Backcasting to Identify Food Waste Prevention and Mitigation Opportunities for Infant Feeding in the Maternity Services

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Highlights

- This paper examines treatment of breast-milk substitute waste in maternity hospitals
- Backcasting method was used to identify causes and mitigation opportunities
- Problem orientation revealed potential aspects for intervention
- International policy on infant feeding and waste regulations guided solutions
- Health policies align with food resource conservation and demand reduction

Abstract

Food waste in hospitals is of major concern for two reasons: first, healthcare needs to move toward preventative and demand led models for sustainability and second, food system sustainability needs to seek preventative measures such as diet adaptation and waste prevention. The impact of breast-milk substitute use on health services is well established in literature in terms of healthcare implications, cost and resourcing, however as a food demand and waste management issue little has been published to date.

This paper presents the use of a desk based backcasting method to analyse food waste prevention, mitigation and management options within the Irish Maternity Service. Best practice in healthcare provision and waste management regulations are used to frame solutions.

Strategic problem orientation revealed that 61% of the volume of ready to use breast-milk substitutes purchased by maternity services remains unconsumed and ends up as waste. Thirteen viable strategies to prevent and manage this waste were identified.

Significant opportunities exist to prevent waste and also decrease food demand leading to both positive health and environmental outcomes. Backcasting methods display great promise in delivering food waste management strategies in healthcare settings, especially where evidenced best practice policies exist to inform solution forming processes.

In terms of food waste prevention and management, difficulties arise in distinguishing between demand reduction, waste prevention and waste reduction measures under the current Waste Management Hierarchy definitions. Ultimately demand reduction at source requires prioritisation, a strategy which is complimentary to health policy on infant feeding.

1 Introduction

Food waste is of major concern especially in healthcare systems and has been the subject of many investigative research studies (Abd El-Salam, 2010; Barton et al., 2000; Halloran et al., 2014; Sonnino and McWilliam, 2011; Williams and Walton, 2011). Williams and Walton (2011) summarised results from 32 hospital studies which suggest a median food wastage rate of 30% by mass with ranges varying between 6% and 65%. Various authors have argued that healthcare needs to shift to preventative and more demand led measures both in terms of demand for healthcare but also in demand of materials and energy required to deliver universal healthcare systems, in order to move toward sustainability (McGain and Naylor, 2014; NHS England, 2014; Ryan-Fogarty et al., 2016; Watts et al., 2015).

To date research regarding the environmental impact of food has tended to focus on production and supply chain waste alleviation rather than addressing consumption and demand factors, which are more challenging in their identification and mitigation (Bajzelj et al., 2014). As humanity begins to focus on the effects of climate change and adaptation to decreased availability of agricultural land attention has shifted to seeking optimal sources of nutrition, particularly protein sources for human consumption. Consensus is growing that in order to effectively curtail environmental impact and provide food security, society needs to address the significant impacts exerted through the cultivation, production, processing and transportation of food, but crucially overall food demand needs to decrease through diet adaptation and food waste reduction (Bajzelj et al., 2014; Garnett, 2011; González et al., 2011; Wirsenius et al., 2010).

In hospital settings infant feeding actions have direct environmental impacts in terms of transport, materials used, unconsumed breast-milk substitute, bottles, teats, packaging, leaflets and product information plus the costs of storage and obsolescence (American Academy of Paediatrics, 2012). Published works have attempted some quantification of the costs to health services of purchasing breast-milk substitutes, and costs of exclusive artificial feeding in terms of health impacts (Pokhrel et al., 2014; Renfrew et al., 2012; UNICEF UK, 2012). Some recent publications have questioned trends in infant feeding practices and their impact on food security, women's health, consumption patterns and ethical considerations (Becker and Ryan-Fogarty, 2016; Cassidy, 2012; Ryan et al., 2013; Salmon, 2015; UNICEF UK, 2015). However available data suggest that the impact of breast-milk substitute food and associated wastes have not been formally quantified nor have measures been taken to mitigate impacts.

1.1 The Irish Context

Ireland's Food Waste Regulations (*Waste Management (Food Waste) Regulations 2009*, 2010) list 11 classes of commercial or other activities that require source segregation and treatment at authorised food waste treatment plants. A number of provisions in the legislation ensure that food waste is consigned for recycling and not disposal via sewage systems, for example, the use of in-sink macerators is prohibited by the Food Waste Regulations where a food waste collection service is available, even if a discharge licence allowing food effluent to sewer has been issued. This provision strives to ensure that all food waste is recycled (Department of Environment, Heritage and Local Government, 2010). Yet it was estimated that on a daily basis up to 36 tonnes of waste food from catering operations enter the Irish drainage system through the use of macerators leading to blockages and reduced effectiveness of grease traps and leading to flooding and increased pressure on wastewater treatment plants (Creedon et al., 2010). Studies of acute hospitals conducted by the Irish Environmental Protection Agency found that approximately 0.73 kg of food waste is generated per in-patient bed day (Environmental Protection Agency, 2013). However, akin to other studies (Costello et al., 2015), accounting for liquid foodstuffs such as fresh milk, breast-milk substitutes and fruit juices that can be poured down drains or soaked into other foods presents a significant challenge. Waste milk and breast-milk substitutes have high biological oxygen demand, are sources of nitrogen and phosphorus pollution and may cause operational issues especially to on-site waste water treatment plants where dilution factors may be lower.

Maternity services (both public and private) are offered through the Irish public hospital system managed by the Health Service Executive (HSE). Ireland has 5 maternity hospitals and a further 14 general hospitals have maternity units or wards, plus infants in paediatric hospitals and wards. Of these 19 maternity service providers, 9 hold Baby Friendly Hospital Designation, and all others are registered as participating in the initiative. The *Baby Friendly Health Initiative* (BFHI) was established in 1991 by UNICEF and WHO. Among the requirements for designation, BFHI designated hospitals are required to abide by the *International Code on Marketing of Breast Milk Substitutes* and subsequent World Health Assembly resolutions (World Health Organization, 2015). Practices of the BFHI and of the International Code are reflected in the *HSE National Infant Feeding Policy for Maternity and Neonatal Units* (Health Service Executive, 2015). This policy reflects expected national practice: however, these practices may not be reflected in their entirety in every maternity unit.

1.2 The Role of Backcasting

Systemic changes and transitions are required in order to achieve sustainability. Backcasting has been proposed as a means to achieve integrated approaches to combine:

- involvement of a range of stakeholders,
- incorporation of economic and social components in tandem with environmental components of sustainability,
- consideration of demand and supply chains as interconnected production and consumption systems (Quist et al. 2002 cited in Quist and Vergragt, 2006).

Backcasting is an approach in which desirable, sustainable, future visions or "normative scenarios" are created, followed by an analysis of how to achieve these, as a foundation for describing strategies and follow up activities to attain desirable futures (Alcamo and Henrichs, 2008; Holmberg and Robert, 2000; Jansen, 2003; Quist and Vergragt, 2006). Scenarios may provide interdisciplinary frameworks in which solutions can be envisioned for complex environmental problems, raise awareness, communicate complex information, facilitate policymakers in engagement with stakeholders and provide assistance in thinking big about an environmental issue (Alcamo, 2008). The complexity of future uncertainties and "inherent ambiguity" of the different values and mental frameworks of stakeholders makes grasping the knowledge of what transitions are required difficult, and there exists a wide variety and diversity in approaches, topics, systems and scales (Quist and Vergragt, 2006; Vergragt and Quist, 2011).

As an iterative and reflexive method, it has been argued that backcasting does not propose a finalised version of the future, instead it assumes that vision and pathway developments employ higher learning processes and that participants learn about desired futures, barriers, contradictions, change agents, incentives and improvements to the future vision (Vergragt and Quist, 2011). The European Commission has developed dedicated resources to assist foresight practitioners, *FOR-LEARN* aims to consolidate and improve access to forsight knowledge including backcasting methods (European Commission Joint Research Centre, 2007).

1.3 Objectives of Paper

The overall goal of this paper is to evaluate the use of backcasting as a tool for mitigation of Ready to Use (RTU) breast-milk substitute food waste in the Irish Maternity Service through:

- identification of sources of waste RTU breast-milk substitutes within the Irish Maternity Service.
- theoretical quantification of RTU breast-milk substitutes procured and volumes of liquid waste arising.
- evaluation of solutions to prevent and mitigate this waste in accordance with international best practice in waste management, World Health Organisation and Baby Friendly Hospital Initiative policies.

2 Methods

The Irish healthcare system, HSE, offers an informative case study as in recent years it has developed sustainability aims and has undertaken extensive waste prevention measures especially with respect to food waste under the Irish Environmental Protection Agency (EPA) Green Healthcare Programme (Environmental Protection Agency, 2014; Ryan-Fogarty et al., 2016). The Maternity Service, through established environmental and health initiative programmes, can provide a test bed for innovative solutions and can therefore be used to identify methods and strategies that have potential for application in other jurisdictions.

This paper utilises backcasting methods as outlined in *FOR-LEARN Backcasting Online Foresight Guide* (European Commission Joint Research Centre, 2007) to develop normative scenarios for breast-milk substitute food waste management. The backcasting method employed is depicted in Figure 1.

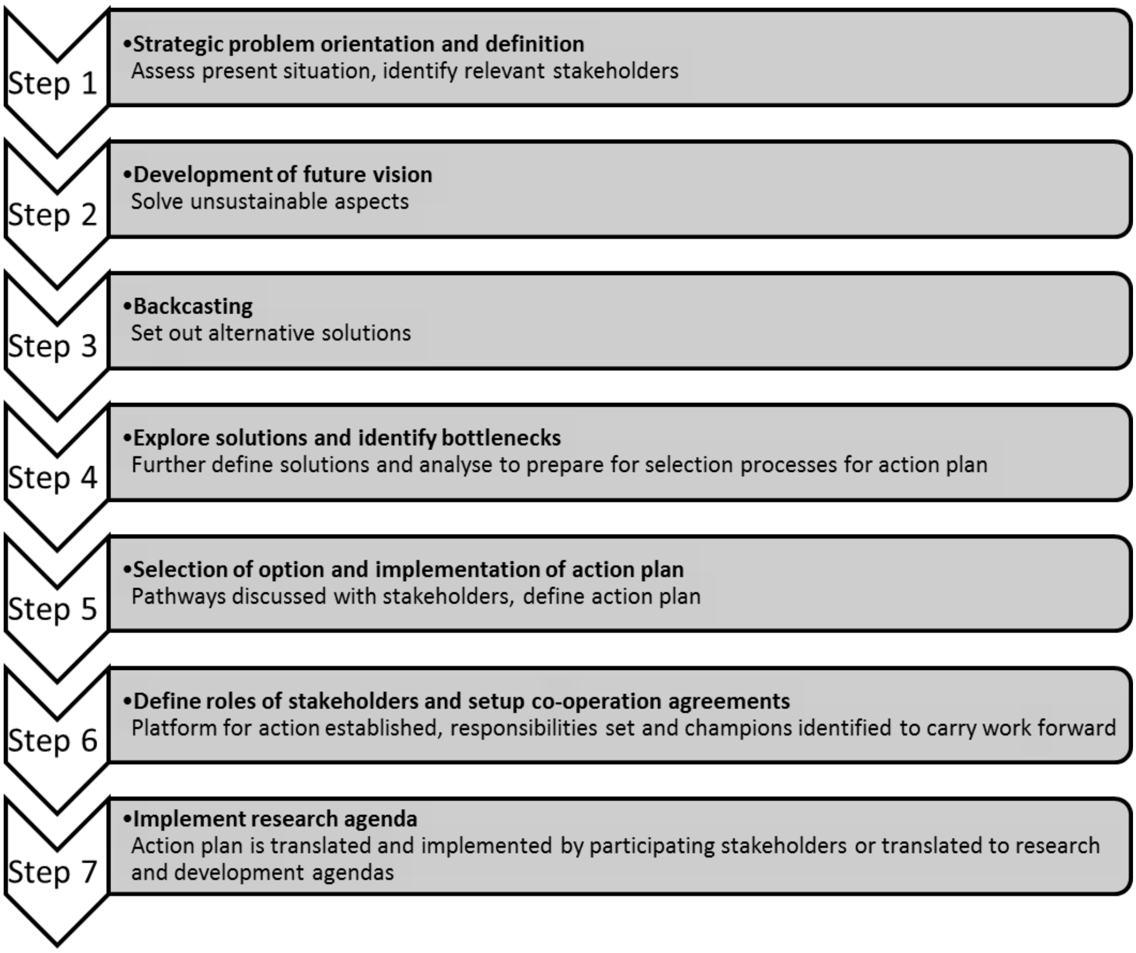

Figure 1: Steps required in conducting full backcasting methods (European Commission Joint Research Centre, 2007)

- **Step 1: Strategic problem orientation and definition**: The sources and extent of RTU breast-milk substitute waste and implications were determined through literature reviews using data from published papers, books, National Perinatal Statistics 2013, BFHI reports and HSE infant feeding policies. The research team also has access to additional knowledge through one of the authors who is familiar with practice in Irish hospitals and is active in reporting best practice in infant feeding through her work with the health services.
- **Step 2: Development of future vision**: To overcome impacts associated with waste breast-milk substitutes, both the *Waste Management Hierarchy* (Council Directive 2008/98/EC, 2008) and the *WHO Global Strategy on Infant and Young Child Feeding* (World Health Organization, 2003)

as enacted through the *Baby Friendly Hospital Initiative* were used to develop the future scenarios and choices. It is not uncommon to have normative assumptions and goals predefined in backcasting approaches, many have used pre-existing targets and goals e.g. "Factor 20" in their approaches (Quist and Vergragt, 2006). EU policies and directives such as the Water Framework, Nitrates Directives and Common Agricultural Policies, have been used successfully as the basis of scenario analyses (Kok et al., 2011; Therond et al., 2009).

- **Step 3: Backcasting: setting out the alternative solutions** and **Step 4: Explore solutions and identify bottlenecks:** Alternative solutions were developed by the research team consisting of persons with expertise in scenario assessments, environmental economics, environmental analysis, dietetics, human lactation and healthcare policy. The opportunities and barriers to the implementation of the scenarios and potential effects on environment and health systems are presented and discussed.

Backcasting method components such as the implementation of action plans, definition of stakeholder roles and establishment of co-operation agreements fall outside the scope of this paper, however the authors identify future research agendas and data gaps in this emergent multidisciplinary field.

3 Findings

3.1 Strategic Problem Orientation and Definition: Breast-Milk Substitute Food Waste Causation and Quantification

The quantification of breast-milk substitute food waste is problematic; the HSE do not appear to record the overall quantities of breast-milk substitutes purchased or related waste arising within the maternity services. Breast-milk substitutes are purchased:

- not only for maternity units but also for paediatric hospitals and neonatal and paediatric units in general hospitals,
- as required from intermediate suppliers as required by individual hospitals,
- from multiple sources as different brands, volumes and types e.g. RTU, powdered infant formula (PIF), hypoallergenic, soya based etc.,
- as a part of food and pharmaceutical budgets.

Therefore, similar to other backcasting applications (Doyle and Davies, 2013), problem orientation was conducted as a "back office exercise" in order to identify key sustainability challenges such as the quantification and causation of breast-milk substitute food waste within maternity units.

Where breast-milk substitute is required, it is provided free of cost to mothers and their babies; however hospitals pay for the purchase of breast-milk substitutes as per guidance established through Ireland's commitments as a signatory to *The International Code of Marketing of Breast Milk Substitutes* (World Health Organization, 1981). The cost to the HSE has been reported to be €1 per bottle and teat (Baby Friendly Health Initiative, 2013), the average cost to consumers through retailers has been calculated by the research team to be, on average, €1.78 for the same items (pricing compiled October 2015). In the main, pre-portioned bottles of RTU breast-milk substitute are used except where specialised formulas are required (Food Safety Authority of Ireland, 2012a). Eight bottles of RTU breast-milk substitute are allocated per day to infants that are exclusively artificially fed, based on advice that artificially fed babies feed every 3-4 hours (Health Service Executive and Safefood, 2012). The advice provided with RTU breast-milk substitutes vary between manufacturers and storage conditions; in a clinical setting, once a bottle is opened and a teat attached, best practice is to discard the bottle after 1 hour (Macqueen et al., 2012). A key determinant in the quantity of breast-milk substitute waste is demand within the maternity services.

Ireland's perinatal statistics from 2013 record artificial, breast and combined feeding rates as 44.3%, 46.3% and 9.4% of 68,830 live births respectively (HSE Healthcare Pricing Office, 2014); however the point at which an infant received breast-milk substitute, nor how much was provided, was not recorded. A typical newborn has a stomach capacity of just 20 ml (Bergman, 2013), babies gradually increase total daily milk intake from 30-60 ml/kg/day at day 1 to 60 ml/kg/day on day 2 and 90 ml/kg/day on day 4 of life over multiple feeding sessions (Sinha et al., 2012). In 2013 the average infant stay in hospital was 3.2 days (HSE Healthcare Pricing Office, 2014). As the bottles are pre-portioned with set volumes, the remaining breast-milk substitute post feeding becomes waste, as decanting of RTU breast-milk substitutes to share between infants does not routinely occur due to infection control, labelling and storage requirements as well as staff time. RTU breast-milk substitutes used in the Irish Maternity service are procured from three manufacturers. Brand A supplies in 100 ml bottles while Brands B and C both supply in 70 ml bottles – each of these are over triple and one is 5 times the typical newborn infant stomach capacity. The research team calculated the average requirements of artificially fed babies for days 1, 2 and 3 of life based on the average stay and average birth weight of 3.493 kg (HSE Healthcare Pricing Office, 2014). The factors leading to breast-milk substitute food waste are summarised in Figure 2.

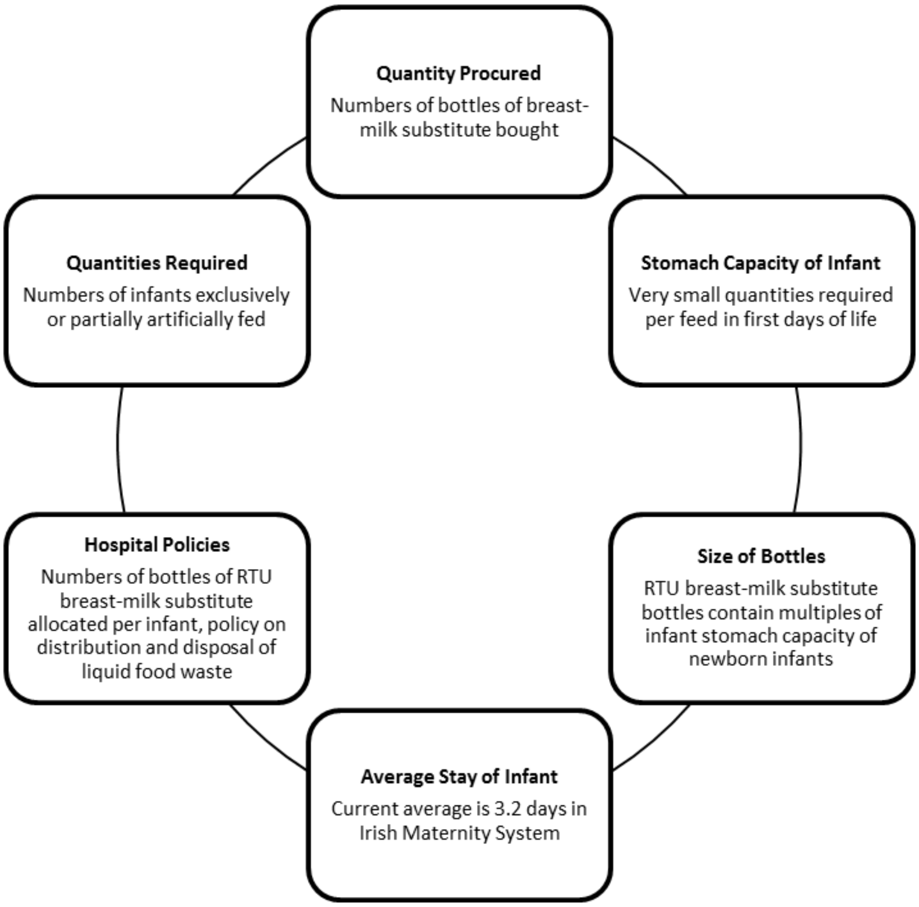

Figure 2: Factors contributing to liquid RTU breast-milk substitute food waste

To move from the causation of RTU breast-milk substitute food waste to an estimation of RTU breast-milk substitute procured and volumes of liquid waste arising the following assumptions were made in the quantification of breast-milk substitute food waste rates:

- Neonatal and perinatal deaths have not been subtracted from live births for 2013, the number of infants feeding is reported as 68,830.
- Infants that are artificially fed or partially breastfed receive one of the three main brands of breast-milk substitutes purchased by the maternity services. Brand use is assumed to be evenly split and so the average volume per bottle was taken to be 80 ml. Specialist or other milks and fortifiers are not included in these calculations.
- Only the 8 bottles allocated per infant are considered. Spilled, out of date and opened but unconsumed bottles (outside of the allocated 8) were not included as there was no available data on which to base a calculation.
- The low use scenario assumes that infants who received breast-milk but were not exclusively breastfed each received only 1 bottle on day 1 of life.
- The high use scenario assumes that infants who received breast-milk but were not exclusively breastfed received as many bottles as exclusively artificially fed infants during the average hospital stay and that the rate of waste remains similar for high and low use models.
- The density of RTU breast-milk substitutes is assumed to be the same as water 1 g/ml.

The estimated consumption levels summarised in Table 1.

Table 1: RTU breast-milk substitutes high and low use scenarios, quantities required and waste quantities

Measures	Low Use	High Use
Number of Bottles Required: Artificially Fed Infants	780,587	780,587
Number of Bottles Required: Partially Breastfed	6,470	165,633
Total Number of Bottles Required	787,057	946,220
Low Cost (Cost of Procurement to HSE) €	787,057	946,220
High Cost (If Retail Prices Paid) €	1,397,901	1,680,591
RTU Breast-Milk Substitute Volumes Required (Tonnes)	63	76
Average Unconsumed (% per volume purchased)	61%	61%
Tonnes Waste RTU Breast-Milk Substitutes Per Annum	38	46

3.2 Development of a Future Vision

In developing a future vision for the sustainable management of breast-milk substitutes food waste both the *Waste Management Hierarchy* (Council Directive 2008/98/EC, 2008) and the *WHO Global Strategy on Infant and Young Child Feeding* (World Health Organization, 2003) as applied through the BFHI and *HSE Infant Feeding Policy for Maternity and Neonatal Units* were used to inform best practice. The *EU Waste Framework Directive* requires that EU member states apply the waste management hierarchy in the following manner: prevention, preparing for reuse, recycling, recovery and disposal, with prevention of waste being the most favourable option and disposal the least.

3.3 Backcasting: Identification of Alternative Solutions and Bottlenecks

Taking the future vision, and pairing this with knowledge gained through the problem orientation (breast-milk substitutes food waste causation and quantification) the alternative solutions and bottlenecks were identified. The following sections group and outline the potential solutions. Table 2 summarises and contextualises these with respect to the *Waste Management Hierarchy* and compatibility with *WHO Global Strategy on Infant and Young Child Feeding*.

Table 2: Alternative solutions with respect to waste management hierarchy

Waste Management Hierarchy		Potential Solution	Rationale	Compatibility with WHO Infant Feeding and Baby Friendly Hospital Initiative Guidelines and Waste Management Hierarchy
	Prevention	Increase exclusive breastfeeding rates	Low rates of exclusive breastfeeding in Ireland. Potential to increase.	**Compatible:** In hospital initiation of BF rates of >80% have been achieved in other parts of the world. Irish hospital initiation range in 2013 was 44-70% (Baby Friendly Health Initiative in Ireland, 2014).
		Increase use of human donor milk and reduce supplementation with breast-milk substitutes	Increase eligibility criteria as only very premature and ill infants are eligible at present.	**Compatible:** Already systems in place for premature/ill infants. Milk sharing and donations for term and non-risk neonates in early stages of development in Ireland.
		Wider range of bottle sizes	New born infant stomach capacity is small, resulting in large percentage of waste unconsumed breast-milk substitutes per feed.	**Compatible:** Ireland is a small market, pressure from larger and international customers may be required.
		Hospital branded or generic branded breast-milk substitutes	All breast-milk substitutes made to standard as per Codex Alimentarius.	**Compatible**
		Decanting of bulk liquid breast-milk substitutes	More accurate amounts can be decanted into bottles on site as per need of infant.	**Compatible:** If number of exclusively artificially fed infants fell, space and resources would not be limiting factors. However infection control measures and bottle/teat requirements need to be established.
		Powdered breast-milk substitutes	Quantities can be prepared as demanded and stored for use as required.	**Compatible:** In hospital guidelines available. If number of exclusively artificially fed infants fell, space and resources would not be limiting factors.
		Mothers to bring own breast-milk substitutes	Hospital provides first bottle if mother not breastfeeding. Mother provides subsequent breast-milk substitute as RTU or as powder.	**Not Compatible:** May result in mothers bringing own breast-milk substitutes into hospital just in case it is needed and may encourage use because it is already purchased. Space, equipment, risk in mothers preparing bottles in hospital particularly when artificial feeding rates are high. Does not solve waste management issues.
		Guidelines regarding stand times in clinical settings	Manufacturers guidelines state 2 hours opened before disposal, yet clinical guidelines indicate one hour.	**Compatible:** Until further investigation is complete.
		Hospital practices regarding bottle distribution	Record and control number of bottles distributed per infant. No bottles on discharge.	**Compatible:** Ensure *HSE National Infant Feeding Policy* is fully implemented.
		Procurement policy and prices of RTU breast-milk substitutes	Pricing of supplies to healthcare may mask cost to families when products are bought for home use.	**Compatible:** However contrary to normal procurement in seeking lowest cost. Paying retail cost of breast-milk substitutes may highlight high use due to greater visibility in cost reporting. Adherence to *Green Procurement Guidelines.*

	Other recovery	Potential animal feed product	Segregated breast-milk substitutes could be used for feed of certain animals (e.g. pets and fur animals)	Increased focus on prevention make this option unlikely as quantities too low for collection
		Onsite composting or anaerobic digestion	All hospitals required to ensure separate food waste collection.	Not feasible when waste prevention practices implemented
		Off-site composting or anaerobic digestion	All hospitals required to ensure separate food waste collection.	Add waste breast-milk substitutes to existing food waste collection on site.
	Disposal	Disposal of waste breast-milk substitutes to drain or waste collection is not permitted	Must abide by waste management hierarchy Some evidence that not all hospitals believe waste breast-milk substitutes to be a food waste requiring treatment as such.	Breast-milk substitutes not to be disposed of in drainage system or general waste collection.

3.3.1 Breast-Milk Substitutes Food Waste Prevention Measures

Reducing waste at source and waste prevention are the highest priority according to the Waste Management Hierarchy. The backcasting model deployed herein resulted in 10 potential solutions to prevent or reduce breast-milk substitutes food waste, of these only one has been identified as not compatible with best practice in infant feeding policies. For ease of description potential solutions were further grouped around inter-related issues.

3.3.2 Breastfeeding and Breastmilk

Potential solutions pertaining to breastfeeding and breast-milk use in maternity hospitals:

- Increase exclusive breastfeeding rates
- Increase use of human donor milk and reduce supplementation with breast-milk substitutes

The World Health Organization (2003) recommends that infants should be exclusively breastfed for the first six months of life and thereafter receive nutritionally adequate and safe complimentary foods whilst breastfeeding continues for up to two years and beyond. Where infants cannot be breastfed, the WHO outlines alternatives in order of preference as: expressed breast-milk from infant's own mother, human milk from a healthy wet nurse or milk bank, and lastly breast-milk substitute fed by cup (World Health Organization, 2003). In principle breast-milk substitutes should only be used in hospital where medically indicated (World Health Organization, 2007). The prevalence of exclusive breastfeeding has increased in Ireland over the past number of years, 56% of mothers recorded any breastfeeding in 2013, compared to 53% and 46% in 2009 and 2004 respectively, yet only 47% of mothers exclusively breastfed during their stay in hospital (Economic and Social Research Institute, 2013). Ireland compares poorly internationally in terms of initiation of breastfeeding, with some countries achieving rates in excess of 80% (UNICEF, 2015), in the UK 90% of mothers initiate breastfeeding (Renfrew et al., 2012). Even within the Irish Maternity Service rates vary from 44-70% in 2013 across units (Baby Friendly Health Initiative in Ireland, 2014), therefore considerable scope exists to increase rates. Women birthing in BFHI hospitals are more likely to breastfeed (Becker, 2013; Declercq et al., 2009); in Irish BFHI accredited hospitals women were found to be 11% more likely to breastfeed (Economic and Social Research Institute, 2012). Not all maternity units in Ireland are BFHI accredited and therefore significant scope exists to increase breastfeeding rates and decrease demand for RTU breast-milk substitutes. A multiplicity of reasons for in hospital supplementation of breastfeeding with breast-milk substitutes have been suggested ranging from maternal anxiety, breastfeeding problems, infant behaviour, maternal fatigue, and maternal education with respect to infant feeding (Gagnon, 2005; Tender et al., 2008). Strategies to reduce "unnecessary in-hospital formula supplementation" include following WHO recommendations on infant feeding and ensuring all hospitals are BFHI compliant (Requejo and Black, 2014).

Increasing the use of human milk as opposed to RTU breast-milk substitutes would reduce demand for RTU breast-milk substitutes. The Food Safety Authority of Ireland guidance in relation to milk sharing, recommends that mothers with surplus milk donate to a registered milk bank (Food Safety Authority of Ireland, 2015), of which there is only one in Ireland (Western Care and Social Care Trust, N.D.). The World Health Organization recommends banked donor human milk as a suitable option where an infant cannot be breastfed or where own mother's breast-milk is unavailable. The use of banked donor human milk has been found to be cost effective in hospitals due to reductions in disease incidences and consequential resource use (Kim and Unger, 2010; Renfrew et al., 2012; UNICEF UK, 2012). However access to donor human milk is restricted to preterm infants and babies recovering from gut surgery (UK Association for Milk Banking, 2014) due to limited supply (Kim and Unger, 2010). It has been argued that access to breastfeeding and human milk are enshrined in United Nations conventions that do not distinguish between sick or well children (Arnold, 2006) since breastfeeding and human milk are the "normative standards for infant feeding and nutrition" (American Academy of Pediatrics, 2012).

Provision of further pathways by which infants can receive human milk may contribute to reduced breast-milk substitute milk waste. Expressed breast-milk may be stored at room temperature for up to 8 hours and refrigerated at ≤4°C for up to 8 days under very clean conditions (The Academy of Breastfeeding Medicine Protocol Committee, 2010). Compared to human milk, unopened RTU prepared PIF feeds can be stored in the refrigerator for up to 24 hours, however liquid breast-milk substitutes (from PIF or opened RTU) should not be left at room temperature for more than 2 hours and opened RTU should be stored in the fridge for no more than 48 hours (Food Safety Authority of Ireland, 2012b).

3.3.3 Changes to Procedures on Provision of Breast-Milk Substitutes

Potential solutions pertaining to changing procedures relating to breast-milk substitutes in maternity hospitals:

- Wider range of bottle sizes
- Decanting of bulk liquid breast-milk substitute
- Powdered infant formula
- Mothers to bring own breast-milk substitutes
- Guidelines regarding stand times in clinical settings
- Hospital practices regarding bottle distribution
- Procurement policies and pricing of RTU breast-milk substitutes

The next available options in terms of WHO infant feeding guidelines, failing breastfeeding or access to human breast-milk is the more appropriate management of breast-milk substitutes of which the research team have identified seven options, one of which, mothers to bring own breast-milk substitutes, was determined to be not feasible in the course of this assessment.

The inappropriate sizing of bottles of RTU breast-milk substitutes (between 70 and 100 ml) leads to waste, strategic problem orientation found that 61% of the volume of RTU breast-milk substitute purchased by the Maternity Service was unconsumed by infants and became waste. RTU bottle sizes have also been identified by healthcare professionals as causing mothers to assume that babies should finish the volume provided in the bottle at each feeding interval, leading to overfeeding (Sinha et al., 2012). In recent times some brands have reduced their bottle size from 100 ml to 70 ml however, as outlined in Section 3.1, these volumes are still too large for new-borns. Infant feeding recommendations suggest that babies should feed on demand and to a volume which satisfies them (Sinha et al., 2012). Ultimately feeding in response to infant's needs ("demand feeding") may require more frequent feeds of smaller volumes placing additional need for RTU bottles thereby resulting in further waste. Options to circumvent these issues are: requiring manufacturers to produce appropriatly sized RTU bottles, decanting of bulk RTU breast-milk substitute or the reconstitution of PIF onsite and provision of bottles based on individual requirements of infants. RTU is sterile and is recommended above PIF for infants with the highest risk of infection (World Health Organization, 2007), yet for healthy infants PIF is acceptable. The use of RTU means that hospital resources are not invested in provision of milk preparation areas, sterilising equipment, water heating, containers, labelling equipment, refrigerators, and staff time (Marino et al., 2013). Bulk preparation of PIF in healthcare settings requires cleaning and sterilisation of feeding and preparation equipment as well as heating of water to temperatures >70^{o}C (World Health Organization, 2007) and sterile bottles and teats and staff time. There may be infection control issues for high risk infants related to pouring of liquids from one container to another in a general ward environment. The safe use of PIFs for specialist formulations and breast-milk substitutes is normal practice in many maternity and paediatric units worldwide. Increased breastfeeding initiation rates, as prioritised by public health policy, would lead to reduced overall demand for artificial milks and therefore decanting of bulk RTU or reconstitution of PIF on site may become a more feasible option for hospitals.

A potential solution to reduce waste breast-milk substitute may be to require parents to provide their own during in hospital stays. This reduces cost of providing the breast-milk substitute but unless parents are bringing home unused amounts from each feed it doesn't reduce the waste to be disposed of within the hospital. The involvement of healthcare professionals in assisting new parents to identify infant feeding requirements and safe practices is crucial to the provision of safe infant care. Uncontrolled use of infant feeds brought into the hospital could pose a potential risk to infants.

As identified as part of the problem orientation, mixed guidelines regarding stand times of bottles may contribute to increased waste and, the variance between clinical guidelines as taught to healthcare workers and manufacturers' guidelines may cause confusion. The revision and possible extension of stand times for opened breast-milk substitute bottles needs further investigation and is therefore left as a potential solution pending further investigation.

The *Infant Feeding Policy for Maternity and Neonatal Services* recommends that breast-milk substitute stocks should only be accessible by staff, stocks should not be in display and RTU breast-milk substitute or related products should not be provided to mothers on discharge (Health Service Executive, 2015). In theory healthcare staff should be monitoring the baby's intake to assist new parents understand the infant's intake and feeding patterns. Many hospitals have in-house policies that require the healthcare staff to receive back a bottle from the mother before a new bottle is dispensed to ensure that excessive amounts are not provided and that the healthcare staff is monitoring the situation.

Free breast-milk substitute supplied by manufacturers has been linked to higher supplementation and lower breastfeeding rates in Hong Kong (Tarrant et al., 2015). Whilst breast-milk substitute is not provided free to hospitals in the Irish Healthcare System its relatively low cost may not flag its high use. Tarrant et al. (2015) report that implementation of hospital policies to pay market prices for breast-milk substitute increased rates of exclusive breastfeeding and breastfeeding duration and decreased in-hospital breast-milk substitute supplementation. The payment of retail prices would increase the cost of RTU breast-milk substitute from approximately €0.8 million to €1.4 million in the low use model alone almost twice the current cost. An Austrian study on pharmaceutical procurement noted discounts to hospitals particularly where medicines were of strategic importance to suppliers i.e. where the patient is prescribed the medication on discharge (Vogler et al., 2013).

Branding of breast-milk substitutes in hospitals is of strategic importance to manufacturers. Studies have found that advice from paediatricians, brand loyalty and recognition of brands used in hospitals influenced brand choice and sales (Tshikovhi et al., 2015) with extending consumption into toddlerhood of strategic importance (Berry et al., 2012) as manufacturers of infant milks strive to generate profitable growth (Mohajan, 2015). CODEX Alimentarius provides the minimum requirement for the constitution and packaging of breast-milk substitute and allows scope for the inclusion of other ingredients that are ordinarily present in human milk (Codex Stan 72, 1981). Hospitals may have scope to appoint a generic brand of breast-milk substitute, manufactured to standard and delivered in a format acceptable to the hospital similar to "National Dried Milk" used by the NHS until it's discontinuation in 1977 (Renfrew et al., 2003).

In terms of pricing and procurement policies, the cost of waste RTU breast-milk substitute does not appear to be calculated by health services and has not been considered in other breast-milk substitute cost comparison studies (Marino et al., 2013). The EPA Green Healthcare estimates that on average the costs of food purchase is €2 per kilogramme. To purchase approximately 1 kilogramme of RTU breast-milk substitute may cost the Irish Health Service between €5.40 and €7.70 per kg. This study estimates that 61% of this becomes waste and therefore additional associated costs in terms of disposal services and staff resources in managing waste exist.

3.3.4 Preparation for reuse, recycling and other recovery

Potential solutions pertaining to waste management of waste breast-milk substitutes:

- Potential recovery as animal feed
- Onsite composting or anaerobic digestion
- Off-site composting or anaerobic digestion

Reuse of waste breast-milk substitute is not possible due to basic health and hygiene best practice. Potential recovery as animal feed is practically impossible. EU and Irish regulations ban the feeding of catering or kitchen waste to animals, except in the cases of certain pet and fur animals, and make provision for those seeking to transfer waste foodstuffs to apply for permits and licences. The enforcement of restrictions and ensuring that all waste streams are segregated places additional administration burdens on healthcare facilities since the quantities involved at individual sites may be insignificant, especially if more desirable waste prevention measures are implemented which diminish available quantities even further. Recycling and recovery could potentially include on-site treatment however transfer to authorised regional facilities mainly composting or anaerobic digestion plants (Environmental Protection Agency, 2016) by the hospital through a waste management contractor is current practice for all wastes including food waste in the Irish Healthcare sector. Many hospitals are small, located on confined sites and have neither space nor staff available to invest in on-site treatment options.

3.3.5 Disposal

Disposal of breast-milk substitute waste is not permitted under Irish legislation. Where food waste producers have access to a separate food waste collection service they must not allow food waste to enter residual waste collection or use macerators to discharge food waste to a sewer (Irish Statute Book, 2009).

4 Discussion

It is clear that a diverse range of actors in society need to be engaged in food systems thinking (Halloran et al., 2014). As Bajzelj et al. (2014) succinctly concluded there are options on the demand side that are rarely considered i.e. improved diets and decreasing food waste. RTU breast-milk substitute, as a dairy derivative has a high embodied environmental impact and its use has impacts in terms of long term food security, health and environmental impact (Salmon, 2015). The most viable, and ultimately desirable, opportunities for the treatment of breast-milk substitute food waste are its prevention of use at source. Similar to Gharfalkar et al. (2015) this paper has highlighted that within the waste management hierarchy, there appears to be an overlap between prevention and reduction measures, however in terms of desirability, both from waste management and health perspective, prevention measures are most desirable and should therefore be prioritised where feasible. In terms of food system sustainability, research and methods that further goals of food demand reduction at source are required.

4.1 Implications of findings for healthcare managers

The problem-orientation aspect of the backcasting method revealed multiple causes of breast-milk substitute food waste and quantified the food waste rate as 61% of RTU purchased yet research conducted on hospitals suggest a median rate of 30% with between 6-65% by mass (Williams and Walton, 2011) this is probably due to approaches taken to quantify food waste in hospitals where specific food waste streams are not isolated for investigation as in this case.

Our findings are particularly relevant for healthcare systems where in-hospital artificial feeding and breast-milk substitute supplementation rates are high. Significant opportunity exists for both waste prevention and reduction which should be prioritised as health, economic and environmental priorities. For some measures a direct relationship can be drawn between public health policy and waste prevention i.e. if 90% of infants were breastfed during the hospital stay, between 700,000-850,000 bottles or 57-68 tonnes RTU breast-milk substitute would not be required. More appropriate bottle sizing by manufacturers or preparation of PIF on demand may play a role in preventing waste as our findings suggest that 61% of all RTU purchased ends up as waste. Our findings are therefore relevant in cases where hospitals are considering switching from PIF to RTU breast-milk substitutes Hospitals must consider broader cost implications, such as environmental costs, of such changes. The situation regarding RTU breast-milk substitute waste management in hospitals, to the author's knowledge, has not been reported in published literature.

Collaboration between environmental and health sciences researchers determined that some proposed solutions were unfeasible. It was decided to present both feasible and unfeasible solutions as part of the selection of solutions to facilitate cross disciplinary knowledge development and ensure that staff, policy makers and hospital management are aware that some alternative solutions, although appealing from cost resource management perspectives, may incur undesirable outcomes in terms of patient care and/or environmental impact. Although analysis of unfeasible solutions is a deviation from traditional backcasting methods, it demonstrates an important point for consideration in development of management strategies within the complex healthcare setting; issues regarding implementation of effective infant feeding and nutrition policies are complex; however, except for a small number of medical conditions, alignment of RTU breast-milk substitute waste prevention and reduction measures are compatible with health promotion and environmental sustainability objectives.

4.2 Implications of findings on healthcare sustainability research

The use of sustainability analysis tools to enhance the environmental performance of healthcare is growing with Substance/Material Flow Analyses, Life Cycle Analysis, audits and checklists featured in current literature. This paper reports on the use of a backcasting method, although some argue that in order to create future visions experts need to disengage from present day values, interests and societal constraints (Vergragt and Quist, 2011), we propose that for selected healthcare issues evidenced best practice exists, yet it is not fully implemented, and in this case backcasting has provided evidence of further benefit of implementation of international protocol and best practices and identified pathways by which these can be achieved. In this case an expert-led backcasting exercise was used, backcasting has been previously demonstrated to be of use for developing policy objectives (Vergragt and Quist, 2011). A limitation in conducting the problem orientation as a back of house exercise was that rates of breast-milk substitute waste due to obsolesce or other factors could not be considered. This led the research team to engage in problem solving more directly affect mothers and their babies and focused on demand reduction measures as opposed to management of current procurement practices. Alcamo and Henrichs (2008) stress the importance of developing legitimate scenarios that involve researchers and or data from relevant scientific disciplines. The use of recognised best practice and policy in both infant feeding and waste management analysed by researchers working in these fields adds legitimacy to the processes employed.

Further research is required based on the solutions presented herein. This study focussed a backcasting method solely on RTU breast-milk substitute waste. Backcasting may provide an insight into multiple research areas, for example concerns have been raised regarding the commodification and commercialisation of human milk and breastfeeding (Cassidy, 2012; Ryan et al., 2013; UNICEF UK, 2015) and the environmental importance of breastfeeding as a preventative measure in food demand and health protection is not fully quantified. Solutions pertaining to breast-milk substitute procurement and hospital policies also require further attention, for example improvements in bottle sizing may lead to increased production perpetuating a rebound effect, and therefore producer responsibility of manufacturers' warrants consideration.

5 Conclusions

This work operationalised successfully a novel method for organising waste management in a hospital campus, with agreed and mutually re-enforcing bottom up and top down actions, based in a systemic view of campus functioning. It represents a model which may be adapted for a great many large institutions, which may be expected to significantly increase the effectiveness of waste management in waste types currently not well managed. The use of backcasting to address specific environmental problems within a healthcare setting shows significant promise as a means of unifying diverse stakeholders. Such techniques are particularly useful where international and national policies exist for desirable health and environmental outcomes.

Many factors determine levels of waste breast-milk substitute generation including: numbers of infants receiving RTU breast-milk substitute, feeding after birth numbers, average infant weight, age of infant, hospital policies and RTU breast-milk substitute bottle size. A theoretical waste rate of 61% was calculated. This does not include obsolete, unopened or unconsumed bottles of breast-milk substitute outside of the designation per infant levels. Waste prevention scenarios include increasing exclusive breastfeeding rates, increasing use of human donor milk and reducing supplementation of breastfeeding infants with processed breast-milk substitute. Waste reduction measures include changes to hospital procurement procedures and RTU breast-milk substitute management policies. Although these solutions fall under the "prevention" category in terms of the waste management hierarchy they ultimately do not address reductions in overall food demand. In terms of recycling and reuse, food waste from clinical settings is not suitable for reuse as animal feed. Disposal to sewage systems is not permitted and therefore the feasible options for residual wastes are on or off-site composting or anaerobic digestion. Not all potential scenarios may be feasible due to waste management legislation and international policy on infant feeding, yet health services management require an awareness of the broad impact of these in order to avoid undesirable effects. Attaining sustainable healthcare and food systems requires increased collaboration between medical and environmental practitioners. Without this synergy, outcomes are liable to be compromised.

6 Acknowledgement

The authors acknowledge support from the Irish Environmental Protection Agency Research Programme 2014-2020.

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