Environmental and economic sustainability assessment of food waste management options in a tortilla industry (a case study)

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Abstract. The aim of this study is to analyse the waste generated in tortilla production process in a tortilla industry located in London and consider a number of potential solutions. This study evaluated the environmental and economic impacts related to anaerobic digestion, using the food waste as animal feed, and reworking the food waste. The impacts of each waste management options were compared to determine the most sustainable option. The Life Cycle Assessment (LCA) and Life Cycle Costs (LCC) methods have been applied using SimaPro 9.3.0.3. The functional unit of the study was set to 1 kg of tortilla. The system boundary included the tortilla production processes (mixing, forming, baking, cooling and packaging) and food waste management scenarios. The LCA results showed that reworking the waste will substantially reduce environmental impacts across all assessed categories. The LCC results show that reworking the food waste within the tortilla production process is the best option with the lowest net costs of GBP4.96/kg. This is followed by AD with a net cost of GBP 5.08/kg and lastly by animal feed with a net cost of GBP 6.45/kg.

1 Introduction

The growing awareness of the adverse impacts associated with waste generation has intensified the need for sustainable waste management approaches across various sectors. Particularly in the food industry, where approximately one-third of all food produced globally is lost or wasted [1], industry players are increasingly prioritizing initiatives aimed at reducing their food waste.

However, the decision to sustainably reduce or manage food waste, is often constrained by economic considerations [2]. As a result, food-manufacturing companies are faced with the challenge of achieving a balance between reducing food waste sustainably and maintaining economic profitability.

Like other food manufacturing companies, tortilla production generates considerable amount of waste at various stages – implying the need for sustainable waste management strategies that not only ensure minimal environmental impacts but are also economically viable. To evaluate the environmental and economic sustainability of the production process and food waste generation options, the life cycle assessment (LCA) and life cycle costing (LCC) methods are considered consistent and comprehensive frameworks [2-3]. LCA is regarded an invaluable technique prescribed by the International Organization for Standardization which assesses resource use, energy use and the potential environmental burdens associated with the system [4]. LCC is regarded as a functional tool to analyse the costs in the entire production process, including the various stages from cradle to grave of a product or a process [5]. LCC method is also useful in rationalising long-term decision making when considering different alternatives, as it assesses the costs both in the short and long-run [6-7].

A review of existing literature revealed few studies which assessed the sustainability of tortilla production, and these studies primarily focused on environmental impacts. Collectively, these studies highlight the role of the life cycle assessment approach in assessing the environmental footprint of the tortilla production process [8-9]. However, no previous study was found which assessed the economic sustainability of the tortilla production, particularly with regards to the costs related to the disposal of food waste. To address this gap, this study evaluates both the environmental and economic sustainability of tortilla production and waste management approaches via a case study.

2 Methods

The study was conducted in a company based in London which specializes in the production of variety of Mexican foods. The company experienced some issues with waste generation production process and seeks to reduce this waste while enhancing economic sustainability. This study analysed the environmental and economic benefits of three food waste management options – anaerobic digestion (AD), animal feed, and

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reworking the tortilla waste into the production process. These options were compared to guide the selection of a more sustainable waste management option.

2.1 Assessing environmental impacts of tortilla production process and food waste management options

The LCA method, under the International Standard ISO 14044 (ISO 14044, 2006), was employed to evaluate the environmental impacts of tortilla production and food waste management options in the company.

System Boundary: Gate-to-Gate system boundary is adopted which is in accordance with the common rules within the framework of the International Environmental Product Declaration (EPD) system – which includes all processes and activities within the company's facility, from the receipt of raw materials to the shipment of finished products [10]. This is considered appropriate as it focuses on the processes and activities within the company's facility, and allows for the assessment of the environmental impacts of the different waste management options. The system boundary, as presented in Fig. 1, therefore includes the mixing, forming, baking, cooling, packaging, waste management process which are explained below.

Mixing: this is the formation of corn dough (i.e. mixing of corn flour, salt and water)

Forming: this is the loading of the corn dough into the machine

Baking: this is the kneading and baking of the corn dough into tortillas

Cooling: this is the cooling of the tortilla before being packed

Packaging: this is the packing of the tortilla into vacuum bags

Reference scenario: food waste is disposed into an unsanitary landfill

Alternative Scenario: food waste is treated using Anaerobic Digestion (AD)

The functional unit used for this study was 1 kg of tortilla.

2.2 Assessing economic impacts of tortilla production process and food waste management options

To assess the economic impact of tortilla production and the different food waste management scenarios, the same system boundary was followed as presented in Figure 1. The economic costs and benefits were considered using the Life cycle costing (LCC) method in Simapro 9.3.0.3. The economic costs assessed include the cost of material inputs (which includes cost of corn flour, cost of salt, price of water, cost of vacuum bags), cost of energy inputs (electricity price for the mixer, oven and sealing machine), and the waste disposal costs. The economic benefits refer to the savings generated from reworking tortilla into the production process.

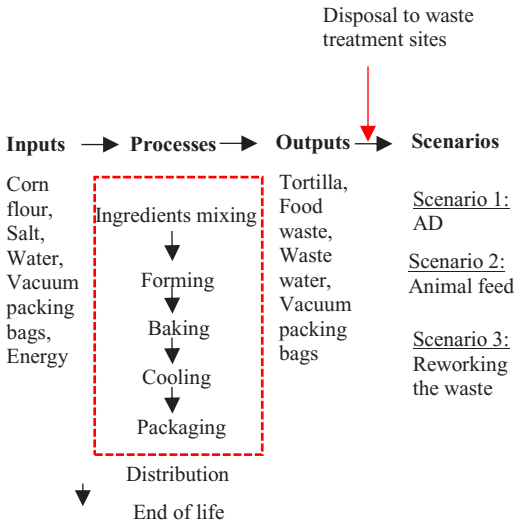

Fig 1: LCA and LCC system boundary for tortilla production and food waste management options

The net economic costs of Scenario 1 (AD) and Scenario 2 (Animal feed) were computed using Equation (1):

Net economic costs = cost of material inputs + cost of energy inputs + disposal costs + disposal cost of wastewater (1)

where

Cost of material inputs equals to the sum of the following costs: cost of corn flour, cost of salt, price of water and cost of vacuum packing bags (based on the functional unit). The prices of these items were derived from different sources: Mextrade, Waitrose, Thames water, and Polybags Ltd respectively.

Cost of energy inputs equals to the total cost of electricity consumed by the mixer, tortilla machine, and sealing machine (based on the functional unit). The energy price was derived from Ofgem.

Disposal costs equal to the price paid to the waste collection company based on the functional unit (this was assumed to be the same price for AD and animal feed).

Disposal cost of wastewater equal to the cost of disposing wastewater based on the functional unit. The price was derived from Thames Water.

The net economic cost of the Scenario 3 (reworking the waste) was computed using Equation (2):

Net economic costs = cost of material inputs + cost of energy inputs + disposal costs + disposal cost of wastewater – savings from reworking (2)

where all terms as explained in Equation (1) apply,

Savings from reworking refer to the sales of tortilla (that is, the tortilla produced from reworking the waste). The sales price of tortilla was derived from Company data.

3 Results and discussion

3.1 LCA of environmental Impacts of tortilla production and food waste management options

The environmental impact assessment was carried out using the Simapro 9.3.0.3 software (Pre Sustainability, Netherlands). It was used to assess the environmental performance of tortilla production and food waste management – comparing AD with the reference scenario. This comparison was based on each of the 18 impact categories from the ReCiPe midpoint E method (Table 1).

The results showed that reworking the waste resulted in considerable reductions in all the environmental impacts when compared with animal feed and AD. The most remarkable reductions include land use – which reduced by 94% to 0.2172 m2a crop eq when compared with animal feed and marine eutrophication – which reduced by 93% to 0.0004 kg N eq when compared with animal feed (0.0061 kg N eq). When compared with AD, reworking also proved to be a more suitable option with great reductions in stratospheric ozone depletion – which reduced by 10% to 5.50 E-06, and human carcinogenic toxicity – which reduced by 6% to 3.9679.

Anaerobic digestion when compared with animal feed was found to be a more suitable waste management option with remarkable reductions in land use – which reduced by 94% to 0.2182 m2a crop eq, terrestrial acidification – which reduced by 83% to 0.0048 kg 1,4-DCB, and marine eutrophication – which reduced by 93% to 0.0004 kg N eq.

Overall, reworking the waste proved to be the most sustainable waste management option with considerable reductions in all environmental impact categories that were assessed.

Table 1: Environmental impacts of tortilla production and food waste management options

Impact category	Unit	AD	Animal Feed	Rework
Global warming	kg CO2 eq	0.8847	1.5983	0.8372
Stratospheric ozone depletion	kg CFC11 eq	6.08E-06	3.300E-05	5.50E-06
Ionizing radiation	kBq Co-60 eq	0.0694	0.0962	0.0688
Ozone formation, Human health	kg NOx eq	0.0053	0.0092	0.0053
Fine particulate matter formation	kg PM2.5 eq	0.0016	0.0056	0.0016
Ozone formation, Terrestrial ecosystems	kg NOx eq	0.0055	0.0095	0.0054
Terrestrial acidification	kg SO2 eq	0.0048	0.0281	0.0047
Freshwater eutrophication	kg P eq	0.0002	0.0005	0.0002
Marine eutrophication	kg N eq	0.0004	0.0061	0.0004
Terrestrial ecotoxicity	kg 1,4-DCB	4.7117	7.4453	4.6345
Freshwater ecotoxicity	kg 1,4-DCB	0.0462	0.0774	0.0454
Marine ecotoxicity	kg 1,4-DCB	292.2972	474.3850	286.5725
Human carcinogenic toxicity	kg 1,4-DCB	4.2172	7.1176	3.9679
Human non-carcinogenic toxicity	kg 1,4-DCB	241.1775	416.2366	236.3813
Land use	m2a crop eq	0.2182	3.4423	0.2172
Mineral resource scarcity	kg Cu eq	0.0041	0.0065	0.0040
Fossil resource scarcity	kg oil eq	0.2602	0.4209	0.2508
Water consumption	m3	0.0451	0.0856	0.0452

3.2 Economic impacts of tortilla production and food waste management options

The life cycle costs and benefits of the food waste management scenarios were quantified and expressed in GBP (based on the functional unit). The cost components were summed up to determine the net costs of the scenarios. The results are presented in Figure 2.

For Scenario 1 (AD), a reduction in the economic impact was revealed – as the total net costs reduced to GBP 5.08/kg of tortilla when AD is used for food waste management. For Scenario 2 (Animal feed), total net costs increased to GBP 6.45/kg. Hence, making this the least favourable option in terms of economic impacts. For Scenario 3 (reworking the waste), total net costs reduced largely to GBP 4.96/kg of tortilla due to the savings from reusing the tortilla waste in the production process. Hence, resulting in the most favourable option in terms of economic impacts.

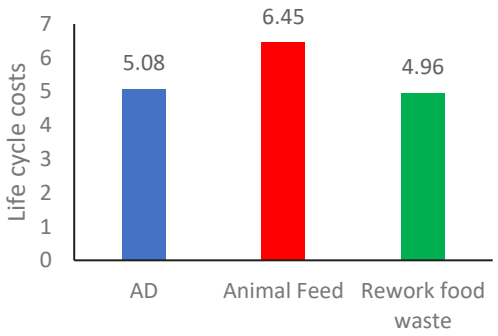

Fig 2: Life cycle costs of different food waste management scenarios (GBP/kg)

4 Conclusions

In this study, the LCA and LCC frameworks were employed to assist decision making on sustainable food waste management for the tortilla industry. The life cycle assessment results show that reworking the waste is a more preferable solution with remarkable environmental benefits – considering all of the impact categories analysed. The life cycle cost results also show that reworking the food waste is the most preferable solution with great economic benefits.

This study provides the company with insights into an alternative food waste management strategy (reworking the food waste) to improve the existing operational system. The contributions of this study include:

1. The coverage of the environmental and economic impacts of food waste management options for the tortilla manufacturing company.
2. The applicability of the results for sustainable decision-making on food waste management in the tortilla industry.

This project was funded by the BBSRC-CDT (Project ref number: BB/V011391/1) and ESPRC through the Park Royal Net Zero Food Systems.

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