| S    | Recycled folding box savings                                               | -0.0026928                                | kg         | 0.14           | -0.000376992   |
| S    | Energy from thermal treatment                                              | -0.00507552                               | MJ         | 0.022          | -0.000111661   |
| EOL  | Waste to thermal treatment (Primary packaging, plastic)                     | 0.010332                                  | kg         | 0.99           | 0.01022868     |
| EOL  | Waste to landfill (Primary packaging, plastic)                             | 0.014268                                  | kg         | 0.1            | 0.0014268      |
|      |                                                                             | -0.18969552                               | MJ         | 0.022          | -0.00417301    |
| EOL  | Bio-waste to composting plant                                              | 0.024                                     | kg         | 0.06           | 0.00144        |
| S    | Savings compost                                                            | -0.00144                                  | kg         | 0.125          | -0.00018       |
| EOL  | Bio-waste to landfill                                                      | 0.176                                     | kg         | 0.1            | 0.0176         |
|      | Waste to recycling (Primary packaging Aluminium)                            | 0.0079152                                 | kg         | 0.06           | 0.000474912    |
| EOL  | Waste to landfill (Primary packaging Aluminium)                            | 0.0056848                                 | kg         | 0.1            | 0.00056848     |
| S    | Savings aluminium                                                          | -0.0079152                                | kg         | 1.22           | -0.000565644   |

| Cupcakes | Activities                                                                 | Value per functional unit (1 kg of product) | Unit       | Unit price (£) | Total cost (£) |
|----------|-----------------------------------------------------------------------------|--------------------------------------------|------------|----------------|----------------|
| RM       | Sugar icing                                                                | 0.36315                                   | kg         | 0.37           | 0.1343655      |
| RM       | Citrus                                                                      | 0.018                                     | kg         | 0.793          | 0.014274       |
| RM       | butter                                                                      | 0.06885                                   | kg         | 1.9437         | 0.133823745    |
| TR       | Transport lorry (raw materials to manufacturer)                            | 13.77                                     | kg*km      | 0.00003        | 0.0004131      |
| RM       | Flour white                                                                | 0.132                                     | kg         | 0.936          | 0.123552       |
| RM       | Palm oil                                                                   | 0.0825                                    | kg         | 0.3698         | 0.0305085      |
| RM       | Sugar                                                                       | 0.099                                     | kg         | 0.37           | 0.03663        |
| RM       | Soda                                                                        | 0.01925                                   | kg         | 0.33           | 0.0063525      |
| RM       | Water                                                                       | 0.044                                     | L          | 0.0016         | 0.0000704      |
| Cupcakes | Activities | Value per functional unit (1 kg of product) | Unit | Unit price (£) | Total cost (£) |
|----------|------------|---------------------------------|------|---------------|---------------|
| RM       | Fructose - Glucose | 0.0275                           | kg   | 3             | 0.0825        |
| RM       | Sorbic acid      | 0.00132                          | kg   | 79.19         | 0.1045308     |
| RM       | Eggs pasteurised | 0.1265                           | kg   | 5.99          | 0.757735      |
| RM       | Acetic acid      | 0.00066                          | kg   | 0.46          | 0.0003036     |
| RM       | Glycerine        | 0.0165                           | kg   | 2.4           | 0.0396        |
| TR       | Transport lorry (raw materials to manufacturer) | 102.85                            | kg*km| 0.00003       | 0.0030855     |
| TR       | Transport ship (raw materials to manufacturer) | 1309                              | kg*km| 5.00E-08      | 0.00006545    |
| MA       | Electricity      | 0.4941                           | MJ   | 0.022         | 0.0108702     |
| MA       | Gas              | 0.515                            | MJ   | 0.0054        | 0.0002781     |
| Ma       | Steam            | 0.4748                           | MJ   | 0.034         | 0.0161432     |
| MA       | Lubricants       | 0.0000055                        | kg   | 0.664         | 0.000003652   |
| MA       | Wastewater       | 0.275                            | L    | 0.0013        | 0.0003575     |
| MA       | Water            | 0.275                            | L    | 0.0016        | 0.00044       |
| PA       | Paper            | 0.0331                           | kg   | 0.14          | 0.004634      |
| PA       | Polyethylene bottle | 0.0922                           | kg   | 1.57          | 0.144754      |
| PA       | Folding box      | 0.0305                           | kg   | 0.14          | 0.00427       |
| PA       | Cardboard secondary packaging | 0.147                           | kg   | 0.14          | 0.02058       |
| TR       | Transport lorry (packaging to manufacturer) | 45.33                             | kg*km| 0.00003       | 0.0013599     |
| DC       | Water            | 0.0137                           | L    | 0.0016        | 0.00002192    |
| TR       | Transport lorry (distribution centre to manufacturer) | 150                                | kg*km| 0.00003       | 0.0045        |
| DC       | Electricity      | 0.00000404                       | MJ   | 0.22          | 8.888E-08     |
| DC       | Wastewater       | 0.0137                           | L    | 0.0013        | 0.00001781    |
| DC       | LDPE tertiary packaging | 0.00047                         | kg   | 1.57          | 0.0007379     |
| TR       | Transport lorry (packaging to distribution centre) | 0.0705                             | kg*km| 0.00003       | 0.000002115   |
| RE       | Water            | 4.1                              | L    | 0.0016        | 0.00656       |
| RE       | Electricity      | 0.00162                          | MJ   | 0.022         | 0.0003564     |
| RE       | Wastewater       | 4.1                              | L    | 0.0013        | 0.00533       |
| RE       | Waste to recycling (secondary packaging) | 0.127155                          | kg   | 0.06          | 0.0076293     |
| S        | Recycled corrugated board savings | -0.1144395                       | kg   | 0.14          | -0.01602153   |
| RE       | Waste to landfill (secondary packaging) | 0.019845                          | kg   | 0.99          | 0.01964655    |
| RE       | Waste to energy (tertiary packaging) | -0.1234359                       | kg   | 0.022         | -0.00271559   |
| Cupcakes | Activities                                                                 | Value per functional unit (1 kg of product) | Unit     | Unit price (£) | Total cost (£) |
|----------|---------------------------------------------------------------------------|---------------------------------------------|----------|----------------|----------------|
| RE       | Waste to landfill (tertiary packaging)                                    | 0.00047                                    | kg       | 0.99           | 0.0004653      |
| S        | Energy from thermal treatment                                            | -0.0106896                                 | MJ       | 0.022          | -0.00234511    |
| TR       | Transport lorry                                                           | 50                                          | kg*km    | 0.00003        | 0.0015         |
| PA       | Plastic bags 1 bag weight 0.0075 kg and costs 5p                         | 0.0091                                     | kg       | 6.6            | 0.06006        |
| TR       | Consumer’s car                                                            | 0.135                                      | km       | 0.12           | 0.0162         |
| CO       | Waste to landfill (plastic bags)                                          | 0.005278                                   | kg       | 0.1            | 0.0005278      |
| CO       | Waste to thermal treatment (plastic bags)                                 | 0.003822                                   | kg       | 0.99           | 0.00378378     |
| S        | Energy from thermal treatment                                            | -0.08305206                                | MJ       | 0.022          | -0.001827145   |
| CO       | Electricity                                                                | 0.105                                      | MJ       | 0.022          | 0.00231        |
| CO       | Detergent                                                                  | 0.0016                                     | kg       | 6.65           | 0.01064        |
| CO       | Water                                                                      | 0.374                                      | L        | 0.0016         | 0.0005984      |
| CO       | Wastewater                                                                 | 0.374                                      | L        | 0.0013         | 0.0004862      |
| EOL      | Waste to thermal treatment (primary packaging folding box)                | 0.00244                                    | kg       | 0.99           | 0.0024156      |
| EOL      | Waste to Landfill (primary packaging folding box)                          | 0.002745                                   | kg       | 0.1            | 0.0002745      |
| EOL      | Waster to recycling plant (primary packaging folding box)                 | 0.025315                                   | kg       | 0.06           | 0.0015189      |
| S        | Recycled folding box savings                                              | -0.006039                                  | kg       | 0.14           | -0.00084546    |
| S        | Energy from thermal treatment                                            | -0.0113826                                 | MJ       | 0.022          | -0.000250417   |
| EOL      | Waste to thermal treatment (primary packaging, plastic)                   | 0.038724                                   | kg       | 0.99           | 0.03833676     |
| EOL      | Waste to landfill (primary packaging, plastic)                            | 0.053476                                   | kg       | 0.1            | 0.0053476      |
| S        | Energy from thermal treatment                                            | -0.87826032                                | MJ       | 0.022          | -0.019321727   |
| EOL      | Bio-waste to composting plant                                             | 0.024                                      | kg       | 0.06           | 0.00144        |
| S        | Savings compost                                                           | -0.00144                                   | kg       | 0.125          | -0.00018       |
| EOL      | Bio-waste to landfill                                                     | 0.176                                      | kg       | 0.1            | 0.00176        |
| EOL      | Waste to recycling (primary packaging , paper )                           | 0.027473                                   | kg       | 0.06           | 0.00164838     |
| EOL      | Waste to landfill (primary packaging , paper)                             | 0.002979                                   | kg       | 0.1            | 0.0002979      |
| EOL      | Waste to thermal treatment (primary packaging, paper)                     | 0.002648                                   | kg       | 0.99           | 0.00262152     |
| S        | Recycled paper                                                            | -0.0247257                                 | kg       | 0.14           | -0.003461598   |
| S        | Savings thermal treatment                                                 | -0.01647056                                | MJ       | 1.22           | -0.020094083   |
| Cheesecake | Activities                                                   | Value per functional unit (1 kg of product) | Unit     | Unit price (£) | Total cost (£)  |
|-----------|--------------------------------------------------------------|------------------------|----------|----------------|-----------------|
| RM        | Flour white                                                 | 0.05264                | kg       | 0.936          | 0.04927104      |
| RM        | Four wholemeal                                               | 0.01232                | kg       | 1              | 0.01232         |
| RM        | Palm oil                                                    | 0.0224                 | kg       | 0.3698         | 0.00828352      |
| RM        | Sugar                                                       | 0.01568                | kg       | 0.37           | 0.0058016       |
| RM        | Soda                                                        | 0.00224                | kg       | 0.33           | 0.0007392       |
| RM        | Salt                                                        | 0.00112                | kg       | 0.13           | 0.0001456       |
| TR        | Transport lorry (raw materials to manufacturer)             | 24.864                 | kg*km    | 0.00003        | 0.00074592      |
| TR        | Transport ship (raw materials to manufacturer)              | 355.04                 | kg*km    | 5.00E-08       | 0.000017752     |
| RM        | Strawberry                                                  | 0.15                   | kg       | 2.26           | 0.339           |
| RM        | Transport lorry (raw materials to manufacturer)             | 30                     | kg*km    | 0.00003        | 0.0009          |
| RM        | Soft cheese                                                 | 0.209592               | kg       | 2.2813         | 0.47814223      |
| MA        | Electricity                                                 | 0.196308               | MJ       | 0.022          | 0.004318776     |
| RM        | Water                                                       | 0.089298               | L        | 0.0016         | 0.000142877     |
| RM        | Milk powder                                                 | 0.208116               | kg       | 2.185          | 0.45473346      |
| RM        | Citrus                                                      | 0.104796               | kg       | 0.793          | 0.083103228     |
| RM        | Milk cream                                                  | 0.089298               | kg       | 0.98           | 0.08751204      |
| TR        | Transport lorry (raw materials to manufacturer)             | 129.7404               | kg*km    | 0.00003        | 0.003892212     |
| MA        | Electricity                                                 | 2.2334                 | MJ       | 0.022          | 0.0491348       |
| MA        | Gas                                                         | 0.466                  | MJ       | 0.0054         | 0.0025164       |
| Ma        | Steam                                                       | 0.1381                 | MJ       | 0.034          | 0.0046954       |
| MA        | Lubricants                                                  | 0.00000112             | kg       | 0.664          | 7.4368E-07      |
| MA        | Wastewater                                                  | 0.056                  | L        | 0.0013         | 0.0000728       |
| MA        | Water                                                       | 0.056                  | L        | 0.0016         | 0.0000896       |
| PA        | Polypropylene                                               | 0.0253                 | kg       | 1.69           | 0.042757        |
| PA        | Polyethylene bottle                                         | 0.0016                 | kg       | 1.57           | 0.002512        |
| PA        | Folding box                                                 | 0.0472                 | kg       | 0.14           | 0.006608        |
| PA        | Cardboard secondary packaging                                | 0.058                  | kg       | 0.14           | 0.00812         |
| TR        | Transport lorry (packaging to manufacturer)                 | 19.82                  | kg*km    | 0.00003        | 0.0005946       |
| TR        | Diesel                                                      | 0.00000118             | L        | 0.024          | 2.832E-07       |
| TR        | Refrigerant R134a                                           | 0.000016               | kg       | 12.8           | 0.0002048       |
| DC        | Water                                                       | 0.00468                | L        | 0.0016         | 0.00007488      |
| DC        | Electricity                                                 | 0.00000323             | MJ       | 0.022          | 7.106E-08       |
| DC        | liquid ammonia                                              | 0.000000357            | L        | 0.33           | 1.1781E-07      |
| Cheesecake | Activities                                                                 | Value per functional unit (1 kg of product) | Unit   | Unit price (£) | Total cost (£) |
|-----------|----------------------------------------------------------------------------|---------------------------------------------|--------|----------------|----------------|
| TR        | Transport lorry (manufacturer to distribution centre)                      | 150                                         | kg*km  | 0.00003        | 0.0045         |
| DC        | Wastewater                                                                 | 0.00468                                    | L      | 0.0013         | 0.000006084    |
| DC        | LDPE tertiary packaging                                                    | 0.00047                                    | kg     | 1.57           | 0.0007379      |
| TR        | Transport lorry (packaging to distribution centre)                        | 0.0705                                     | kg*km  | 0.00003        | 0.00002115     |
| TR        | Diesel                                                                     | 0.00000148                                 | L      | 0.24           | 3.552E-07      |
| TR        | Refrigerant R134a (transport to retailer)                                  | 0.000016                                   | kg     | 12.8           | 0.0002048      |
| RE        | Water                                                                      | 0.702                                      | L      | 0.0016         | 0.0001232      |
| RE        | Refrigerant R134a                                                         | 0.00000268                                 | kg     | 12.8           | 0.000034304    |
| TR        | Transport lorry (packaging to distribution centre)                        | 0.0705                                     | kg*km  | 0.00003        | 0.00000215     |
| TR        | Diesel                                                                     | 0.00000148                                 | L      | 0.24           | 3.552E-07      |
| TR        | Refrigerant R134a (transport to retailer)                                  | 0.000016                                   | kg     | 12.8           | 0.0002048      |
| RE        | Water                                                                      | 0.702                                      | L      | 0.0016         | 0.0001232      |
| RE        | Refrigerant R134a                                                         | 0.00000268                                 | kg     | 12.8           | 0.000034304    |
| RE        | Electricity                                                                | 0.00159                                    | MJ     | 0.022          | 0.00003498     |
| RE        | Wastewater                                                                 | 0.702                                      | L      | 0.0013         | 0.0009126      |
| RE        | Waste to recycling (secondary packaging)                                   | 0.05017                                    | kg     | 0.06           | 0.00030102     |
| S         | Recycled corrugated board savings                                          | -0.045153                                  | kg     | 0.14           | -0.00632142    |
| RE        | Waste to landfill (secondary packaging)                                    | 0.00783                                    | kg     | 0.99           | 0.0077517      |
| RE        | Waste to energy (tertiary packaging)                                       | -0.0487026                                 | kg     | 0.022          | -0.001071457   |
| RE        | Waste to landfill (tertiary packaging)                                     | 0.00047                                    | kg     | 0.99           | 0.0004653      |
| S         | Energy from thermal treatment                                              | -0.0106596                                 | MJ     | 0.022          | -0.000234511   |
| TR        | Transport lorry                                                            | 50                                         | kg*km  | 0.00003        | 0.0015         |
| PA        | Plastic bags 1 bag weight 0.0075 kg and costs 5p                           | 0.0032                                     | kg     | 6.6            | 0.02112        |
| TR        | Consumer’s car                                                             | 0.135                                      | km     | 0.12           | 0.0162         |
| CO        | Waste to landfill (plastic bags)                                           | 0.001856                                   | kg     | 0.1            | 0.0001856      |
| CO        | Waste to thermal treatment (plastic bags)                                  | 0.001344                                   | kg     | 0.99           | 0.00133056     |
| S         | Energy from thermal treatment                                              | -0.03048192                                 | MJ     | 0.022          | -0.000670602   |
| CO        | Refrigerant R134a                                                         | 0.00000456                                 | kg     | 12.8           | 0.000058368    |
| CO        | Electricity                                                                | 0.4315                                     | MJ     | 0.022          | 0.009493      |
| CO        | Detergent                                                                  | 0.0024                                     | kg     | 6.65           | 0.01596       |
| CO        | Water                                                                      | 0.281                                      | L      | 0.0016         | 0.0004496     |
| CO        | Wastewater                                                                 | 0.281                                      | L      | 0.0013         | 0.0003653     |
| EOL       | Waste to thermal treatment (primary packaging folding box)                 | 0.003776                                   | kg     | 0.99           | 0.00373824     |
| EOL       | Waste to Landfill (primary packaging folding box)                          | 0.004248                                   | kg     | 0.1            | 0.0004248     |
| EOL       | Waste to recycling plant (primary packaging folding box)                   | 0.039176                                   | kg     | 0.06           | 0.00235056       |
| S         | Recycled folding box savings                                               | -0.0093456                                 | kg     | 0.14           | -0.001308384   |
| S         | Energy from thermal treatment                                              | -0.01761504                                 | MJ     | 0.022          | -0.000387531   |
| Cheesecake Activities | Value per functional unit (1 kg of product) | Unit | Unit price (£) | Total cost (£) |
|----------------------|--------------------------------------------|------|----------------|----------------|
| EOL Waste to thermal treatment (primary packaging, plastic) | 0.011298 | kg | 0.99 | 0.01118502 |
| EOL Waste to landfill (primary packaging, plastic) | 0.015602 | kg | 0.1 | 0.0015602 |
| S Energy from thermal treatment | -0.25623864 | MJ | 0.022 | -0.00563725 |
| EOL Bio-waste to composting plant | 0.024 | kg | 0.06 | 0.00144 |
| S Savings compost | -0.00144 | kg | 0.125 | -0.00018 |
| EOL Bio-waste to landfill | 0.176 | kg | 0.1 | 0.0176 |

| Moulded chocolate Activities | Value per functional unit (1 kg of product) | Unit | Unit price (£) | Total cost (£) |
|-------------------------------|--------------------------------------------|------|----------------|----------------|
| RM Sugar | 0.44 | kg | 0.37 | 0.1628 |
| RM Palm oil | 0.05 | kg | 0.3698 | 0.01849 |
| RM Cocoa butter | 0.17 | kg | 2.114 | 0.35938 |
| RM Cocoa liquor | 0.1 | kg | 2.6507 | 0.26507 |
| RM Milk powder | 0.24 | kg | 2.185 | 0.5244 |
| TR Transport lorry (raw materials to manufacturer) | 73 | kg*km | 0.00003 | 0.000219 |
| TR Transport ship (raw materials to manufacturer) | 793 | kg*km | 5.00E-08 | 0.0003965 |
| MA Electricity | 1.3586 | MJ | 0.022 | 0.0298892 |
| MA Ammonia | 0.00021 | kg | 0.033 | 0.0000693 |
| MA Wastewater | 0.5 | L | 0.0013 | 0.000065 |
| MA Water | 0.5 | L | 0.0016 | 0.0008 |
| PA Aluminium | 0.0015 | kg | 1.22 | 0.00183 |
| PA Cardboard secondary packaging | 0.0868 | kg | 0.14 | 0.009576 |
| TR Transport lorry (packaging to manufacturer) | 68.625 | kg*km | 0.00003 | 0.00205875 |
| DC Water | 0.00356 | L | 0.0016 | 0.00005696 |
| TR Transport lorry (manufacturer to distribution centre) | 150 | kg*km | 0.00003 | 0.0045 |
| DC Electricity | 0.00000105 | MJ | 0.022 | 2.31E-08 |
| DC Wastewater | 0.00356 | L | 0.0013 | 0.00004628 |
| DC LDPE tertiary packaging | 0.00047 | kg | 1.57 | 0.0007379 |
| TR Transport lorry (distribution centre to retailer) | 0.0705 | kg*km | 0.00003 | 0.00002115 |
| PA Plastic bags 1 bag weight 0.0075 kg and costs 5p | 0.0024 | kg | 6.6 | 0.01584 |
| RE Water | 1.07 | L | 0.0016 | 0.001712 |
| RE Electricity | 0.000421 | MJ | 0.022 | 0.00009262 |
| RE Wastewater | 1.07 | L | 0.0013 | 0.001391 |
| TR | 50 | kg*km | 0.00003 | 0.0015 |
| Moulded chocolate | Activities                                      | Value per functional unit (1 kg of product) | Unit | Unit price (£) | Total cost (£) |
|-------------------|------------------------------------------------|---------------------------------------------|------|----------------|----------------|
| RE                | Waste to recycling (secondary packaging)       | 0.059166                                   | kg   | 0.06           | 0.00354996     |
| RE                | Waste to energy (secondary packaging)          | 0.009234                                   | kg   | 0.1            | 0.0009234      |
| S                 | Recycled corrugated board savings              | -0.0532494                                 | kg   | 0.14           | -0.00745916    |
| S                 | Energy from thermal treatment (secondary packaging) | -0.05743548                               | MJ   | 0.022          | -0.00126358    |
| RE                | Waste to energy (tertiary packaging)           | 0.00047                                    | kg   | 0.99           | 0.0004653      |
| S                 | Energy from thermal treatment (tertiary packaging) | -0.106596                                 | MJ   | 0.022          | -0.002345112   |
| TR                | Consumer’s car                                 | 0.135                                      | km   | 0.12           | 0.0162         |
| CO                | Waste to landfill (plastic bags)               | 0.001392                                   | kg   | 0.1            | 0.0001392      |
| EOL               | Waste to thermal treatment (plastic bags)      | 0.001008                                   | kg   | 0.99           | 0.00099792     |
| S                 | Energy from thermal treatment (plastic bags)   | -0.02286144                                | MJ   | 0.022          | -0.000502952   |
| EOL               | Waste to recycling plant (primary packaging)   | 0.000873                                   | kg   | 0.06           | 0.00005238     |
| EOL               | Waste to Landfill (primary packaging)          | 0.000627                                   | kg   | 0.1            | 0.0000627      |
| S                 | Saving from recycling (primary packaging)      | -0.000873                                 | kg   | 1.22           | -0.00106506    |

| Chocolate countlines | Activities                              | Value per functional unit (1 kg of product) | Unit | Unit price (£) | Total cost (£) |
|-----------------------|-----------------------------------------|---------------------------------------------|------|----------------|----------------|
| RM                    | Sugar                                   | 0.2904                                     | kg   | 0.37           | 0.107448       |
| RM                    | Palm oil                                 | 0.033                                      | kg   | 0.3698         | 0.0122034      |
| RM                    | Cocoa butter                             | 0.1122                                     | kg   | 2.114          | 0.2371908      |
| RM                    | Cocoa liquor                             | 0.086                                      | kg   | 2.6507         | 0.1749462      |
| RM                    | Milk powder                              | 0.1584                                     | kg   | 2.185          | 0.346104       |
| TR                    | Transport lorry (raw materials to manufacturer) | 48.18                                      | kg*km| 0.00003        | 0.0014454      |
| TR                    | Transport ship (raw materials to manufacturer) | 523.38                                    | kg*km| 5.00E-08       | 0.000026169    |
| RM                    | Flour white                              | 0.1156                                     | kg   | 0.936          | 0.1082016      |
| RM                    | Sugar                                    | 0.0833                                     | kg   | 0.37           | 0.030821       |
| RM                    | Eggs pasteurised                         | 0.00238                                   | kg   | 5.99           | 0.0145262      |
| RM                    | Salt                                     | 0.00068                                   | kg   | 0.13           | 0.0000884      |
| RM                    | Water                                    | 0.13328                                   | L    | 0.0016         | 0.000213248    |
| RM                    | Butter                                   | 0.00238                                   | kg   | 1.9437         | 0.004626006    |
| RM                    | Whey powder                              | 0.00238                                   | kg   | 1.0644         | 0.002533272    |
| RM                    | Transport lorry (raw materials to manufacturer) | 24.684                                    | kg*km| 0.00003        | 0.00074052     |
| MA                    | Electricity (manufacturing milk chocolate) | 0.176616                                  | MJ   | 0.022          | 0.003885552    |
| MA                    | Electricity (manufacturing wafers)         | 0.26384                                   | MJ   | 0.022          | 0.00580448     |
| MA                    | Gas [manufacturing wafers]                | 1.4144                                    | MJ   | 0.0054         | 0.00763776     |
| Chocolate countlines | Activities                                                                 | Value per functional unit (1 kg of product) | Unit     | Unit price (£) | Total cost (£) |
|----------------------|-----------------------------------------------------------------------------|---------------------------------------------|----------|----------------|----------------|
| MA                   | Electricity (final production line)                                         | 1.635                                       | MJ       | 0.022          | 0.03597        |
| MA                   | Ammonia                                                                     | 0.00021                                    | MJ       | 0.33           | 0.000693       |
| MA                   | Wastewater                                                                  | 0.5                                         | L        | 0.0013         | 0.00065        |
| MA                   | Water                                                                       | 0.5                                         | L        | 0.0016         | 0.0008         |
| PA                   | Aluminium                                                                   | 0.0253                                      | kg       | 1.22           | 0.030866       |
| PA                   | Cardboard secondary packaging                                              | 0.0566                                      | kg       | 0.14           | 0.007924       |
| TR                   | Transport lorry (packaging to manufacturer)                                | 12.29                                       | kg*km    | 0.00003        | 0.0003687      |
| DC                   | Water                                                                       | 0.00374                                     | L        | 0.0016         | 0.0005984      |
| TR                   | Transport lorry (manufacturer to distribution centre)                       | 150                                         | kg*km    | 0.00003        | 0.0045         |
| DC                   | Electricity                                                                 | 0.000001111                                | MJ       | 0.022          | 2.442E-08      |
| DC                   | Wastewater                                                                  | 0.00374                                    | L        | 0.0013         | 0.00004862     |
| DC                   | LDPE tertiary packaging                                                     | 0.00047                                    | kg       | 1.57           | 0.0007379      |
| TR                   | Transport lorry (packaging to distribution centre)                         | 0.0705                                      | kg*km    | 0.00003        | 0.00002115     |
| PA                   | Plastic bags 1 bag weight 0.0075 kg and costs 5p                           | 0.0025                                      | kg       | 6.6            | 0.0165         |
| RE                   | Water                                                                       | 1.12                                        | L        | 0.0016         | 0.001792       |
| RE                   | Wastewater                                                                  | 0.000443                                    | L        | 0.0013         | 5.759E-07      |
| TR                   | Transport lorry (distribution centre to retailer)                          | 50                                          | kg*km    | 0.00003        | 0.0015         |
| RE                   | Waste to recycling (secondary packaging)                                    | 0.048959                                    | kg       | 0.06           | 0.00293754     |
| RE                   | Waste to energy [secondary packaging]                                       | 0.007641                                    | kg       | 0.1            | 0.0007641      |
| S                    | Recycled corrugated board savings                                          | -0.0440631                                  | kg       | 0.14           | -0.006168834   |
| S                    | Energy from thermal treatment [secondary packaging]                        | -0.04752702                                 | MJ       | 0.022          | -0.001045594   |
| RE                   | Waste to energy (tertiary packaging)                                       | 0.00047                                    | kg       | 0.99           | 0.0004653      |
| S                    | Energy from thermal treatment [tertiary packaging]                         | -0.0106596                                  | MJ       | 0.022          | -0.000234511   |
| TR                   | Consumers’ car [km]                                                        | 0.135                                       | km       | 0.12           | 0.0162         |
| CO                   | Waste to landfill [plastic bags]                                           | 0.00145                                    | kg       | 0.1            | 0.000145       |
| CO                   | Waste to thermal treatment (plastic bags)                                  | 0.00105                                    | kg       | 0.99           | 0.0010395      |
| S                    | Energy from thermal treatment [plastic bags]                               | -0.019278                                  | MJ       | 0.022          | -0.000424116   |
| EOL                  | Waste to recycling plant (Primary packaging)                               | 0.0147246                                   | kg       | 0.06           | 0.000883476    |
| EOL                  | Waste to Landfill (primary packaging)                                       | 0.0105754                                   | kg       | 0.1            | 0.00105754     |
| S                    | Saving from recycling (primary packaging)                                  | -0.0147246                                  | kg       | 1.22           | -0.017964012   |
| Chocolates in bag | Activities | Value per functional unit (1 kg of product) | Unit | Unit price (£) | Total cost (£) |
|-------------------|------------|-------------------------------------------|------|----------------|----------------|
| RM                | Sugar      | 0.3212                                    | kg   | 0.37           | 0.118844       |
| RM                | Palm oil   | 0.0365                                    | kg   | 0.3698         | 0.0134977      |
| RM                | Cocoa butter | 0.1241                                | kg   | 2.114          | 0.2623474      |
| RM                | Cocoa liquor | 0.073                                   | kg   | 2.6507         | 0.1935011      |
| RM                | Milk powder | 0.1752                                   | kg   | 2.185          | 0.382812       |
| TR                | Transport lorry (raw materials to manufacturer) | 53.29 kg*km | 0.000003 | 0.0015987     |
| TR                | Transport ship (raw materials to manufacturer) | 578.89 kg*km | 5.00E-08 | 2.89445E-05  |
| RM                | Sugar      | 0.0481                                    | kg   | 0.37           | 0.017797       |
| RM                | Milk powder | 0.0429                                   | kg   | 2.185          | 0.0937365      |
| RM                | Cocoa butter | 0.039                                   | kg   | 2.114          | 0.082446       |
| TR                | Transport lorry (raw materials to manufacturer) | 8.58 kg*km | 0.000003 | 0.0002574     |
| RM                | Flour white | 0.02171                                  | kg   | 0.936          | 0.2032056      |
| RM                | Milk powder | 0.04329                                  | kg   | 2.185          | 0.0958865      |
| RM                | Starch     | 0.02171                                   | kg   | 1.12           | 0.0243152      |
| RM                | Sugar      | 0.04329                                   | kg   | 0.37           | 0.0160173      |
| TR                | Transport lorry (raw materials to manufacturer) | 17.342 kg*km | 0.000003 | 0.00052026    |
| MA                | Electricity [manufacturing milk chocolate until tempering] | 0.195348 MJ | 0.22 | 0.004297656   |
| MA                | Electricity [manufacturing white chocolate] | 0.021398 MJ | 0.22 | 0.000470756   |
| MA                | Electricity [Manufacturing malted milk powder] | 0.00351 MJ | 0.22 | 0.00007722    |
| MA                | Electricity [manufacturing maltesers centre] | 0.054106 MJ | 0.22 | 0.00190332    |
| MA                | Electricity [manufacturing chocolate in bags] | 1.372 MJ | 0.22 | 0.030184      |
| MA                | Ammonia    | 0.00021                                  | kg   | 0.33           | 0.0000693      |
| MA                | Wastewater | 0.5                                       | L    | 0.0013         | 0.00065       |
| MA                | Water      | 0.5                                       | L    | 0.0016         | 0.0008        |
| PA                | Aluminium  | 0.0398                                    | kg   | 1.22           | 0.048556       |
| PA                | Cardboard secondary packaging | 0.137                                 | kg   | 0.14           | 0.01918       |
| TR                | Transport lorry (packaging to manufacturer) | 26.57 kg*km | 0.000003 | 0.0007971     |
| DC                | Water      | 0.0116                                    | L    | 0.0016         | 0.0001856      |
| TR                | Transport lorry (manufacturer to distribution centre) | 150 kg*km | 0.000003 | 0.0045       |
| DC                | Electricity | 0.00000343 MJ | 0.22 | 7.546E-08     |
| DC                | Wastewater | 0.0116                                    | L    | 0.0013         | 0.0007379      |
| DC                | LDPE tertiary packaging | 0.00047                                 | kg   | 1.57           | 0.0007379      |
| Activities                                      | Value per functional unit (1 kg of product) | Unit     | Unit price (£) | Total cost (£) |
|------------------------------------------------|---------------------------------------------|----------|----------------|----------------|
| TR Transport lorry (packaging to distribution centre) | 0.0705                                      | kg*km    | 0.00003        | 0.000002115    |
| PA Plastic bags 1 bag weight 0.0075 kg and costs 5p | 0.0035                                      | kg       | 6.6            | 0.0231        |
| RE Water                                       | 3.48                                        | L        | 0.0016         | 0.005568      |
| RE Electricity                                 | 0.00137                                     | MJ       | 0.022          | 0.000003014    |
| RE Wastewater                                  | 3.48                                        | L        | 0.0013         | 0.004524      |
| TR Transport lorry (distribution centre to retailer) | 50                                          | kg*km    | 0.00003        | 0.0015        |
| RE Waste to recycling (secondary packaging)     | 0.118505                                    | kg       | 0.06           | 0.0071103     |
| RE Waste to energy [secondary packaging]        | 0.018495                                    | kg       | 0.1            | 0.0018495     |
| S Recycled corrugated board savings            | -0.1066545                                   | kg       | 0.14           | -0.01493163   |
| S Energy from thermal treatment (secondary packaging) | -0.1150389                                  | MJ       | 0.022          | -0.002530856  |
| RE Waste to energy (tertiary packaging)        | 0.00047                                     | kg       | 0.99           | 0.004653      |
| S Energy from thermal treatment (tertiary packaging) | -0.0106596                                  | MJ       | 0.022          | -0.00234511   |
| TR Consumer’s car                              | 0.135                                       | km       | 0.12           | 0.0162        |
| CO Waste to landfill (plastic bags)            | 0.00203                                     | kg       | 0.1            | 0.000203      |
| CO Waste to thermal treatment (plastic bags)   | 0.00147                                     | kg       | 0.99           | 0.0014553     |
| S Energy from thermal treatment (plastic bags) | -0.0269892                                  | MJ       | 0.022          | -0.000593762  |
| EOL Waste to recycling plant (primary packaging) | 0.0231636                                    | kg       | 0.06           | 0.00138916    |
| EOL Waste to Landfill (primary packaging)      | 0.0166364                                   | kg       | 0.1            | 0.00166364    |
| S Saving for recycling (primary packaging)     | -0.0231636                                  | kg       | 1.22           | -0.028259592  |
| Vanilla regular Ice cream                      |                                             |          |                |                |
| RM Sugar                                       | 0.15                                        | kg       | 0.37           | 0.0555        |
| RM Vanillin                                    | 0.000034                                    | kg       | 11.97          | 0.00040698    |
| RM Raw milk                                    | 1.56                                        | kg       | 0.2444         | 0.381264      |
| TR Transport lorry (raw materials to manufacturer) | 157                                        | kg*km    | 0.00003        | 0.000471      |
| MA Electricity (manufacturing milk pre-processing) | 0.26995                                    | MJ       | 0.022          | 0.00593898    |
| MA Steam (milk pre-processing)                 | 0.2551                                      | MJ       | 0.034          | 0.0086734     |
| MA Ammonia                                     | 6.45E-08                                    | L        | 0.33           | 2.1285E-08    |
| MA Water                                       | 1.538                                       | L        | 0.0016         | 0.0024608     |
| MA Wastewater                                  | 1.3613                                      | L        | 0.0013         | 0.00176969    |
| MA Sodium hydroxide                            | 0.00102                                     | kg       | 0.416          | 0.00042432    |
| MA Nitric acid                                 | 0.00049                                     | kg       | 0.141          | 0.00006909    |
| Vanilla regular ice cream | Activities                                               | Value per functional unit (1 kg of product) | Unit | Unit price (£) | Total cost (£) |
|--------------------------|----------------------------------------------------------|---------------------------------------------|------|----------------|---------------|
| MA                       | Electricity (manufacturing ice cream)                     | 3.3713                                      | MJ   | 0.022          | 0.0741686     |
| MA                       | Steam (ice cream manufacturing)                          | 0.2365                                      | MJ   | 0.034          | 0.008041      |
| MA                       | Ammonia                                                  | 0.00543                                     | kg   | 0.33           | 0.0017919     |
| MA                       | light fuel                                               | 0.034                                       | L    | 1.2            | 0.0408        |
| PA                       | Polypropylene                                            | 0.075                                       | kg   | 1.69           | 0.12675       |
| PA                       | Low density polyethylene film                            | 0.00047                                     | kg   | 1.57           | 0.0007379     |
| PA                       | Cardboard secondary packaging                            | 0.033                                       | kg   | 0.14           | 0.00462       |
| TR                       | Transport lorry (packaging to manufacturer)              | 10.8                                        | kg*km| 0.00003        | 0.000324      |
| RE                       | Electricity                                              | 2                                           | MJ   | 0.022          | 0.044         |
| TR                       | Transport lorry (manufacturer to retailer)               | 100                                         | kg*km| 0.00003        | 0.003         |
| RE                       | Waste to recycling (secondary packaging)                 | 0.028545                                    | kg   | 0.06           | 0.0017127     |
| RE                       | Waste to energy (secondary packaging)                    | 0.004455                                    | kg   | 0.1            | 0.0004455     |
| S                        | Recycled corrugated board savings                        | -0.0256905                                  | kg   | 0.14           | -0.00359667   |
| S                        | Energy from thermal treatment (secondary packaging)      | -0.00277101                                 | MJ   | 0.0684         | -0.000189537  |
| RE                       | Waste to energy (tertiary packaging)                     | 0.00047                                     | kg   | 0.99           | 0.0004653     |
| S                        | Energy from thermal treatment (tertiary packaging)       | -0.0106596                                  | MJ   | 0.022          | -0.000234511  |
| TR                       | Diesel                                                   | 0.00082                                     | L    | 1.2            | 0.000984      |
| RE                       | Refrigerant R134a                                        | 0.0005176                                   | kg   | 12.8           | 0.0662528     |
| PA                       | Plastic bags 1 bag weight 0.0075 kg and costs 5p        | 0.025                                       | kg   | 6.6            | 0.165         |
| TR                       | Consumer’s car                                           | 0.135                                       | km   | 0.12           | 0.0162        |
| CO                       | Refrigerant R134a                                        | 0.000000084                                 | kg   | 12.8           | 1.0752E-06    |
| CO                       | Detergent                                                | 0.0016                                      | kg   | 6.65           | 0.01064       |
| CO                       | Electricity                                              | 0.2242                                      | MJ   | 0.1519         | 0.03405598    |
| CO                       | Water                                                    | 0.0722                                     | L    | 0.0016         | 0.00011552    |
| CO                       | Wastewater                                               | 0.272                                       | L    | 0.0013         | 0.0003536     |
| CO                       | Waste to landfill (plastic bags)                         | 0.0145                                      | kg   | 0.1            | 0.00145       |
| CO                       | Waste to thermal treatment (plastic bags)                | 0.0105                                      | kg   | 0.99           | 0.010395      |
| S                        | Energy from thermal treatment (plastic bags)             | -0.19278                                    | kg   | 0.022          | -0.00424116   |
| EOL                      | Waste to landfill (primary packaging)                    | 0.0435                                      | kg   | 0.1            | 0.00435       |
| EOL                      | Waste to thermal treatment (primary packaging)           | 0.0315                                      | kg   | 0.99           | 0.031185      |
| S                        | Energy from thermal treatment (primary packaging)        | -0.57834                                    | MJ   | 0.022          | -0.01272348   |
| Chocolate regular Ice cream | Activities                                                                 | Value per functional unit (1 kg of product) | Unit       | Unit price (£) | Total cost (£) |
|----------------------------|----------------------------------------------------------------------------|---------------------------------------------|------------|----------------|----------------|
| RM Sugar                   |                                                                             | 0.16                                        | kg         | 0.37           | 0.0592         |
| RM Cocoa powder            |                                                                             | 0.03                                        | k          | 2.8471         | 0.085413       |
| RM Raw milk                |                                                                             | 1.5                                         | kg         | 0.2444         | 0.3666         |
| TR Transport lorry (raw materials to manufacturing) | 151 kg*km | 0.00003 | 0.00453 |
| MA Electricity (manufacturing milk pre-processing) | 0.22966 MJ | 0.022 | 0.00505252 |
| MA Steam (milk pre-processing) | 0.3281 MJ | 0.034 | 0.0111554 |
| MA Ammonia                 |                                                                             | 6.07E-08                                   |            | 0.33           | 2.0031E-08     |
| MA Water                   |                                                                             | 1.634                                      | L          | 0.0016         | 0.0026144      |
| MA Wastewater              |                                                                             | 1.28123                                    | L          | 0.0013         | 0.00165599     |
| MA Sodium hydroxide        |                                                                             | 0.000961                                   | kg         | 0.416          | 0.000399776    |
| MA Nitric acid             |                                                                             | 0.000461                                   | kg         | 0.141          | 0.000065001    |
| MA Electricity (manufacturing ice cream) | 3.1913 MJ | 0.022 | 0.0702086 |
| MA Steam (ice cream manufacturing) | 0.2365 MJ | 0.034 | 0.008041 |
| MA Ammonia                 |                                                                             | 0.005604                                   |            | 0.33           | 0.00184932     |
| MA Light fuel              |                                                                             | 0.034                                      | L          | 1.2            | 0.0408         |
| PA Polypropylene           |                                                                             | 0.075                                      | kg         | 1.69           | 0.12675        |
| PA Low density polyethylene film | 0.000047 kg | 1.57 | 0.0007379 |
| PA Cardboard secondary packaging | 0.033 kg | 0.14 | 0.00462 |
| TR Transport lorry (packaging to manufacturer) | 10.8 kg*km | 0.00003 | 0.000324 |
| RE Electricity             |                                                                             | 2                                          | MJ         | 0.022          | 0.044          |
| TR Transport lorry (manufacturer to retailer) | 100 kg*km | 0.00003 | 0.003 |
| RE Waste to recycling (secondary packaging) | 0.028545 kg | 0.06 | 0.0017127 |
| RE Waste to energy (secondary packaging) | 0.004455 kg | 0.1 | 0.0004455 |
| S Recycled corrugated board savings | -0.0256905 kg | 0.14 | -0.00359667 |
| S Energy from thermal treatment (secondary packaging) | -0.0277101 MJ | 0.0684 | -0.001895371 |
| RE Waste to energy (tertiary packaging) | 0.00047 kg | 0.99 | 0.0004653 |
| S Energy from thermal treatment (tertiary packaging) | -0.0106596 kg | 0.022 | -0.000234511 |
| TR Diesel                  |                                                                             | 0.00082                                    | L          | 1.2            | 0.000984       |
| RE Refrigerant R134a       |                                                                             | 0.0005176                                  | kg         | 12.8           | 0.00662528     |
| PA Plastic bags 1 bag weight 0.0075 kg and costs 5p | 0.025 kg | 6.6 | 0.165 |
| TR Consumer's car         |                                                                             | 0.135                                      | km         | 0.12           | 0.0162         |
| CO Refrigerant R134a      |                                                                             | 0.0000000084                               | km         | 12.8           | 1.0752E-06     |
| CO Detergent              |                                                                             | 0.0016                                    | kg         | 6.65           | 0.01064        |
| CO Electricity            |                                                                             | 0.2242                                    | MJ         | 0.1519         | 0.03405598     |
| CO Water                  |                                                                             | 0.0722                                    | L          | 0.0016         | 0.00011552     |
| Chocolate regular ice cream | Activities                                      | Value per functional unit (1 kg of product) | Unit | Unit price (£) | Total cost (£) |
|-----------------------------|-------------------------------------------------|--------------------------------------------|------|---------------|----------------|
| CO                          | Wastewater                                      | 0.272                                      | L    | 0.0013        | 0.0003536      |
| CO                          | Waste to landfill (plastic bags)                | 0.0145                                    | kg   | 0.1           | 0.00145        |
| CO                          | Waste to thermal treatment (plastic bags)       | 0.0105                                    | kg   | 0.99          | 0.010395       |
| S                           | Energy from thermal treatment (plastic bags)    | -0.19278                                  | MJ   | 0.022         | -0.00424116    |
| EOL                         | Waste to landfill (primary packaging)           | 0.0435                                    | kg   | 0.1           | 0.00435        |
| EOL                         | Waste to thermal treatment (primary packaging)  | 0.0315                                    | kg   | 0.99          | 0.031185       |
| S                           | Energy from thermal treatment (primary packaging)| -0.57834                                  | kg   | 0.022         | -0.01272348    |

| Vanilla premium ice cream   | Activities                                      | Value per functional unit (1 kg of product) | Unit | Unit price (£) | Total cost (£) |
|-----------------------------|-------------------------------------------------|--------------------------------------------|------|---------------|----------------|
| RM                          | Sugar                                           | 0.17                                       | kg   | 0.37          | 0.0629         |
| RM                          | Vanilla extract                                 | 0.000034                                  | kg   | 155           | 0.00527        |
| RM                          | Egg yolk                                        | 0.014                                     | kg   | 10.95         | 0.1533         |
| RM                          | Raw milk                                        | 1.63                                      | kg   | 0.2444        | 0.398372       |
| TR                          | Transport lorry (raw materials to manufacturer) | 168.4034                                  | kg*km | 0.00003       | 0.005052102    |
| MA                          | Electricity (manufacturing milk pre-processing) | 0.25382                                   | MJ   | 0.022         | 0.00558404     |
| MA                          | Steam (milk pre-processing)                     | 0.1631                                    | MJ   | 0.034         | 0.0055454      |
| MA                          | Ammonia                                         | 6.87E-08                                  |      | 0.33          | 2.2671E-08     |
| MA                          | Water                                           | 1.844                                     | L    | 0.0016        | 0.0029504      |
| MA                          | Wastewater                                      | 1.45139                                   | L    | 0.0013        | 0.001888807    |
| MA                          | Sodium hydroxide                                | 0.00109                                   | kg   | 0.416         | 0.00045344     |
| MA                          | Nitric acid                                     | 0.000521                                  | kg   | 0.141         | 0.000073461    |
| MA                          | Electricity (manufacturing ice cream)            | 3.3713                                    | MJ   | 0.022         | 0.0741866      |
| MA                          | Steam (ice cream manufacturing)                  | 0.2365                                    | MJ   | 0.034         | 0.008041       |
| MA                          | Ammonia                                         | 0.005577                                  |      | 0.33          | 0.00184041     |
| MA                          | light fuel                                      | 0.034                                     | L    | 1.2           | 0.0408         |
| PA                          | Polypropylene                                   | 0.075                                     | kg   | 1.69          | 0.12675        |
| PA                          | Low density polyethylene film                   | 0.00047                                   | kg   | 1.57          | 0.0007379      |
| PA                          | Cardboard secondary packaging                    | 0.033                                     | kg   | 0.14          | 0.00462        |
| TR                          | Transport lorry (packaging to manufacturer)     | 78.3                                      | kg*km | 0.00003       | 0.002349       |
| RE                          | Electricity                                     | 2                                         | MJ   | 0.022         | 0.044          |
| Activity Description                                                                 | Value per functional unit (1 kg of product) | Unit        | Unit price (£) | Total cost (£) |
|-------------------------------------------------------------------------------------|--------------------------------------------|-------------|----------------|----------------|
| TR  Transport lorry (manufacturer to retailer)                                       | 100 kg*km                                   |             | 0.00003        | 0.003          |
| RE  Waste to recycling (secondary packaging)                                         | 0.028545 kg                                | kg          | 0.06           | 0.0017127      |
| RE  Waste to energy (secondary packaging)                                            | 0.004455 kg                                | kg          | 0.1            | 0.0004455      |
| S   Recycled corrugated board savings                                               | -0.0256905 kg                              | kg          | 0.14           | -0.00359667    |
| S   Energy from thermal treatment (secondary packaging)                              | -0.0277101 MJ                              | MJ          | 0.0684         | -0.001895371   |
| RE  Waste to energy (tertiary packaging)                                             | 0.00047 kg                                 | kg          | 0.99           | 0.0004653      |
| S   Energy from thermal treatment (tertiary packaging)                               | -0.0106596 kg                              | kg          | 0.022          | -0.000234511   |
| TR  Diesel                                                                          | 0.00082 L                                  | L           | 1.2            | 0.00984        |
| RE  Refrigerant R134a                                                                | 0.0005176 kg                               | kg          | 12.8           | 0.00662528     |
| PA  Plastic bags 1 bag weight 0.0075 kg and costs 5p                                 | 0.025 kg                                   | kg          | 6.6            | 0.165          |
| TR  Consumer's car                                                                   | 0.135 km                                   | km          | 0.12           | 0.0162         |
| CO  Refrigerant R134a                                                                | 8.40E-08 kg                                | kg          | 12.8           | 1.0752E-06     |
| CO  Detergent                                                                        | 0.0016 kg                                  | kg          | 6.65           | 0.01064        |
| CO  Electricity                                                                      | 0.2242 MJ                                  | MJ          | 0.1519         | 0.03405598     |
| CO  Water                                                                            | 0.0722 L                                   | L           | 0.0016         | 0.00011552     |
| CO  Wastewater                                                                       | 0.272 L                                    | L           | 0.0013         | 0.0003536      |
| CO  Waste to landfill (plastic bags)                                                 | 0.0145 kg                                  | kg          | 0.1            | 0.00145        |
| CO  Waste to thermal treatment (plastic bags)                                        | 0.0105 kg                                  | kg          | 0.99           | 0.010395       |
| S   Energy from thermal treatment (plastic bags)                                     | -0.19278 MJ                                | MJ          | 0.022          | -0.00424116    |
| EOL Waste to landfill (primary packaging)                                            | 0.0435 kg                                  | kg          | 0.1            | 0.00435        |
| EOL Waste to thermal treatment (primary packaging)                                   | 0.0315 kg                                  | kg          | 0.99           | 0.031185       |
| S   Energy from thermal treatment (primary packaging)                                | -0.57834 MJ                                | MJ          | 0.022          | -0.01272348    |

| Activity Description                                                                 | Value per functional unit (1 kg of product) | Unit        | Unit price (£) | Total cost (£) |
|-------------------------------------------------------------------------------------|--------------------------------------------|-------------|----------------|----------------|
| RM Sugar                                                                            | 0.19 kg                                    | kg          | 0.37           | 0.0703         |
| RM Cocoa powder                                                                     | 0.035 kg                                   | kg          | 2.8471         | 0.0996485      |
| RM Egg yolk                                                                         | 0.014 kg                                   | kg          | 10.95          | 0.1533         |
| RM Raw milk                                                                         | 1.59 kg                                    | kg          | 0.2444         | 0.388596       |
| TR Transport lorry (raw materials to manufacturer)                                  | 166.9 kg                                   | kg*km       | 0.00003        | 0.005007       |
| MA Electricity [manufacturing milk pre-processing]                                   | 0.24569 MJ                                 | MJ          | 0.022          | 0.00540518     |
| Chocolate premium Ice cream | Activities                                                                 | Value per functional unit (1 kg of product) | Unit  | Unit price (£) | Total cost (£) |
|-----------------------------|----------------------------------------------------------------------------|---------------------------------------------|-------|---------------|----------------|
| MA                          | Steam [milk pre-processing]                                               | 0.1616                                      | MJ    | 0.034         | 0.0054944      |
| MA                          | Ammonia                                                                  | 6.67E-08                                    |       | 0.33          | 2.2011E-08     |
| MA                          | Water                                                                    | 1.792                                       | L     | 0.0016        | 0.0028672      |
| MA                          | Wastewater                                                               | 1.40135                                     | L     | 0.0013        | 0.001821755    |
| MA                          | Sodium hydroxide                                                         | 0.00105                                     | kg    | 0.416         | 0.0004368      |
| MA                          | Nitric acid                                                              | 0.000506                                    | kg    | 0.141         | 0.000071346    |
| MA                          | Electricity [manufacturing ice cream]                                     | 3.3713                                      | MJ    | 0.022         | 0.0741686      |
| MA                          | Steam [ice cream manufacturing]                                          | 0.2365                                      | MJ    | 0.034         | 0.008041       |
| MA                          | Ammonia                                                                  | 0.005577                                    |       | 0.33          | 0.00184041     |
| MA                          | light fuel                                                               | 0.034                                       | L     | 1.2           | 0.0408         |
| PA                          | Polypropylene                                                            | 0.075                                       | kg    | 1.69          | 0.12675        |
| PA                          | Low density polyethylene film                                            | 0.00047                                    | kg    | 1.57          | 0.0007379      |
| PA                          | Cardboard secondary packaging                                            | 0.033                                       | kg    | 0.14          | 0.00462        |
| TR                          | Transport lorry (packaging to manufacturer)                              | 78.3                                        | kg*km | 0.00003      | 0.002349       |
| RE                          | Electricity                                                              | 0.022                                       | MJ    | 0.022         | 0.044          |
| TR                          | Transport lorry (manufacturer to retailer)                                | 100                                         | kg*km | 0.00003      | 0.003          |
| RE                          | Waste to recycling (secondary packaging)                                  | 0.028545                                    | kg    | 0.06          | 0.0017127      |
| RE                          | Waste to energy (secondary packaging)                                     | 0.004455                                    | kg    | 0.1           | 0.0004455      |
| S                           | Recycled corrugated board savings                                        | -0.0256905                                  | kg    | 0.14          | -0.00359667    |
| S                           | Energy from thermal treatment (secondary packaging)                       | -0.0277101                                  | MJ    | 0.0684        | -0.001895371   |
| RE                          | Waste to energy (tertiary packaging)                                      | 0.00047                                    | kg    | 0.99          | 0.0004653      |
| S                           | Energy from thermal treatment (tertiary packaging)                       | -0.0106596                                  | MJ    | 0.022         | -0.000234511   |
| TR                          | Diesel                                                                   | 0.00082                                     | L     | 1.2           | 0.000984       |
| RE                          | Refrigerant R134a                                                        | 0.0005176                                   | kg    | 12.8          | 0.00662528     |
| PA                          | Plastic bags 1 bag weight 0.0075 kg and costs 5p                         | 0.025                                       | kg    | 6.6           | 0.165          |
| TR                          | Consumer’s car                                                           | 0.135                                       | km    | 0.12          | 0.0162         |
| CO                          | Refrigerant R134a                                                        | 8.40E-08                                    | kg    | 12.8          | 1.0752E-06     |
| CO                          | Detergent                                                                | 0.0016                                      | kg    | 6.65          | 0.01064        |
| CO                          | Electricity                                                              | 0.2242                                      | MJ    | 0.1519        | 0.03405598     |
| CO                          | Water                                                                    | 0.0722                                      | L     | 0.0016        | 0.00011552     |
| CO                          | Wastewater                                                               | 0.272                                       | L     | 0.0013        | 0.0003536      |
| CO                          | Waste to landfill (plastic bags)                                         | 0.0145                                      | kg    | 0.1           | 0.00145        |
### Table S2 continued

| Chocolate premium Ice cream | Activities                                               | Value per functional unit (1 kg of product) | Unit      | Unit price (£) | Total cost (£) |
|-----------------------------|----------------------------------------------------------|--------------------------------------------|-----------|----------------|----------------|
| S                           | Energy from thermal treatment (plastic bags)             | -0.19278                                   | MJ        | 0.022          | -0.00424116    |
| EOL                         | Waste to landfill (primary packaging)                    | 0.0435                                     | kg        | 0.1            | 0.00435        |
| EOL                         | Waste to thermal treatment (primary packaging)           | 0.0315                                     | kg        | 0.99           | 0.031185       |
| S                           | Energy from thermal treatment (primary packaging)        | -0.57834                                   | MJ        | 0.022          | -0.01272348    |

### Table S3 Contribution of different life cycle stages to the total life cycle costs (contribution <1% excluded)

| Products | Raw materials | Manufacturing | Packaging | Distribution centre | Retail | Consumption | End-of-life waste management | Transport | Credits |
|----------|---------------|---------------|-----------|----------------------|--------|-------------|-------------------------------|-----------|---------|
| Biscuits |               |               |           |                      |        |             |                               |           |         |
| Crackers | 78.8%         | 5.7%          | 11.2%     |                      |        |             |                               |           | 3.1%    |
| Low fat/sugar | 84.1%     | 6.4%          | 5.6%      |                      |        |             |                               |           | 3.4%    |
| Semi-Sweet | 83.1%     | 6.6%          | 5.7%      |                      |        |             |                               |           | 3.5%    |
| Chocolate coated | 85.1%     | 7.3%          | 3.8%      |                      |        |             |                               |           | 3.3%    |
| Chocolate cream | 85.9%     | 5.8%          | 3.9%      |                      |        |             |                               |           | 3.6%    |
| Vanilla cream | 84.8%     | 6.3%          | 4.3%      |                      |        |             |                               |           | 3.6%    |
| Cakes      |               |               |           |                      |        |             |                               |           |         |
| Whole cakes | 93.5%     | 1.2%          | 2.2%      |                      |        |             |                               |           |         |
| Slices    | 86.0%         | 2.0%          | 8.0%      |                      |        |             |                               |           | 3.0%    |
| Pies      | 84.3%         | 4.0%          | 7.0%      |                      | 1.2%   |             | 2.2%                          | 2.0%      | -1.5%   |
| Cupcakes  | 80.1%         | 1.7%          | 12.8%     |                      | 2.2%   |             | 3.9%                          | 1.5%      | -3.2%   |
| Cheesecake | 86.5%     | 3.5%          | 4.6%      |                      |        | 1.6%        | 2.2%                          | 1.6%      |         |
| Chocolates |               |               |           |                      |        |             |                               |           |         |
| Milk chocolate | 94.1%     | 2.2%          | 1.9%      |                      |        |             |                               |           | 1.8%    |
| Chocolate | 89.9%         | 4.7%          | 4.8%      |                      |        |             |                               | 2.0%      | -2.3%   |
| Chocolates in bag | 90.6%     | 2.6%          | 6.2%      |                      | 1.3%   |             |                               | 1.7%      | -2.9%   |
| Ice cream |               |               |           |                      |        |             |                               |           |         |
| Vanilla regular | 43.0%     | 14.0%         | 29.0%     |                      | 5.0%   | 6.0%        | 3.0%                          | 2.0%      | -2.0%   |
| Chocolate regular | 47.0%     | 13.0%         | 27.0%     |                      | 5.0%   | 5.0%        | 3.0%                          | 2.0%      | -2.0%   |
| Vanilla premium | 51.0%     | 12.0%         | 25.0%     |                      | 4.0%   | 5.0%        | 3.0%                          | 2.0%      | -2.0%   |
| Chocolate premium | 55.0%     | 11.0%         | 23.0%     |                      | 4.0%   | 4.0%        | 3.0%                          | 2.0%      | -2.0%   |
**Table S4** Costs, sales prices and value added (£/kg)

| Product category | Product               | Cost to manufacturer (£/kg) | Cost to retailer (£/kg) | Costs to consumer (£/kg) | Total life cycle costs (£/kg) | Sales price (£/kg) | Value added (£/kg) |
|------------------|-----------------------|----------------------------|-------------------------|--------------------------|-------------------------------|-------------------|------------------|
| Biscuits         | Crackers              | 0.844                      | 0.857                   | 0.904                    | 0.908                         | 1.3               | 0.443            |
|                  | Low fat biscuits      | 0.760                      | 0.774                   | 0.812                    | 0.808                         | 1.5               | 0.726            |
|                  | Semi-sweet            | 0.735                      | 0.749                   | 0.787                    | 0.787                         | 1.1               | 0.351            |
|                  | Chocolate coated      | 0.838                      | 0.851                   | 0.881                    | 0.879                         | 2                 | 1.149            |
|                  | Chocolate cream       | 0.739                      | 0.752                   | 0.784                    | 0.783                         | 6.5               | 5.748            |
|                  | Vanilla cream         | 0.674                      | 0.685                   | 0.717                    | 0.717                         | 6.4               | 5.715            |
| Cakes            | Whole cakes           | 2.534                      | 2.556                   | 2.601                    | 2.640                         | 6.8               | 4.244            |
|                  | Slices                | 1.998                      | 2.019                   | 2.070                    | 2.128                         | 8                 | 5.981            |
|                  | Pies                  | 1.423                      | 1.448                   | 1.494                    | 1.517                         | 2                 | 0.552            |
|                  | Cupcakes              | 1.674                      | 1.720                   | 1.797                    | 1.828                         | 13                | 11.280           |
|                  | Cheese cake           | 1.645                      | 1.666                   | 1.703                    | 1.756                         | 4.3               | 2.634            |
| Chocolate        | Moulded chocolate     | 1.377                      | 1.391                   | 1.423                    | 1.414                         | 7.5               | 6.109            |
|                  | Chocolate countlines  | 1.135                      | 1.146                   | 1.179                    | 1.156                         | 6                 | 4.854            |
|                  | Chocolate in bags      | 1.429                      | 1.455                   | 1.495                    | 1.458                         | 8.3               | 6.845            |
| Ice cream        | Vanilla regular       | 0.721                      | 0.778                   | 0.959                    | 1.029                         | 2                 | 1.222            |
|                  | Chocolate regular     | 0.785                      | 0.842                   | 1.023                    | 1.099                         | 2                 | 1.158            |
|                  | Vanilla premium       | 0.910                      | 0.967                   | 1.149                    | 1.210                         | 5                 | 4.033            |
|                  | Chocolate premium     | 0.999                      | 1.056                   | 1.238                    | 1.301                         | 5                 | 3.944            |
### Table S5 Data for uncertainty analysis

| Crackers          | Value (-) | Percentile | Value (-) |
|-------------------|-----------|------------|-----------|
| Minimum           | 0.74      | 5%         | 0.81      |
| Maximum           | 1.06      | 10%        | 0.83      |
| Mean              | 0.91      | 15%        | 0.84      |
| Std Dev           | 0.06      | 20%        | 0.85      |
| Variance          | 0.00      | 25%        | 0.86      |
| Skewness          | -0.01     | 30%        | 0.87      |
| Kurtosis          | 2.36      | 35%        | 0.88      |
| Median            | 0.91      | 40%        | 0.89      |
| Mode              | 0.91      | 45%        | 0.90      |
| Left X            | 0.81      | 50%        | 0.91      |
| Left P            | 0.03      | 55%        | 0.92      |
| Right X           | 1.00      | 60%        | 0.92      |
| Right P           | 0.98      | 65%        | 0.93      |
| Diff X            | 0.19      | 70%        | 0.94      |
| Diff P            | 0.95      | 75%        | 0.95      |
| #Errors           | 0.00      | 80%        | 0.96      |
| Filter Min        | Off       | 85%        | 0.97      |
| Filter Max        | Off       | 90%        | 0.99      |
| #Filtered         | 0.00      | 95%        | 1.00      |

| Semi sweet biscuits | Value (-) | Percentile | Value (-) |
|---------------------|-----------|------------|-----------|
| Minimum             | 0.64      | 5%         | 0.69      |
| Maximum             | 0.92      | 10%        | 0.71      |
| Mean                | 0.78      | 15%        | 0.72      |
| Std Dev             | 0.05      | 20%        | 0.73      |
| Variance            | 0.00      | 25%        | 0.74      |
| Skewness            | -0.01     | 30%        | 0.75      |
| Kurtosis            | 2.34      | 35%        | 0.76      |
| Median              | 0.78      | 40%        | 0.77      |
| Mode                | 0.79      | 45%        | 0.78      |
| Left X              | 0.69      | 50%        | 0.78      |
| Left P              | 0.03      | 55%        | 0.79      |

| Low fat/sugar biscuits | Value (-) | Percentile | Value (-) |
|------------------------|-----------|------------|-----------|
| Minimum                | 0.65      | 5%         | 0.71      |
| Maximum                | 0.96      | 10%        | 0.73      |
| Mean                   | 0.81      | 15%        | 0.74      |
| Std Dev                | 0.06      | 20%        | 0.75      |
| Variance               | 0.00      | 25%        | 0.76      |
| Skewness               | -0.01     | 30%        | 0.77      |
| Kurtosis               | 2.34      | 35%        | 0.78      |
| Median                 | 0.81      | 40%        | 0.79      |
| Mode                   | 0.82      | 45%        | 0.80      |
| Left X                 | 0.71      | 50%        | 0.81      |
| Left P                 | 0.03      | 55%        | 0.82      |

| Chocolate coated Biscuits | Value (-) | Percentile | Value (-) |
|---------------------------|-----------|------------|-----------|
| Minimum                   | 0.76      | 5%         | 0.82      |
| Maximum                   | 1.00      | 10%        | 0.83      |
| Mean                      | 0.88      | 15%        | 0.84      |
| Std Dev                   | 0.04      | 20%        | 0.85      |
| Variance                  | 0.00      | 25%        | 0.85      |
| Skewness                  | 0.00      | 30%        | 0.86      |
| Kurtosis                  | 2.62      | 35%        | 0.86      |
| Median                    | 0.88      | 40%        | 0.87      |
| Mode                      | 0.87      | 45%        | 0.87      |
| Left X                    | 0.82      | 50%        | 0.88      |
| Left P                    | 0.03      | 55%        | 0.88      |
Table S5 continued

| Semi sweet biscuits | Value (-) | Percentile | Value (-) | Chocolate coated Biscuits | Value (-) | Percentile | Value (-) |
|---------------------|-----------|------------|-----------|---------------------------|-----------|------------|-----------|
| Right X             | 0.87      | 60%        | 0.80      | Right X                   | 0.94      | 60%        | 0.89      |
| Right P             | 0.98      | 65%        | 0.80      | Right P                   | 0.98      | 65%        | 0.89      |
| Diff X              | 0.17      | 70%        | 0.81      | Diff X                    | 0.11      | 70%        | 0.90      |
| Diff P              | 0.95      | 75%        | 0.82      | Diff P                    | 0.95      | 75%        | 0.90      |
| #Errors             | 0.00      | 80%        | 0.83      | #Errors                   | 0.00      | 80%        | 0.91      |
| Filter Min          | Off       | 85%        | 0.84      | Filter Min                | Off       | 85%        | 0.92      |
| Filter Max          | Off       | 90%        | 0.85      | Filter Max                | Off       | 90%        | 0.93      |
| #Filtered           | 0.00      | 95%        | 0.87      | #Filtered                 | 0.00      | 95%        | 0.94      |

| Chocolate cream biscuits | Value (-) | Percentile | Value (-) | Vanilla cream biscuits | Value (-) | Percentile | Value (-) |
|---------------------------|-----------|------------|-----------|-------------------------|-----------|------------|-----------|
| Minimum                   | 0.68      | 5%         | 0.72      | Minimum                 | 0.61      | 5%         | 0.66      |
| Maximum                   | 0.90      | 10%        | 0.74      | Maximum                 | 0.82      | 10%        | 0.67      |
| Mean                      | 0.78      | 15%        | 0.74      | Mean                    | 0.72      | 15%        | 0.68      |
| Std Dev                   | 0.04      | 20%        | 0.75      | Std Dev                  | 0.04      | 20%        | 0.68      |
| Variance                  | 0.00      | 25%        | 0.76      | Variance                 | 0.00      | 25%        | 0.69      |
| Skewness                  | -0.01     | 30%        | 0.76      | Skewness                 | -0.01     | 30%        | 0.70      |
| Kurtosis                  | 2.50      | 35%        | 0.77      | Kurtosis                 | 2.45      | 35%        | 0.70      |
| Median                    | 0.78      | 40%        | 0.77      | Median                   | 0.72      | 40%        | 0.71      |
| Mode                      | 0.78      | 45%        | 0.78      | Mode                     | 0.72      | 45%        | 0.71      |
| Left X                    | 0.72      | 50%        | 0.78      | Left X                   | 0.66      | 50%        | 0.72      |
| Left P                    | 0.03      | 55%        | 0.79      | Left P                   | 0.03      | 55%        | 0.72      |
| Right X                   | 0.84      | 60%        | 0.79      | Right X                  | 0.78      | 60%        | 0.73      |
| Right P                   | 0.98      | 65%        | 0.80      | Right P                  | 0.98      | 65%        | 0.73      |
| Diff X                    | 0.12      | 70%        | 0.80      | Diff X                   | 0.12      | 70%        | 0.74      |
| Diff P                    | 0.95      | 75%        | 0.81      | Diff P                   | 0.95      | 75%        | 0.74      |
| #Errors                   | 0.00      | 80%        | 0.82      | #Errors                  | 0.00      | 80%        | 0.75      |
| Filter Min                | Off       | 85%        | 0.82      | Filter Min               | Off       | 85%        | 0.76      |
| Filter Max                | Off       | 90%        | 0.83      | Filter Max               | Off       | 90%        | 0.77      |
| #Filtered                 | 0.00      | 95%        | 0.84      | #Filtered                | 0.00      | 95%        | 0.78      |
Table S5: continued

| Whole cakes | Value (-) | Percentile | Value (-) | Cake slices | Value (-) | Percentile | Value (-) |
|-------------|-----------|------------|-----------|-------------|-----------|------------|-----------|
| Minimum     | 2.21      | 5%         | 2.40      | Minimum     | 1.81      | 5%         | 1.95      |
| Maximum     | 3.09      | 10%        | 2.45      | Maximum     | 2.44      | 10%        | 1.98      |
| Mean        | 2.64      | 15%        | 2.48      | Mean        | 2.13      | 15%        | 2.01      |
| Std Dev     | 0.14      | 20%        | 2.51      | Std Dev     | 0.11      | 20%        | 2.03      |
| Variance    | 0.02      | 25%        | 2.53      | Variance    | 0.01      | 25%        | 2.05      |
| Skewness    | 0.00      | 30%        | 2.56      | Skewness    | -0.01     | 30%        | 2.06      |
| Kurtosis    | 2.44      | 35%        | 2.58      | Kurtosis    | 2.40      | 35%        | 2.08      |
| Median      | 2.64      | 40%        | 2.60      | Median      | 2.13      | 40%        | 2.10      |
| Mode        | 2.63      | 45%        | 2.62      | Mode        | 2.13      | 45%        | 2.11      |
| Left X      | 2.40      | 50%        | 2.64      | Left X      | 1.95      | 50%        | 2.13      |
| Left P      | 0.03      | 55%        | 2.66      | Left P      | 0.03      | 55%        | 2.14      |
| Right X     | 2.88      | 60%        | 2.68      | Right X     | 2.30      | 60%        | 2.16      |
| Right P     | 0.98      | 65%        | 2.70      | Right P     | 0.98      | 65%        | 2.17      |
| Diff X      | 0.47      | 70%        | 2.72      | Diff X      | 0.36      | 70%        | 2.19      |
| Diff P      | 0.95      | 75%        | 2.75      | Diff P      | 0.95      | 75%        | 2.21      |
| #Errors     | 0.00      | 80%        | 2.77      | #Errors     | 0         | 80%        | 2.23      |
| Filter Min  | Off       | 85%        | 2.80      | Filter Min  | Off       | 85%        | 2.25      |
| Filter Max  | Off       | 90%        | 2.83      | Filter Max  | Off       | 90%        | 2.27      |
| #Filtered   | 0.00      | 95%        | 2.88      | #Filtered   | 0.00      | 95%        | 2.30      |

| Pies | Value (-) | Percentile | Value (-) | Cupcakes | Value (-) | Percentile | Value (-) |
|------|-----------|------------|-----------|----------|-----------|------------|-----------|
| Minimum | 1.26  | 5%        | 1.38      | Minimum | 1.57  | 5%        | 1.70      |
| Maximum | 1.78  | 10%       | 1.41      | Maximum | 2.07  | 10%       | 1.73      |
| Mean | 1.52  | 15%       | 1.43      | Mean | 1.83  | 15%       | 1.74      |
| Std Dev | 0.08  | 20%       | 1.44      | Std Dev | 0.08  | 20%       | 1.76      |
| Variance | 0.01  | 25%       | 1.46      | Variance | 0.01  | 25%       | 1.77      |
| Skewness | 0.00  | 30%       | 1.47      | Skewness | -0.01 | 30%       | 1.78      |
| Kurtosis | 2.53  | 35%       | 1.48      | Kurtosis | 2.50  | 35%       | 1.80      |
| Median | 1.52  | 40%       | 1.49      | Median | 1.83  | 40%       | 1.81      |
| Mode | 1.51  | 45%       | 1.51      | Mode | 1.85  | 45%       | 1.82      |
| Left X | 1.38  | 50%       | 1.52      | Left X | 1.70  | 50%       | 1.83      |
| Left P | 0.03  | 55%       | 1.53      | Left P | 0.03  | 55%       | 1.84      |
| Right X | 1.66  | 60%       | 1.54      | Right X | 1.95  | 60%       | 1.85      |
| Pies       | Value (-) | Percentile | Value (-) | Cupcakes   | Value (-) | Percentile | Value (-) |
|------------|-----------|------------|-----------|------------|-----------|------------|-----------|
| Right P    | 0.98      | 65%        | 1.55      | Right P    | 0.98      | 65%        | 1.86      |
| Diff X     | 0.28      | 70%        | 1.56      | Diff X     | 0.25      | 70%        | 1.87      |
| Diff P     | 0.95      | 75%        | 1.58      | Diff P     | 0.95      | 75%        | 1.88      |
| #Errors    | 0.00      | 80%        | 1.59      | #Errors    | 0.00      | 80%        | 1.90      |
| Filter Min | Off       | 85%        | 1.61      | Filter Min | Off       | 85%        | 1.91      |
| Filter Max | Off       | 90%        | 1.63      | Filter Max | Off       | 90%        | 1.93      |
| #Filtered  | 0.00      | 95%        | 1.66      | #Filtered  | 0.00      | 95%        | 1.95      |

| Cheesecake | Value (-) | Percentile | Value (-) | Moulded chocolates | Value (-) | Percentile | Value (-) |
|------------|-----------|------------|-----------|---------------------|-----------|------------|-----------|
| Minimum    | 1.52      | 5%         | 1.64      | Minimum             | 1.17      | 5%         | 1.30      |
| Maximum    | 2.03      | 10%        | 1.66      | Maximum             | 1.66      | 10%        | 1.33      |
| Mean       | 1.76      | 15%        | 1.68      | Mean                | 1.41      | 15%        | 1.34      |
| Std Dev    | 0.07      | 20%        | 1.70      | Std Dev             | 0.07      | 20%        | 1.36      |
| Variance   | 0.01      | 25%        | 1.71      | Variance            | 0.00      | 25%        | 1.37      |
| Skewness   | -0.01     | 30%        | 1.72      | Skewness            | -0.03     | 30%        | 1.38      |
| Kurtosis   | 2.79      | 35%        | 1.73      | Kurtosis            | 2.77      | 35%        | 1.39      |
| Median     | 1.76      | 40%        | 1.74      | Median              | 1.41      | 40%        | 1.40      |
| Mode       | 1.77      | 45%        | 1.75      | Mode                | 1.41      | 45%        | 1.41      |
| Left X     | 1.64      | 50%        | 1.76      | Left X              | 1.30      | 50%        | 1.41      |
| Left P     | 0.03      | 55%        | 1.77      | Left P              | 0.03      | 55%        | 1.42      |
| Right X    | 1.87      | 60%        | 1.78      | Right X             | 1.52      | 60%        | 1.43      |
| Right P    | 0.98      | 65%        | 1.78      | Right P             | 0.98      | 65%        | 1.44      |
| Diff X     | 0.24      | 70%        | 1.79      | Diff X              | 0.22      | 70%        | 1.45      |
| Diff P     | 0.95      | 75%        | 1.81      | Diff P              | 0.95      | 75%        | 1.46      |
| #Errors    | 0.00      | 80%        | 1.82      | #Errors             | 0.00      | 80%        | 1.47      |
| Filter Min | Off       | 85%        | 1.83      | Filter Min          | Off       | 85%        | 1.48      |
| Filter Max | Off       | 90%        | 1.85      | Filter Max          | Off       | 90%        | 1.50      |
| #Filtered  | 0.00      | 95%        | 1.87      | #Filtered            | 0.00      | 95%        | 1.52      |
Table S5: continued

| Chocolate count lines | Value (-) | Percentile | Value (-) | Value (-) | Value (-) | Percentile | Value (-) | Percentile | Value (-) | Percentile |
|-----------------------|-----------|------------|-----------|-----------|-----------|------------|-----------|------------|-----------|------------|
| Minimum               | 0.98      | 5%         | 1.08      | Minimum   | 1.26      | 5%         | 1.37      | 5%         | 1.37      | 5%         |
| Maximum               | 1.31      | 10%        | 1.10      | Maximum   | 1.63      | 10%        | 1.39      | 10%        | 1.39      | 10%        |
| Mean                  | 1.16      | 15%        | 1.11      | Mean      | 1.46      | 15%        | 1.40      | 15%        | 1.40      | 15%        |
| Std Dev               | 0.05      | 20%        | 1.12      | Std Dev   | 0.05      | 20%        | 1.41      | 20%        | 1.41      | 20%        |
| Variance              | 0.00      | 25%        | 1.12      | Variance  | 0.00      | 25%        | 1.42      | 25%        | 1.42      | 25%        |
| Skewness              | 0.01      | 30%        | 1.13      | Skewness  | -0.03     | 30%        | 1.43      | 30%        | 1.43      | 30%        |
| Kurtosis              | 2.75      | 35%        | 1.14      | Kurtosis  | 2.79      | 35%        | 1.44      | 35%        | 1.44      | 35%        |
| Median                | 1.16      | 40%        | 1.14      | Median    | 1.46      | 40%        | 1.44      | 40%        | 1.44      | 40%        |
| Mode                  | 1.17      | 45%        | 1.15      | Mode      | 1.46      | 45%        | 1.45      | 45%        | 1.45      | 45%        |
| Left X                | 1.08      | 50%        | 1.16      | Left X    | 1.37      | 50%        | 1.46      | 50%        | 1.46      | 50%        |
| Left P                | 0.03      | 55%        | 1.16      | Left P    | 0.03      | 55%        | 1.46      | 55%        | 1.46      | 55%        |
| Right X               | 1.23      | 60%        | 1.17      | Right X   | 1.54      | 60%        | 1.47      | 60%        | 1.47      | 60%        |
| Right P               | 0.98      | 65%        | 1.17      | Right P   | 0.98      | 65%        | 1.48      | 65%        | 1.48      | 65%        |
| Diff X                | 0.15      | 70%        | 1.18      | Diff X    | 0.17      | 70%        | 1.49      | 70%        | 1.49      | 70%        |
| Diff P                | 0.95      | 75%        | 1.19      | Diff P    | 0.95      | 75%        | 1.49      | 75%        | 1.49      | 75%        |
| #Errors               | 0.00      | 80%        | 1.20      | #Errors   | 0.00      | 80%        | 1.50      | 80%        | 1.50      | 80%        |
| Filter Min            | Off       | 85%        | 1.20      | Filter Min| Off       | 85%        | 1.51      | 85%        | 1.51      | 85%        |
| Filter Max            | Off       | 90%        | 1.22      | Filter Max| Off       | 90%        | 1.52      | 90%        | 1.52      | 90%        |
| #Filtered             | 0.00      | 95%        | 1.23      | #Filtered | 0.00      | 95%        | 1.54      | 95%        | 1.54      | 95%        |

| Vanilla regular ice cream | Value (-) | Percentile | Value (-) | Chocolate regular ice cream | Value (-) | Percentile | Value (-) |
|---------------------------|-----------|------------|-----------|----------------------------|-----------|------------|-----------|
| Minimum                   | 0.88      | 5%         | 0.96      | Minimum                    | 0.95      | 5%         | 1.03      |
| Maximum                   | 1.18      | 10%        | 0.98      | Maximum                    | 1.24      | 10%        | 1.04      |
| Mean                      | 1.03      | 15%        | 0.99      | Mean                       | 1.10      | 15%        | 1.05      |
| Std Dev                   | 0.04      | 20%        | 0.99      | Std Dev                    | 0.04      | 20%        | 1.06      |
| Variance                  | 0.00      | 25%        | 1.00      | Variance                   | 0.00      | 25%        | 1.06      |
| Skewness                  | -0.02     | 30%        | 1.01      | Skewness                   | 0.02      | 30%        | 1.07      |
| Kurtosis                  | 2.62      | 35%        | 1.01      | Kurtosis                   | 2.65      | 35%        | 1.08      |
| Median                    | 1.03      | 40%        | 1.02      | Median                     | 1.09      | 40%        | 1.08      |
| Mode                      | 1.04      | 45%        | 1.03      | Mode                       | 1.10      | 45%        | 1.09      |
| Left X                    | 0.96      | 50%        | 1.03      | Left X                     | 1.03      | 50%        | 1.09      |
| Left P                    | 0.03      | 55%        | 1.04      | Left P                     | 0.03      | 55%        | 1.10      |
Table S5: continued

| Vanilla regular ice cream | Value (-) | Percentile | Value (-) | Chocolate regular ice cream | Value (-) | Percentile | Value (-) |
|---------------------------|-----------|------------|-----------|-----------------------------|-----------|------------|-----------|
| Right X                   | 1.10      | 60%        | 1.04      | Right X                     | 1.16      | 60%        | 1.11      |
| Right P                   | 0.98      | 65%        | 1.05      | Right P                     | 0.98      | 65%        | 1.11      |
| Diff X                    | 0.14      | 70%        | 1.06      | Diff X                      | 0.14      | 70%        | 1.12      |
| Diff P                    | 0.95      | 75%        | 1.06      | Diff P                      | 0.95      | 75%        | 1.12      |
| #Errors                   | 0.00      | 80%        | 1.07      | #Errors                     | 0.00      | 80%        | 1.13      |
| Filter Min                | Off       | 85%        | 1.08      | Filter Min                  | Off       | 85%        | 1.14      |
| Filter Max                | Off       | 90%        | 1.09      | Filter Max                  | Off       | 90%        | 1.15      |
| #Filtered                 | 0.00      | 95%        | 1.10      | #Filtered                   | 0.00      | 95%        | 1.20      |

| Vanilla premium ice cream | Value (-) | Percentile | Value (-) | Chocolate premium ice cream | Value (-) | Percentile | Value (-) |
|---------------------------|-----------|------------|-----------|-----------------------------|-----------|------------|-----------|
| Minimum                   | 1.05      | 5%         | 1.14      | Minimum                     | 1.15      | 5%         | 1.23      |
| Maximum                   | 1.39      | 10%        | 1.16      | Maximum                     | 1.49      | 10%        | 1.25      |
| Mean                      | 1.21      | 15%        | 1.17      | Mean                        | 1.30      | 15%        | 1.26      |
| Std Dev                   | 0.05      | 20%        | 1.18      | Std Dev                     | 0.05      | 20%        | 1.27      |
| Variance                  | 0.00      | 25%        | 1.19      | Variance                    | 0.00      | 25%        | 1.28      |
| Skewness                  | -0.01     | 30%        | 1.19      | Skewness                    | 0.00      | 30%        | 1.28      |
| Kurtosis                  | 2.70      | 35%        | 1.20      | Kurtosis                    | 2.74      | 35%        | 1.29      |
| Median                    | 1.22      | 40%        | 1.21      | Median                      | 1.31      | 40%        | 1.30      |
| Mode                      | 1.21      | 45%        | 1.21      | Mode                        | 1.30      | 45%        | 1.30      |
| Left X                    | 1.14      | 50%        | 1.22      | Left X                      | 1.23      | 50%        | 1.31      |
| Left P                    | 0.03      | 55%        | 1.23      | Left P                      | 0.03      | 55%        | 1.32      |
| Right X                   | 1.30      | 60%        | 1.23      | Right X                     | 1.39      | 60%        | 1.32      |
| Right P                   | 0.98      | 65%        | 1.24      | Right P                     | 0.98      | 65%        | 1.33      |
| Diff X                    | 0.15      | 70%        | 1.25      | Diff X                      | 0.16      | 70%        | 1.33      |
| Diff P                    | 0.90      | 75%        | 1.25      | Diff P                      | 0.95      | 75%        | 1.34      |
| #Errors                   | 0.00      | 80%        | 1.26      | #Errors                     | 0.00      | 80%        | 1.35      |
| Filter Min                | Off       | 85%        | 1.27      | Filter Min                  | Off       | 85%        | 1.36      |
| Filter Max                | Off       | 90%        | 1.28      | Filter Max                  | Off       | 90%        | 1.37      |
| #Filtered                 | 0.00      | 95%        | 1.30      | #Filtered                   | 0.00      | 95%        | 1.39      |
| Products                        | Sales value (£m) | Retail price (£) | Yearly sales volumes (t) | Product shares to sub-sectors | Life cycle costs (£/kg) | Savings (£/kg) | Costs to retailer (£/kg) | Value added (£/kg) |
|--------------------------------|-----------------|------------------|--------------------------|-------------------------------|-------------------------|--------------|--------------------------|------------------|
| Crackers                       | 362             | 1.3              | 278,462                  | 16.2%                         | 0.908                   | 0.006        | 0.857                    | 0.443            |
| Low fat biscuits               | 612             | 1.5              | 408,000                  | 23.8%                         | 0.808                   | 0.010        | 0.774                    | 0.726            |
| Semi-sweet biscuits            | 281.5           | 1.1              | 255,909                  | 14.9%                         | 0.787                   | 0.006        | 0.749                    | 0.351            |
| Chocolate-coated biscuits      | 208.5           | 2                | 104,250                  | 6.1%                          | 0.879                   | 0.007        | 0.851                    | 1.149            |
| Chocolate cream biscuits       | 208.5           | 6.5              | 32,077                   | 1.9%                          | 0.783                   | 0.005        | 0.752                    | 5.748            |
| Vanilla cream biscuits         | 281.5           | 6.4              | 43,984                   | 2.6%                          | 0.717                   | 0.004        | 0.685                    | 5.715            |
| Other biscuits confectionary   | 654             | 1.1              | 594,545                  | 34.6%                         | 0.908                   | 0.004        | 0.857                    | 0.243            |
| Whole cakes                    | 287             | 6.8              | 42,206                   | 11.7%                         | 2.640                   | 0.009        | 2.556                    | 4.244            |
| Slices/bars                    | 362.3           | 8                | 45,288                   | 12.6%                         | 2.128                   | 0.020        | 2.019                    | 5.981            |
| Pies                           | 362.3           | 2                | 181,150                  | 50.4%                         | 1.517                   | 0.022        | 1.448                    | 0.552            |
| Cupcakes                       | 362.3           | 13               | 27,869                   | 7.7%                          | 1.828                   | 0.058        | 1.720                    | 11.280           |
| Cheesecake                     | 272             | 4.3              | 63,256                   | 17.6%                         | 1.756                   | 0.013        | 1.666                    | 2.634            |
| Moulded chocolate              | 845             | 7.5              | 112,667                  | 17.7%                         | 1.414                   | 0.010        | 1.391                    | 6.109            |
| Chocolate countlines           | 1817            | 6                | 302,833                  | 47.6%                         | 1.156                   | 0.026        | 1.146                    | 4.854            |
| Chocolate in bags              | 1304            | 8.3              | 157,108                  | 24.7%                         | 1.458                   | 0.042        | 1.455                    | 6.845            |
| Other chocolate confectionary  | 378             | 6                | 63,000                   | 9.9%                          | 1.458                   | 0.01         | 1.455                    | 4.545            |
| Vanilla regular ice cream      | 55              | 2                | 27,500                   | 6.8%                          | 1.029                   | 0.020        | 0.778                    | 1.222            |
| Chocolate regular ice cream    | 55              | 2                | 27,500                   | 6.8%                          | 1.099                   | 0.022        | 0.842                    | 1.158            |
| Vanilla premium ice cream      | 221.5           | 5                | 44,300                   | 11.0%                         | 1.210                   | 0.022        | 0.967                    | 4.033            |
| Chocolate premium ice cream    | 221.5           | 5                | 44,300                   | 11.0%                         | 1.301                   | 0.022        | 1.056                    | 3.944            |
| Other ice cream products       | 580             | 2.225            | 260,674                  | 64.5%                         | 1.301                   | 0.02         | 1.056                    | 1.169            |
| Products                          | Annual life cycle costs (£m) | Annual life cycle savings (£m) | Annual value added (£m) |
|----------------------------------|-----------------------------|-------------------------------|-------------------------|
| Crackers                         | 253                         | 1.75                          | 123                     |
| Low fat biscuits                 | 330                         | 4.05                          | 296                     |
| Semi-sweet biscuits              | 201                         | 1.56                          | 90                      |
| Chocolate-coated biscuits        | 92                          | 0.76                          | 120                     |
| Chocolate cream biscuits         | 25                          | 0.16                          | 184                     |
| Vanilla cream biscuits           | 31                          | 0.18                          | 251                     |
| Other biscuits confectionary     | 540                         | 2.38                          | 144                     |
| Whole cakes                      | 111                         | 0.40                          | 179                     |
| Cakes slices                     | 96                          | 0.92                          | 271                     |
| Pies                             | 275                         | 4.04                          | 100                     |
| Cupcakes                         | 51                          | 1.62                          | 314                     |
| Cheesecake                       | 111                         | 0.84                          | 167                     |
| Moulded chocolate                | 159                         | 1.15                          | 688                     |
| Chocolate countlines             | 350                         | 7.88                          | 1470                    |
| Chocolate in bags                | 229                         | 6.54                          | 1075                    |
| Other chocolate confectionary    | 92                          | 0.63                          | 286                     |
| Vanilla regular ice cream        | 28                          | 0.54                          | 34                      |
| Chocolate regular ice cream      | 30                          | 0.59                          | 32                      |
| Vanilla premium ice cream        | 54                          | 0.95                          | 179                     |
| Chocolate premium ice cream      | 58                          | 0.95                          | 175                     |
| Other ice cream products         | 339                         | 5.21                          | 305                     |