Resources, Conservation & Recycling 144 (2019) 82–89

Contents lists available at ScienceDirect

Resources, Conservation & Recycling

journal homepage: www.elsevier.com/locate/resconrec

Full length article

Adopting the circular economy approach on food loss and waste: The case of Italian pasta production

Ludovica Principato[a,*], Luca Ruini[b], Matteo Guidi[c], Luca Secondi[d]

[a] Roma Tre University, Department of Business Studies, Via Silvio D'Amico, 77, 00145, Rome, Italy
[b] Barilla G. & R. Flli, Supply Chain Department, Via Mantova, 166, 43122, Parma, Italy
[c] Last Minute Market, Via Jacopo della Lana 3\A, 40137, Bologna, Italy
[d] University of Tuscia - Department for Innovation in Biological, Agro-food and Forest systems (DIBAF), Via S.C. De Lellis, snc, 01100, Viterbo, Italy

ARTICLE INFO

Keywords:
Food loss and waste
Circular economy
Food supply chain
Pasta production
FLW standard
Agri-food chain

ABSTRACT

Food loss and waste (FLW) is one of the most serious social, economic and environmental issues undermining our planet's sustainability, and by reducing it some UN Sustainable Development Goals may be achieved. The European Commission *Circular Economy (CE) Package* foresees FLW prevention, but to date few studies have adopted the CE perspective for analysing FLW. In 2017 only 20% of the world's 50 largest food companies have established FLW reduction programs.

However, reducing FLW is also beneficial for company economic sustainability since it was observed that for every dollar invested in reducing FLW there is a saving of 14 dollars in operating costs. Therefore, main aim of this research is to quantify the main FLW and their causes along the FSC of the pasta production and to understand if these FLW could be reused according to the CE approach.

Based on a single case study analysis, for the first time, this study quantifies FLW along the pasta supply chain, emphasizing FLW valorisation from a CE perspective using the global Food Loss and Waste Accounting and Reporting Standard.

Our results show that pasta supply chain is a good example of CE as little is lost. Food losses in the field are very limited (less than 2%), while the straw obtained during the harvest is normally used as animal feed and litter. The losses generated during the grinding of the wheat and pasta production amounted to approximately 2%. In line with previous literature, most FLW occurs during the cultivation and consumption, thus demonstrating that further research is required in order to reduce FLW in these two supply chain phases.

1. Introduction

Almost 30% of the food produced globally is lost or wasted at some point along the food supply chain (FSC) (Gustavsson et al., 2011) causing serious economic, environmental and social issues (FAO, 2013; Halloran et al., 2014; Grizzetti et al., 2013). According to some studies, food loss and waste (FLW) management is one of the world's major issues (EIU-BCFN, 2018; Garcia-Garcia et al., 2016; Winkler and Aschemann, 2017). In fact, according to a study carried out in the EU-28 countries, Food Waste (FW) is expected to rise to 126 million tons per year by 2020 if no additional prevention policies are implemented (Xu et al., 2018). This forecast is in contrast with the ambitious goal set by the UN and included within the Sustainable Development Goal (SDG) number 12.3 that states "*by 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses*" (United Nations General Assembly, 2015, p. 27).

According to FAO (Gustavsson et al., 2011) definition of food loss are losses that occur during the initial FSC stages, which covers the period from agriculture up to industrial transformation, while food waste is the food wasted during the final retail and consumption stages.

To date, FW is one of the most serious issues in developed countries, therefore most academic and practical interventions have been focused on consumer food waste (Principato et al., 2018; Van Geffen et al., 2016; Secondi et al., 2015; Principato et al., 2015) since it is mainly caused by the fact that individuals residing in these countries tend to waste much more food than individuals in developing countries. According to Gustavsson et al. (2011), the amount of food wasted per capita by consumers in Europe and North America amounts to 95–115 kg per year, while in Sub-Saharan Africa and South/South East

* Corresponding author.
E-mail addresses: ludovica.principato@uniroma3.it (L. Principato), luca.ruini@barilla.com (L. Ruini), matteo@lastminutemarket.com (M. Guidi), secondi@unitus.it (L. Secondi).

https://doi.org/10.1016/j.resconrec.2019.01.025
Received 23 August 2018; Received in revised form 21 December 2018; Accepted 15 January 2019
Available online 23 January 2019

Asia it is only 6–11 kg/year. However, surprisingly food losses (FL) in industrialized countries are as high as in developing countries and equally as serious (Gustavsson et al., 2011). Nevertheless, little research has been carried out in order to gain better understanding of this phenomenon in developed countries (Redlingshöfer et al., 2017; Stenmarck et al., 2016; Monier et al., 2010).

As previously mentioned, FL that occurs during the initial stages of the FSC are mainly managed by farmers and agro-food companies, which is why, their commitment in assessing and reducing FL is essential in order to reach the SDG n. 12.3. According to a study (Champions 12.3, 2018), in 2017 more than a quarter of the world's 50 largest food companies are measuring FLW within their operations, with the vast majority of these companies also publicly reporting, but only 20 percent of the world's 50 largest food companies have established FLW reduction programs.

As well as the commitment of food companies, it is important to be supported by policy makers (Principato, 2018). The European Commission acknowledged the importance of FLW prevention and included it as a part of Circular Economy Package (European Commission, 2015). FLW management within the Circular Economy (CE) framework represents a new stream of research oriented towards understanding FL in the initial FSC stages. To our best knowledge, to date, few studies focused on FLW according to the CE perspective. Ingrao et al. (2018) specifically focused on recovering FW and transforming it into energy, while other studies focused on implementing food sharing models in order to reduce FW without defining an explicit CE framework (Michelini et al., 2018; Sarti et al., 2017). Moreover, all of these studies only focused on consumer and retail FW and did not take FL into consideration.

With the aim of making an important contribution to literature, in this paper we will focus mainly on FL and also on FW from a circular economy perspective by analysing an Italian pasta supply chain. Thanks to the data provided by the Barilla Company - the global pasta market leader – and calculated by the Bologna University spin off Last Minute Market, we intend to analyse pasta losses, waste and its causes along the entire life cycle, from field to table, and illustrate that most of FLW that occur in this supply chain could be reused or recycled under the CE perspective.

The remainder of the paper is structured as follows. In Section 2 the FLW generated in the pasta supply chain are presented as well as the fundamental basis and principles of CE framework. Section 3 focuses on the method used - the Food Loss and Waste Accounting and Reporting standard developed by Hanson et al. (2016) – for analysing the Italian pasta supply chain and specifically the Barilla Blue Box. In the same section the definition of terms and application of the Barilla Blue Box inventory are illustrated. Section 4 describes the inventory results in terms of loss and waste generated in each stage of the pasta supply chain by focusing on the main underlying causes. In Section 5 we discuss the results obtained and some concluding remarks are drawn.

2. FLW pasta production management from a circular economy perspective

Concerning cereal waste, it is important to note that wheat, the raw material used for pasta production, is the leading crop in medium-and high income countries (Gustavsson et al., 2011). In Europe, North America and industrialized Asia, cereal FLW accounts for approximately 35% of the total production, and in the pre-consumption stages (from agriculture until distribution), about 10–12% of the total production is lost in Europe and North America, while it reaches up to 18% of the total FLW amount in the industrialized Asia (Gustavsson et al., 2011). The majority of these losses occur during the postharvest and processing stages (Gustavsson et al., 2011). Therefore, it is essential to understand why FLW occurs, how it is caused and if it is possible to minimize through reuse and/or recycling, which is in line with the CE perspective. The CE concept could be an accelerator of the 2030 Agenda (Ellen MacArthur Foundation (EMAF et al., 2015), it was also repetitively mentioned as a key solution during the 2018 High-Level Political Forum, especially for the achievement of SDG number 12 (Sustainable Consumption and Production) and in particular for the reduction and reuse of FLW (SDG 12.3). But for the moment, the importance of CE in meeting the SGDs has been disregarded by both scholars and practitioners (Kirchherr et al., 2018).

FLW could be integrated into a broader sustainable development perspective, and reducing and managing it according to CE perspective may enable us to achieve other SDGs and not only the 12.3, i.g. climate action or life on land (Principato, 2018). Sustainable FLW management may play an important role in the transition towards more sustainable societies (Kim et al., 2013; Ingrao et al., 2018), and communities (Chen et al., 2015). As well as the numerous economic opportunities provided by reuse and recycling, recently much attention has been paid to energy and nutrient recovery as opposed to landfill (Xu et al., 2018; Bernstad Saraiva Scott et al., 2015) which would not only lead to economic advantages for the companies involved in the supply chain, but would also bring environmental benefits. Indeed, by reducing the exploitation of natural resources, greenhouse gas emissions (GHGs) could be lowered as well as other pollutants (Takata et al., 2012; Kim et al., 2013).

In the past 150 years, economy has been based on the traditional linear extract-produce-use-dump material and energy flow which has now proved to be unsustainable from an economic, environmental and societal perspective (Korhonen et al., 2018). The CE concept, which has been recently promoted by the EU and several other Countries such China, Japan and Canada, basically promotes an economic growth with an alternative cyclical flow model which does not undermine the sustainable development of our planet (Ellen MacArthur Foundation (EMAF et al., 2015; CIRAIG, 2015; European Commission, 2015; Ruggieri et al., 2016). According to Korhonen et al. (2018) the CE approach "*emphasizes product, component and material reuse, remanufacturing, refurbishment, repair, cascading and upgrading as well as solar, wind, biomass and waste-derived energy utilization throughout the product value chain and cradle-to-cradle life cycle*" (p.37). In short, CE encompasses all the activities aimed at reducing, reusing and recycling materials along the FSC (Murray et al., 2015). As already mentioned, CE emphasizes the importance of minimizing waste (including FLW) by transforming it into a new resource that can be used as a new manufacturing input or as a raw material for other purposes, like animal feed (Topi and Bilinska, 2017; Ellen MacArthur Foundation (EMAF et al., 2015). Therefore, CE can offer multiple opportunities for recycling resources and waste in closed-loop systems (Venkata Mohan et al., 2016). Bearing in mind the CE framework, it is important to note that FLW management should follow a waste management hierarchy (Ingrao et al., 2018; Garcia-Garcia et al., 2016) which in order to minimize FLW we must prevent its generation, after which the second best option for inevitable FLW is to reuse it firstly for human consumption and secondly using for animal feed. The third option is to recycle it for (i) industrial use, (ii) anaerobic digestion, (iii) composting and (iv) combustion for energy recovery; lastly, landfilling represents the final option. Therefore, according the CE perspective, waste management should not only focused on waste prevention, but since some types of FLW are inevitable, FLW should be reused and/or recycled for renewable energy and other materials (Valenti et al., 2017a, 2017b). It is important to note that the EU is also committed to encouraging waste reduction and implementing recovery initiatives according to the waste hierarchy framework and CE concept (Mihai and Ingrao, 2018).

To sum up, the correct and sustainable implementation of waste management practices, established in line with waste hierarchy and CE approach, can help companies to give (food) losses a *second life* and to use them as secondary raw materials and energy (Jimenez-Rivero and García-Navarro, 2017). Therefore, the main research questions that this study seeks to answer are: (i) which are the main FLW and their causes

Table 1
Case study steps.

Case study Steps	Data Source
Selected Case: Barilla Company	
Crafting Instruments and Protocol	FLW Accounting and Reporting Standard
Data Collection	Multiple method approach according to the different FSC phases
Analysing data	Multiple method approach according to the different FSC phases
Enfolding Literature and Reaching Closure	It is possible to treat FLW along the FSC of the pasta production under a CE approach

along the FSC of the pasta production? (ii) could these FLW be reused according to the CE approach?

3. Materials and methods

3.1. The food loss and waste accounting and reporting standard

In order to answer to our study's questions, we elaborate a single case study within Barilla Company as a rich empirical example of FLW in the pasta production, using multiple data source (Yin, 1994, 2009). According to Gehman et al. (2017), within Barilla case study we are able to identify multiple processes with multiple temporal phases which ultimately will allow us to build evidence-based theory on this topic.

According to previous studies (Eisenhardt, 1989; Gehman et al., 2017), we structured our research process following these steps: (i) selecting cases; (ii) crafting instruments and protocol; (iii) data collection; (iv) analysing data; (v) enfolding literature and reaching closure (see the Table 1 for the methodology steps and sources).

With the aim of defining and quantifying Food Losses and Waste (FLW) along the entire pasta supply chain in Italy - and with specific reference to the Barilla Blue Box product - we referred to the global Food Loss and Waste Accounting and Reporting Standard (hereafter called the FLW Standard) developed by Hanson et al. (2016). Indeed, the FLW standard "*is a global standard that provides requirements and guidance for quantifying and reporting on the weight of food and/or associated inedible parts removed from the food supply chain*" (Hanson et al, 2016: page 11) which was introduced to help entities – which may include intergovernmental agencies, governments (e.g., of nations, states, cities), industrial associations, companies and farmers- to prepare inventories that represent a true view of their FLW.

When preparing an inventory, the FLW Standard firstly requires users to take two components into account: material types and destination.

Material type refers to the material that is removed from the food supply chain (i.e., food and/or associated inedible parts) and quantified in an FLW inventory. Depending on its goals, an entity may quantify: i) both food and associated inedible parts; ii) food only; or iii) associated inedible parts.

Destination refers to which of the 10 possible destinations the material removed from the food supply chain is directed (animal feed; bio-based materials/biochemical processing; codigestion/anaerobic digestion; composting/aerobic processes; controlled combustion; land application; landfill; not harvested/plowed-in; refuse/discards/litter; sewer/wastewater treatment).

Moreover, the preparation of the FLW inventory in compliance with the FLW Standard requires users to define and report on four components: (i) timeframe: the period of time for which the inventory results are reported; (ii) material type: the materials that are included in the inventory (food only, inedible parts only, or both); (iii) destination: where FLW goes when removed from the food supply chain; and (iv) boundaries: the food category, lifecycle stage, geography and organization.

The above-mentioned definitions and steps were used for analysing, describing and reporting FLW when producing the Barilla Blue box pasta which is the focus of our study (Table 2).

3.2. The Barilla Blue Box inventory

3.2.1. Product

The case study was carried out by analysing the life cycle of the Barilla Blue Box (which contain 1 kg pack of pasta of different shapes).

Since 1877 Barilla has been manufacturing semolina pasta with the utmost attention to quality. Barilla is the leading pasta producer in Italy and worldwide and it also produces different kinds of ready sauces. It also offers almost 180 bakery products, encompassing breakfast to between-meal snacks.

Barilla has 28 production plants (14 in Italy and 14 abroad) that export to more than 100 countries, with total revenues of 3.413 billion euros in 2016 and more than 8000 employees.

3.2.2. Timeframe and data collection

The study was initiated in March 2016 and ended in December 2016. The data concerning semolina and pasta production were collected in 2015.

Three different sources of data were used to (re-)construct the entire pasta life cycle (Table 3). Firstly, Barilla G.&R. Fratelli S.p.A. provided us with data and information concerning cultivation, milling, pasta production and consumption.

Secondly, Ergo Consulting S.r.l. - an accredited University of Bologna and Agricultural Sciences Department (Alma Mater Studiorum, University of Bologna) spin-off – completed data collection concerning the cultivation stage.

Thirdly, Last Minute Market Srl - an accredited University of Bologna spin-off - collected the data concerning the distribution and consumption stages.

By integrating the different sources of data we were able to reconstruct the contribution of each stage to the entire pasta FLW and to quantify the amount of losses and waste. As regards the presentation of data collection and the inventory results, we refer to the following lifecycle stages:

i) *durum wheat cultivation*: in order to obtain the percentage of durum field loss during the cultivation stage, we firstly analyzed the existing literature (Davoodi and Houshyar, 2010; Shamabadi, 2012; Muhammad et al., 2015) which provided us with an overview about food losses, particularly during the harvest stage. Moreover, specifically referring to the pasta production, the average percentage of durum wheat field loss during this stage was obtained by considering both the evidence reported in the report by FAO - "Global Food Losses and Food Waste" - (FAO, 2011) and the empirical results obtained during a Barilla study concerning loss in primary production.

ii) *milling* and iii) *pasta production*: primary data were collected from Barilla. Specifically, for the primary processing procedure data were gathered from three mills located in: Ferrara in the region of Emilia Romagna, Altamura in the region of Apulia e Castelplanio in the Marche region while for the secondary processing procedure data were collected in two production plants located in Foggia (Apulia region) and Pedrignano (Emilia-Romagna region).

iv) *retail and markets* (distribution): we referred to data collected by Last Minute Market through a survey conducted on 5 Italian large-scale distribution chains and involving 1.699 outlets representative of the distribution chains located across the Italian territory, from small

Table 2
Case Study inventory according to the FLW Standard.

Timeframe	Material Type	Boundaries	Destinations Included
March- December 2016 (7 months)	The total weight of the FLW has been quantified for 1 kg of pasta production	Food Category: Durum what products Lifecycle stage: entire FSC Geography: Italy Organization: Barilla Company	Human consumption Animal feed Composting/aerobic processes Not harvested/plowed–in Energy recovery Landfill

Table 3
Data sources per each FSC stage.

FSC Stage	Data Source and Analysis
Durum wheat cultivation	Average durum wheat field loss based on: (i) FAO's "Global Food Losses and Food Waste" report (FAO, 2011); (ii) empirical study by Barilla concerning loss in primary production
Milling	Primary data collected within Barilla mills located in Ferrara in the region of Emilia Romagna, Altamura in the region of Apulia e Castelplanio in the Marche region
Pasta Production	Primary data collected in two production plants located in Foggia (Apulia region) and Pedrignano (Emilia-Romagna region)
Retail and Distribution	Survey conducted on 5 Italian large-scale distribution chains with approximately 1.700 outlets representative of the Italian distribution chains.
Consumption (at home waste)	Sample survey implemented by Last Minute Market - carried out in May 2013 on 2000 individuals representative of Italian population – using SWG web panel of consumers (Waste Watcher, 2013).
Consumption (outside home waste)	Based on surveys carried out by Last Minute Market on food waste generated in Italian schools

supermarkets to larger hypermarkets. In these outlets, the observation monitored the percentage of both wasted pasta (which is the focus of our study), bread and sauces.

v) *consumption* – the collection of data was carried out for both at-home and outside home consumption.

Data regarding domestic waste (*at home waste*) were obtained from a survey implemented by Last Minute Market - Monitoring Centre for domestic waste in Italian families (Waste Watcher, 2013) and managed by SWG on a sample of 2000 individuals (web panel) representative of Italian citizens.

Data regarding public catering (*outside home waste*), especially school catering, were obtained from the survey carried out in various Italian towns by Last Minute Market.

3.2.3. Material type

We distinguished the type of material removed for the food supply chain in (i) "Food" which refers to any substance—whether processed, semi-processed or raw—that is intended for human consumption and (ii) "Inedible parts" which refers to components associated with food that are not intended to be consumed by humans.

As illustrated in detail in Section 4, the sum of the two components enabled us to state that the total amount of food losses and waste generated throughout the entire pasta supply chain is approximately 1.98 kg per 1 kg of produced pasta. It is important to note that this overall amount, is obtained – according to the FLW standard – by considering both the inedible parts (1.65 kg) and the food which was discarded (0.33 kg), this latter component amounting to 16.6% of the total FLW.

It is worth noting that packaging and any other non-FLW materials were excluded from this inventory results. Moreover, the inventory results reflect the condition in which the FLW was generated (i.e., before water was added or before intrinsic water weight of FLW was removed) as well as pre-harvest losses were excluded from the inventory results.

3.2.4. Destinations

When analysing the entire pasta lifecycle, the following *destinations* selected from the 10 categories foreseen by the FLW standard, were included and reported separately: (i) human consumption, (ii) animal feed, (iii) composting/aerobic processes; (iv) not harvested/plowed–in; (v) energy recovery; (vi) landfill.

3.2.5. Boundaries

As recommended by the FLW standard, we specified the boundary of the FLW inventory in terms of food category, lifecycle stage, geography and organizational unit. Table 4 summarises the boundary dimensions for the Barilla pasta lifecycle.

4. Results

4.1. Inventory results

Table 5 shows the inventory results by distinguishing FLW (in grams) according to the lifecycle stages and type of materials removed from the pasta supply chain.

The first general result obtained through the inventory is that each kg of pasta produces 1978.73 g of loss and waste throughout its entire lifecycle, mainly represented by inedible parts (1650.91 g out of 1978.73 therefore representing approximately 83.4% of the total FLW generated[1] while the remaining part is composed by edible FLW. The main reason of this composition of overall FLW is that in the pasta production process it is used the grain of wheat (durum wheat) only and not the whole wheat ear.[2] For this reason, it is essential to jointly analyse both the composition, distribution across stages and causes of FLW in order to determine inevitable losses and re-usable waste as well as identifying corrective actions whenever required.

From the lifecycle perspective, the analysis of FLW per stage (whose percentage distribution is reported in Fig. 1a) shows that approximately 69% of the total FLW – which include both edible and inedible parts - are generated during the cultivation stage. Furthermore, 17.22% of the total FLW is generated during milling stage, while 12.61% during

[1] Indeed, 83.4% of all the FLW generated along the entire pasta supply chain consists in inedible parts and are due to physiological reasons like straw concentrated in the cultivation stage and a small part of husks and bran during milling and pasta production stages.

[2] That is in the durum wheat cultivation phase we have 48% of the harvest represented by straw which is an inevitable FL as this part is not usable for the production of pasta.

Table 4
The Barilla Blue Box inventory dimensions.

Boundary dimension	
Food category	Cereal products – Not ready to eat (shelf stable) (GPC codes 10000285)
Lifecycle stages	Entire food supply chain. Manufacture of macaroni, noodles, couscous and similar farinaceous products (ISIC code: C1074)
Geography	Italy (UN code: 380)
Organisation	All sectors in the company

Table 5
Inventory results: food and inedible parts removed from the pasta food supply chain (in grams).

Lifecycle stage	TOTAL FLW (in grams)	*Total FLW distinguished in:*	
		Edible parts	Inedible parts
Durum wheat cultivation	1362.95	54.52	1308.43
Milling	340.74	0	340.74
Pasta product	23.54	21.81	1.74
Retail and markets	2	2	0
Consumption	249.5	249.5	0
Total (all lifecycle stages)	**1978.73**	**327.83**	**1650.91**

consumption. Pasta production, retail and markets represent stages with the lowest amount of overall FLW.

On the other hand, in Fig. 1b) we isolated the edible parts of FLW and we divided this total amount (327.83 g) across the studied lifecycle stages. In contrast with the results obtained in Fig. 1a, we found that most parts of the edible FLW are generated during the consumption stage (249.5 g of FLW were produced when “consuming” pasta) while 16.63% during durum wheat cultivation, 6.65% in the pasta production stage and lastly 0.61% within the retail stage.

According to the FLW protocol, Table 6 shows the destinations of the overall amount of FLW in terms of “where” (various types of re-use and landfill) the materials removed from the supply chain is directed.

Table 6
Destinations of food losses and waste.

Destination	Weight of FLW (in grams)	%
Human consumption	1.3	0.07
Animal feed	797.1	40.28
Composting/aerobic processes	126.7	6.40
Not harvested (left in field)/plowed-in	490.7	24.80
Energy recovery	436.3	22.05
Landfill	126.7	6.40
Total (overall amount of FLW)	**1978.8**	**100.00**

By considering the sum of edible and inedible parts (therefore the amount of approximately 1978 g of FLW), it can be observed that most part of them (93.6%) are used (valorized) for alternative productions (into alternative sectors), as also highlighted by Fig. 2 which distinguished destinations per stage.

4.2. Investigating the causes of food loss and waste

We also analysed total FLW according to the types of materials and stages in which it is generated. As shown in Table 7, two types of loss were generated in the cultivation stage: straw (amounting to 66.13% of the whole FLW) – which represents a physiological intermediate product since it is an inevitable part of the wheat cultivation process – and field losses (amounting to 2.76% of the whole FLW).

Moreover, approximately 17% of the total FLW was generated during the milling stage: wheat co-products (340.46 g) due to milling, since in order to produce a certain quantity of semolina, a certain amount of bran is produced and used in alternative productions. In the same stage, some waste was generated (milling waste, 0.27 g) due to wheat pre-cleaning. Indeed, the pre-cleaning plants remove impurities before the wheat is stored in silos. These losses are partially used for animal feed while the non-edible parts are thrown-away as waste.

In the production stage (pasta production) scraps and waste are generated due to equipment cleaning, transportation and packaging. On one hand, pasta production scraps are generated when the production lines are cleaned and the pasta shapes are changed. Most of these losses

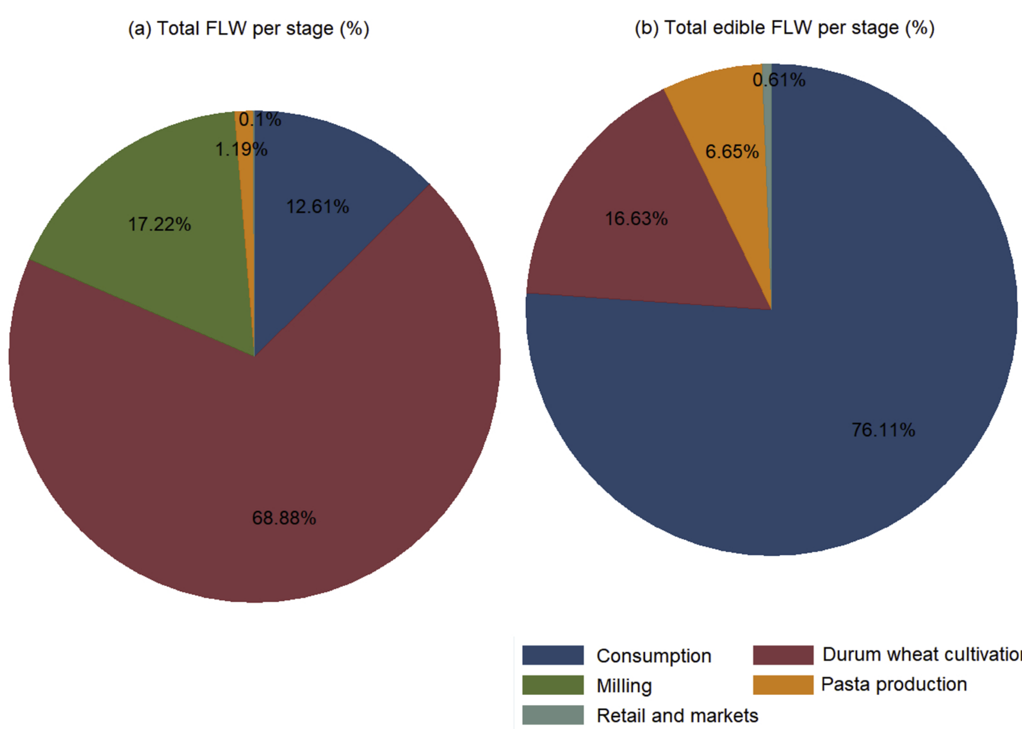

Fig. 1. (a) Total FLW per stage; (b) Total edible FLW per stage: percentage values.

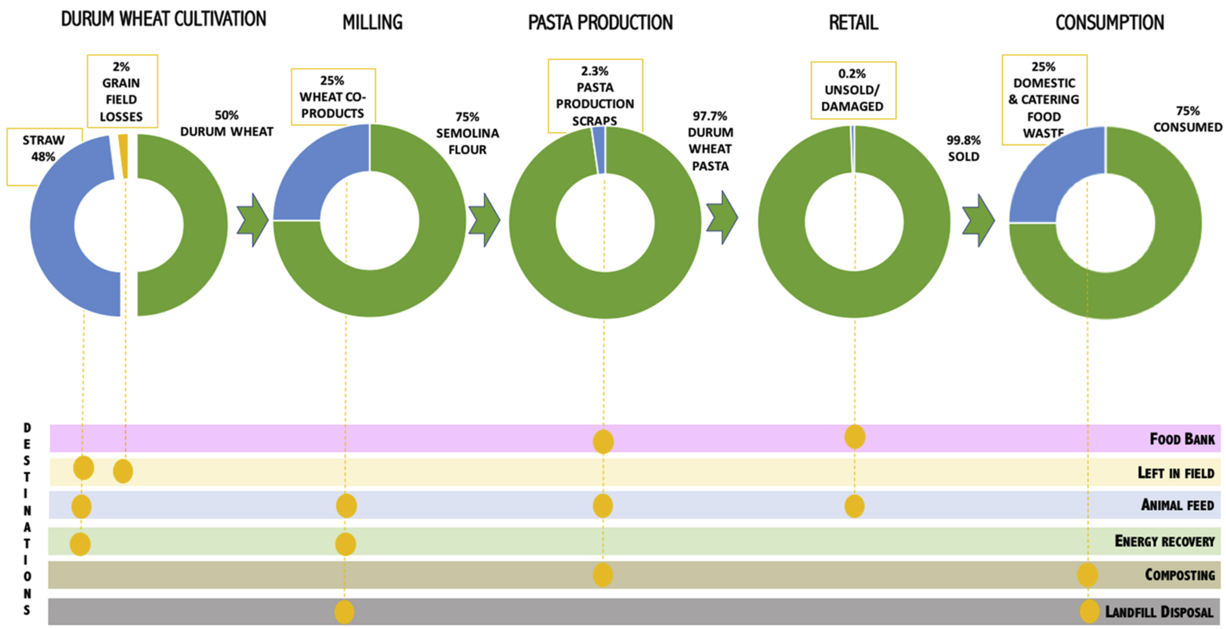

Fig. 2. The pasta production chain: product, co-product, inedible and edible loss and waste *per stage*.

Table 7
Description of FLW generated throughout the pasta supply chain: weight reported in grams.

Stage	FLW type	Weight (in grams)	% FLW	Cause
Cultivation	Straw	1308.43	66.13	Physiological
Cultivation	Field losses	54.52	2.76	Combine harvester failure
Milling	Wheat co-products	340.46	17.21	Milling
Milling	Waste	0.27	0.01	Wheat pre-cleaning
Pasta product.	Production scraps	20.47	1.03	Equipment cleaning
Pasta product.	Production scraps	1.33	0.07	Equipment cleaning
Pasta product.	Production waste	1.74	0.09	Transport, packaging
Retail	Unsold	2.00	0.10	Damage
Consumption	waste	249.50	12.61	Cooked, too large servings, disliked
TOTAL		**1978.73**	**100.00**	

are not for human consumption (20.47 g) while a small part is still edible (1.33 g). As regards the transportation and packaging sub-phases, pasta is wasted for various reasons such as during filling of mobile silos, emptying of mobile silos, packaging and transportation of unpackaged pasta.

The main cause of waste during the retail phase is damaged packaging which makes the pasta unsellable. Indeed, dry pasta is an easily preserved and long-lasting food product.

In the consumption phase, dry pasta (before cooking) is not generally wasted, due to the fact it is shelf-stable while cooked pasta, abundant servings and unappetizing pasta are more likely to be wasted. In most cases, the main cause is excessive food portions (Quested et al., 2013; Principato et al., 2015; Secondi et al., 2015; Mondéjar-Jiménez et al., 2016) while in school catering, 10%–40% of the pasta dishes proved to be discarded, probably due to the students' aversion to the sauce recipe. 50% of the food wasted during the consumption stage is destined to composting and 50% to landfill disposal.

5. Discussion and conclusion

Reporting good CE implementation practices may help academics and companies to gain knowledge on circular economic sustainable business models (Kirchherr et al., 2018) as well as on sustainable consumption and production patterns. Moreover, scholars should contribute by showing relevant results obtained by applying CE principles (Reike et al., 2018), thus helping companies to reduce their food losses and waste.

The results of our analysis focused on the description of lifecycle for pasta production, showed that the FLW occurring along this production chain can be effectively reused for other purposes thus provided us with valuable insights on the application of the CE perspective in order to reduce FLW. In particular, we found that the straw produced during the cultivation phase, that does not enter in the milling phase due to physiological reasons, could be reused with these destinations: left in the field as a natural fertilizer; animal feeding; energy recovery. In the milling phase wheat co-products can be reused for animal feeding; energy recovery, and landfill disposal. During the next phase, that is the pasta production, the 2.3% of what is wasted – as described in Fig. 2 – could be given to people in need (through food banks), to animals, or composted. At retail level the 0.2% of unsold product could be given to food banks and as animal feeding. According to the literature, the main issue remains at consumption level where basically the 25% of food wasted could be reused with difficulty and ends up in landfill or at best being composted.

By observing the results of empirical studies, policymakers and businesses should focus their efforts on realizing more desirable, shorter loop retention options, like remanufacturing, refurbishing and re-purposing taking into account feasibility and overall system effects (Reike et al., 2018).

As regards our specific case-study, FL in the field proved to be very limited (less than 2%) while the straw collected during the harvest is normally used as animal feed and litter. The losses generated during the grinding of the wheat and pasta production amounted approximately to 2% of the total FLW.

Although the loss of the edible parts (pasta, grain and flour) concern every stage of pasta supply chain, in line with previous literature (Gustavsson et al., 2011) our study confirm that the greatest amount of waste occurs during cultivation and consumption phase. A study carried out in 2013 by Last Minute Market on domestic waste in Italian households, in collaboration with the Waste Watcher monitoring centre (Waste Watcher, 2013), indicated that dry pasta is the least wasted product in domestic contexts, while cooked pasta is the most wasted product of all cooked food. Therefore dry pasta is easily preserved and manageable in domestic contexts yet when prepared and served in excessive portions it becomes one of the most important component of domestic waste. However, further research must be carried out in order to tackle the phenomenon at consumption level.

Furthermore, our findings confirm the suitability of applying the FLW standard to a specific supply chain and highlight the occurrence of food losses also in a developed country like Italy. Indeed, the need of optimizing re-use and minimizing FLW throughout the entire pasta supply chain is also motivated by considering the dimension of this phenomenon in Italy – according to the Italian National Institute of Statistics (ISTAT) data – since the amount of production (sold) of pasta (not cooked or stuffed) amounted to about 3.6 million tons in 2017. This issue can represent the topic of a further in-depth analysis in future development of this research line.

As a general overall result, quantifying agricultural and agro-industrial wastes as well as FW which represent biomass streams that can be used as renewable energy sources can contribute to reducing our current dependence on fossil fuels (Volpe et al., 2016).

Further research should be focused on other supply chains (such as bread or tomato sauce supply chains) in order to verify whether other products can be framed under a CE perspective, by realizing loops including animal feed or energy production, that are feasible and affordable for companies and have an overall positive effect on the system where they operate.

Acknowledgments

This work was partially funded by Barilla G. & R. F.lli (Supply Chain Group). The authors thank all those employed in the Supply Chain Group of Barilla G. & R. F.lli for their enthusiasm and collaboration in this study. In particular, they are grateful to Nicola Cornini for his constant effort and availability.

The authors also wish to thank the Cattolica University's Horta spin off, especially the President and Co-Founder Pierluigi Meriggi for helping to calculate food losses in the agricultural phase.

References

Bernstad Saraiva Scott, A., Canovas, A., 2015. Current practice, challenges and potential methodological improvements in environmental evaluations of food waste prevention - a discussion paper. Resour. Conserv. Recycl. 101, 132e142.
Champions 12.3, 2018. Road Map to Achieving SDG Target 12.3.
Chen, R., Rojas-Downing, M.M., Zhong, Y., Saffron, C.M., Liao, W., 2015. Life cycle and economic assessment of anaerobic Co-digestion of dairy manure and food waste. Ind. Biotechnol. 11 (2), 127e139.
CIRAIG (International Reference Centre for the Life Cycle of Products, Processes and Services), 2015. Circular Economy: A Critical Literature Review of Concepts. Polytechnique Montréal, Canada.
Davoodi, M.S., Houshyar, E., 2010. Evaluation of wheat losses using New Holland combine harvester in Iran. Am.-Eur. J. Agric. Environ. Sci. 8 (1), 104–108.
Eisenhardt, K.M., 1989. Building theories from case study research. Acad. Manag. Rev. 14, 532–550.
Fixing Food 2018. Barilla Center for Food and Nutrition, available at: http://foodsustainability.eiu.com/wp-content/uploads/sites/34/2016/09/FixingFood2018.pdf).
Ellen MacArthur Foundation (EMAF), SUN, McKinsey & Co, 2015. Growth Within: A Circular Economy Vision for a Competitive Europe.
European Commission, 2015. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions Closing the Loop - an EU Action Plan for the Circular Economy. Brussels, Belgium. .
FAO, 2013. Food Wastage Footprint: Impacts on Natural Resources. Retrieved from:. http://www.fao.org/docrep/018/i3347e/i3347e.pdf.
Garcia-Garcia, G., Woolley, E., Rahimifard, S., Colwill, J., White, R., Needham, L., 2016. A methodology for sustainable management of food waste, waste and biomass valorization. Waste Biomass Valorization 8 (6) 2209e2227.
Gehman, J., Glaser, V.R., Eisenhardt, K.M., Gioia, D., Langley, A., Corley, K., 2017. Finding theory-method fit: a comparison of three qualitative approaches to theory building. Synthesized Summary of a Showcase Symposium Held at the 2016 Academy of Management Annual Meeting. available at. https://ssrn.com/abstract=2937310.
Grizzetti, B., Pretato, U., Lassalletta, L., Billen, G., Garnier, J., 2013. The contribution of food waste to global and European nitrogen pollution. Environ. Sci. Policy 33, 186e195.
Gustavsson, J., Cederberg, C., Sonesson, U., 2011. Global Food Losses and Food Waste. Swedish Institute for Food and Biotechnology (SIK), Gothenburg.
Halloran, A., Clement, J., Kornum, N., Bucatariu, C., Magid, J., 2014. Addressing food waste reduction in Denmark. Food Policy 49, 294e301.
Hanson, C., Lipinski, B., et al., 2016. The Food Loss and Waste Accounting and Reporting Standard. . http://www.wri.org/sites/default/files/FLW_Standard_final_2016.pdf.
Ingrao, C., Faccilongo, N., Di Gioia, L., Messineo, A., 2018. Food waste recovery into energy in a circular economy perspective: a comprehensive review of aspects related to plant operation and environmental assessment. J. Clean. Prod. 184, 869e892.
Jimenez-Rivero, A., García-Navarro, J., 2017. Best practices for the management of end-of-life gypsum in a circular economy. J. Clean. Prod. 167 1335e1344.
Kim, M.H., Song, H.B., Song, Y., Jeong, I.T., Kim, J.W., 2013. Evaluation of food waste disposal options in terms of global warming and energy recovery: Korea. Int. J. Energy Environ. Eng. 4 1e12.
Kirchherr, J., Reike, D., Hekkert, M., 2018. Conceptualizing the circular economy: an analysis of 114 definitions. Resour., Conserv. Recycl. 127, 221–232.
Korhonen, J., Honkasalo, A., Seppälä, J., 2018. Circular economy: the concept and its limitations. Ecol. Econ. 143, 37–46.
Michelini, L., Principato, L., Iasevoli, G., 2018. Understanding food sharing models to tackle sustainability challenges. Ecol. Econ. 145, 205–217.
Mihai, F.-C., Ingrao, C., 2018. Assessment of biowaste losses through unsound waste management practices in rural areas and the role of home composting. J. Clean. Prod. 172, 1631e1638.
Mondéjar-Jiménez, J.A., Ferrari, G., Secondi, L., Principato, L., 2016. From the table to waste: an exploratory study on behaviour towards food waste of Spanish and Italian youths. J. Clean. Prod. 138, 8–18.
Monier, V., Mudgal, S., Escalon, V., Gibon, T., Anderson, G., Montoux, H., Reisinger, H., Dolley, P., Ogilvie, S., Morton, G., 2010. Preparatory Study on Food Waste Across EU.
Muhammad, S., Mueen, D., Mushtaq, A., Liaqat, A., Masood, Q., Muhammad, A., Laila, K., 2015. Grain losses of wheat as affected by different harvesting and threshing techniques. Int. J. Res. Agric. For. 2 (6), 20–26.
Murray, A., Skene, K., Haynes, K., 2015. The circular economy: an interdisciplinary exploration of the concept and application in a global context. J. Bus. Ethics.
Principato, L., 2018. Food Waste at the Consumer Level. A Comprehensive Literature Review. Springer International Publishing, Cham (ZG)Switzerland.
Principato, L., Secondi, L., Pratesi, C.A., 2015. Reducing food waste: an investigation on the behaviour of Italian Youths. Br. Food J. 117 (2), 731–748.
Principato, L., Pratesi, C.A., Secondi, L., 2018. Towards zero waste: an exploratory study on restaurant managers. Int. J. Hosp. Manag. 74, 130–137.
Quested, T.E., Marsh, E., Stunell, D., Parry, A.D., 2013. Spaghetti soup: the complex world of food waste behaviours. Resour. Conserv. Recycl. 79, 43–51.
Redlingshöfer, G., Coudurier, B., Georget, M., 2017. Quantifying food loss during primary production and processing in France. J. Clean. Prod. 164, 703–714.
Reike, D., Vermeulen, W.J.V., Witjes, S., 2018. The circular economy: new or refurbished as CE 3.0? — exploring controversies in the conceptualization of the circular economy through a focus on history and resource value retention. Resour. Conserv. Recycl. 135, 246–264.
Ruggieri, A., Braccini, A.M., Poponi, S., Mosconi, E.M., 2016. A meta-model of inter-organisational cooperation for the transition to a circular economy. Sustainability 8 (11), 1153.
Sarti, S., Corsini, F., Gusmerotti, N.M., Frey, M., 2017. Food sharing: making sense between new business models and responsible social initiatives for food waste prevention. Econ. Policy Energy Environ. 2017, 1–2 ISSN 2280-7659, ISSNe 2280-7667.
Secondi, L., Principato, L., Laureti, T., 2015. Household food waste behaviour in EU-27 countries: a multilevel analysis. Food Policy 56, 25–40.
Shamabadi, Z., 2012. Measurement the wheat losses in harvesting stage. Int. J. Agric. Crop Sci. 4 (23), 1797–1802.
Stenmarck, A., Jensen, C., Quested, T., Moates, G., 2016. Estimates of European Food Waste Levels. Stockholm, Sweden. .
Takata, M., Fukushima, K., Kino-Kimata, N., Nagao, N., Niwa, C., Toda, T., 2012. The effects of recycling loops in food waste management in Japan: based on the environmental and economic evaluation of food recycling. Sci. Total Environ. 432, 309e317.
Topi, C., Bilinska, M., 2017. The economic case for the circular economy: from food waste to resource. In: Morone, P., Papendiek, F., Tartiu, V. (Eds.), Food Waste Reduction and Valorisation- Sustainability Assessment and Policy Analysis, first ed. Cham: Springer International Publishing, pp. 25e41.
United Nations General Assembly, 2015. Transforming Our World: The 2030 Agenda for Sustainable Development. New York, United States. https://doi.org/10.1007/s13398-014-0173-7.2.
Valenti, F., Porto, S.M.C., Cascone, G., Arcidiacono, C., 2017a. Potential biogas production from agricultural by-products in sicily: a case study of citrus pulp and Olive pomace. J. Agric. Eng. 48 (4), 196e202.
Valenti, F., Porto, S.M., Chinnici, G., Cascone, G., Arcidiacono, C., 2017b. Assessment of citrus pulp availability for biogas production by using a GIS-based model the case

study of an area in southern Italy. Chem. Eng. Trans. 58, 529e534.
Van Geffen, L.E.J., van Herpen, E., van Trijp, J.C.M., 2016. ‘Causes & Determinants of Consumers Food Waste. Project Report’, EU Horizon 2020 REFRESH. Wageningen University and Research, Wageningen, The Netherlands 44 pp.
Venkata Mohan, S., Annie Modestra, J., Amulya, K., Butti, S.K., Velvizhi, G., 2016. A circular bioeconomy with biobased products from CO2 sequestration. Trends Biotechnol. 34 (6), 506e519.
Volpe, R., Messineo, A., Millan, M., 2016. Carbon reactivity in biomass thermal breakdown. Fuel 139e144.
Waste Watcher, 2013. Gli sprechi alimentari delle famiglie italiane. Rapporto 2013 Waste Watcher, November 2013. .
Winkler, T., Aschemann, R., 2017. “Decreasing greenhouse gas emissions of meat products through food waste reduction. A framework for a sustainability assessment approach”. In: Morone, P., Papendiek, F., Tartiu, V. (Eds.), Food Waste Reduction and Valorisation- Sustainability Assessment and Policy Analysis, first ed. Cham: Springer International Publishing pp. 43e67.
Xu, F., Li, Y., Ge, X., Yang, L., Li, Y., 2018. Anaerobic digestion of food waste e challenges and opportunities. Bioresour. Technol. 247, 1047e1058.
Yin, R.K., 1994. Case Study Research, vol. 2nd Sage, Thousand Oaks.
Yin, R.K., 2009. Case Study Research, vol. 4th Sage, Thousand Oaks.