Taking-home goods from supermarket: the role of biodegradable carrier bags

Francesco Razza[1], Sandra Zaccheo[1], Francesco Degli Innocenti[2]*

[1]Novamont S.p.A., P.le Donegani, 4 05100 Terni, Italy

[2]Novamont S.p.A., Via Fauser 8 28100 Novara, Italy

*fdi@novamont.com

Abstract Carrier bags are regarded with growing concern. More and more, biodegradable and compostable (B&C) bags are offered together with long life reusable bags. After primary use (take-home goods) B&C bags can be used as "multi-purpose" waste bags that can be used both for residual waste and bio-waste (e.g. kitchen waste). The use of B&C bags allows the creation of a homogeneous waste, where both the content (bio-waste) and the container (the B&C bag) share the same ‘degradability’ property. This, in turn, improves recyclability i.e. the quantity and quality of compost, whose marketability is improved by the absence of residual plastics and other contaminants. A Carbon Footprint (CF) analysis based on such scenarios suggests that GHG emissions caused by B&C carrier bags are insignificant. The “cradle to grave” CF ranges from 1.8 to 2.0 kg CO_2 eq. for every 100 B&C bags used.

1 Introduction

Carrier bags distributed by supermarkets are regarded with concern because, at a worldwide level, they are consumed in huge quantities and are often subjected to uncontrolled release (littering) [1-2]. In order to improve the environmental performance of their business mass retailers are seeking better solutions. Several LCAs have shown that the most preferable option is "waste prevention" i.e. the use of long life reusable bags, a kind of shopping basket to be used several times and not just once ("bag for life") [3]. The environmental cost of long life reusable bags is low because their production costs are mitigated by several ñsupermarket-homeò trips.

Nevertheless, disposable bags are still requested at the cash desk by consumers who have forgotten to bring their reusable bags. More and more, biodegradable and compostable (B&C) bags are offered for such occurrences. Several mass retailers supply B&C bags with the aim to offer both a service to customers who need to take home goods (primary use) and a "multi-purpose" waste bag, necessary for the proper management of household waste (secondary use). After use, the B&C bags can be reused as waste bags suitable both for residual waste (any waste that cannot be collected in a separate way) as well as for bio-waste (e.g. kitchen waste).

In the first case biodegradability and compostability is a óneutralô property, neither necessary nor deleterious. Residual wastes are recovered by incineration with energy recovery or disposed of in controlled landfills, being both systems unaffected by the presence of B&C bags.

In the second case the use of B&C bags is a very important factor because it allows the creation of a homogeneous waste, where both the content (bio-waste) and the container (B&C bag) share the same ódegradabilityô property. This, in turn, improves recyclability i.e. the quantity and quality of compost, whose marketability is improved by the absence of residual plastics and other contaminants.

In this study the carbon footprint of B&C carrier bags made with second generation Mater-Bi has been determined. The LCA results and environmental data for this material were published in 2010 [4].

2 Materials & Methods

2.1 Materials

The carrier bags are made with a second generation grade of Mater-Bi (CF05S) produced by Novamont which mainly consists of: starch from maize, biodegradable and partly renewable polyesters and natural additives. Main characteristics are shown in Table 1.

Tab.1: Characteristics of the carrier bag analysed in this study

Characteristics	Value
Material	Mater-Bi® CF05S
Volume	19.5 litres
Thickness	24 µm
Mass	15 g
Width	300 mm
Height	580 mm
Grammage	29 g/m2
Biogenic carbon content	50%
Biodegradability and compostability	In compliance with the EN 13432 [5]
Stress at break	25-30 MPa
Strain at Break	250-350%
Elastic Modulus	400-500 MPa

The total biogenic organic carbon content has been determined by Beta analytics (USA) in accordance with ASTM D6866-05 [6]. The material complies with the European Standard EN 13432 [5] .

2.2 Goal and scope of the study

This study had the goal of defining the carbon footprint of B&C carrier bags and providing indications to:

- Mass retailers, who are called to implement new scenarios and increase the environmental sustainability of their business;
- Political planners and public administrators who wish to improve the overall environmental impact of social systems; and
- Municipal waste management organizations, which are interested in increasing recoverability of waste (waste management planning).

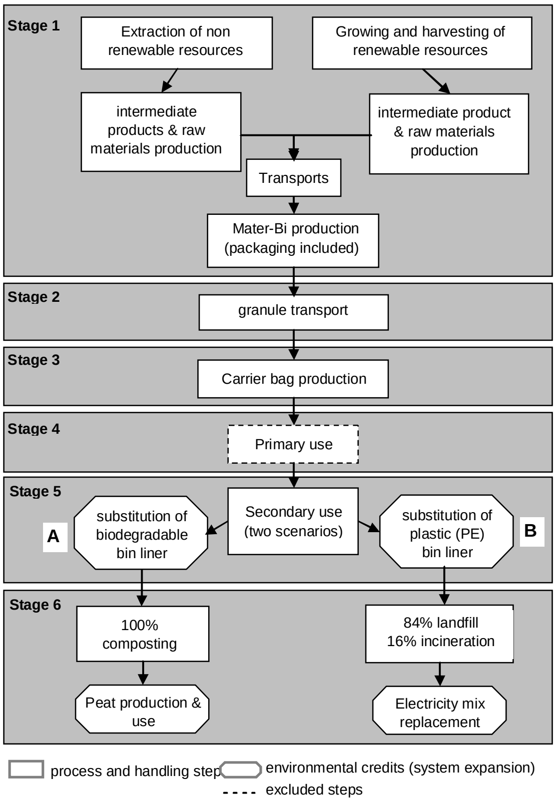
2.3 Methodology

The study is an analysis of the carbon footprint of using B&C bags made with Mater-Bi CF05S, taking into consideration different waste treatment patterns.
The study has been carried out following the Life Cycle methodology in agreement with the following standards: ISO 14040 [7], ISO 14044 [8], PCR 2010:16 [9], General Programme Instructions for Environmental Product Declaration [10] and supporting annexes [11].

2.4 Functional Unit and system boundaries

The functional unit of this study was defined as the: "Production and disposal of 100 carrier bags made with Mater-Bi CF05S". The life cycle stages considered in this study are reported in Figure 1.

Fig.1: The life cycle stages considered in this study



3 Inventory data and assumptions

3.1 Stage 1: Raw materials supply and Mater-Bi production

The production of Mater-Bi CF05S is described in an Environmental Product Declaration (EPD) [4].

3.2 Stage 2: Mater-Bi granule transportation

From production facility (Terni, Italy) to the conversion factory. An average (weighed) distance was considered [4].

3.3 Stage 3: Carrier bag production

Electricity and Mater-Bi CF05S granule required for producing 1.5 kg of biodegradable carrier bags (i.e. F.U.) are respectively 1.05 kWh and 1.53 kg.

3.4 Stage 4: Primary use

Primary use is carrying goods. For this stage no impacts were accounted for.

3.5 Stage 5: Secondary use

A B&C carrier bag can be reused as a "multi-purpose" waste bag, needed for the management of both residual waste and organic waste. Whenever a B&C carrier bag is reused as a bin liner, it avoids the production, use and disposal of a corresponding bin liner (i.e. avoided impacts due to system expansion). B&C carrier bags can substitute both B&C bin liners (for source-separated collection of bio-waste) and traditional plastic bin liners (for collection of residual waste).
Table 2 summarizes the sources and assumptions for bin liners. It was assumed that each carrier bag replaces one bin liner. The quantity and weight of bin liners substitution is shown in Table 3.

Tab.2: Hypothesis and ass umptions for bin liners

Bin liner Life cycle stages	B&C bin liner	Plastic (LDPE) bin liner
Granule production	EPD Mater-Bi CF05S [4]	Industrial average data [13]
Transport	500 km on the road (assumption)	500 km on the road (assumption)
Bin liner production	Electricity consumption: 0.5 kWh/kg bin liners (Italian mix)	Electricity consumption: 0.5 kWh/kg bin liners (Italian mix)
End of life	According to Table 4	According to Table 4
Environmental benefits	According to Table 4	According to Table 4

Tab. 3: Bin liners replaced during secondary use of 100 carrier bag (F.U.)

Parameter	B&C bin liner replaced Scenario A	Plastic (LDPE) bin liner replaced Scenario B
Number	100	100
Weight	9 g	8 g
Total weight	0.9 kg	0.8 kg

3.6 Stage 6: End of life of carrier bags

During composting 40-50% of the organic carbon contained in the bio-waste is mineralised into CO_2 [12] with the remained being converted into biomass i.e. compost, a substrate containing humic carbon. During compost utilisation, a further 45% mineralization of the original carbon is assumed (time frame: 100 years), whereas the residual 10% is assumed to be stable within 100 years generating a C-sink effect. The carbon of bioplastics is expected to behave like the other bio-waste. Mineralization of Mater-Bi in landfill is assumed to be absent in agreement with laboratory tests performed at Organic Waste Systems OWS ï Belgium [14].

Inventory data for End of Life (EoL) treatments have been worked out according to EoL handbook supporting the I-LCA database [15]. Material specific air emissions and the consumption of auxiliary materials for flue gas cleaning (i.e. incineration) were considered for the EoL treatment. The technology considered in this study has been described elsewhere [16]. The environmental credits of the EoL treatments are the following. The electric power produced by the incinerator is assumed to substitute the electricity produced in Italy and consumed at grid at medium-voltage. Compost obtained from composting process is assumed to replace peat considering an average substitution factor of 0.6 kg peat for each kg of compost using the Volume/Volume method [17]. The inventory data related to the replacement of peat with 1 kg of wet compost (H_2O=40%) are shown in another paper, in this volume [18].

In Table 4 the overall inventory data regarding the EoL treatments of 1 kg of analysed materials are shown.

Tab. 4: Inventory data related to the end of life treatments of 1 kg Mater-Bi CF05S and polyethylene (i.e. PE)

	Unit	Composting		Incineration		Landfill	
Environmental loads							
Energy/materials from technosphere		Mater-Bi® CF05S	PE	Mater-Bi® CF05S	PE	Mater-Bi® CF05S	PE
Diesel	MJ	0.072	-	-	-	0.072	0.072
Electricity	MJ	0.126	-	-	-	0.004	-
Heat (for the NOx reduction system)	MJ	-	-	0.94	Not specified	-	-
Infrastructure	P[1]	$4*10^{-9}$	-	$2.5*10^{-10}$	$2.5*10^{-10}$	$5.56*10^{-10}$	$5.56*10^{-10}$
Transport	tkm	0.017[2]	-	-	-	-	-
Activated carbon	g	-	-	9.4	15.3	-	-
CaO	g	-	-	0.86	2.21	-	-
Ammonia	g	-	-	9.4	23	-	-
Emission to air							
Biogenic CO_2	g	474 + 480[3]	-	1048	-	-	-
Fossil CO_2	g	484 + 490[3]	-	1071	3060	-	-
Methane	g	-	-	0.0007	0.0023	-	-
Waste							
Solid waste to landfill	kg	-	-	0.014[4]	0.0224[4]	-	-
Environmental credits							
CO_2 atm[5] (i.e. C-sink)	g	-110	-	-	-	-	-
Peat	g	330	-	-	-	-	-
Net electricity	MJ	-	-	3.35	6.71	-	-

[1] p= "parts" of the infrastructure needed for the tretament of 1kg of material ; [2] Related to the compost transport (30 km); [3] Emissions coming from compost use phase; [4] Ash and dust in landfill. Ecoinvent 2.2 dataset ñDisposal, average incineration residue, 0% water, to residual material landfill; [5] atm= atmospheric.

4 Results and discussion

In Table 5 the ñCradle to graveò carbon footprint results related to the production, use and disposal of 100 B&C carrier bags are shown.

Tab.5: "Cradle to grave" carbon footprint results for F.U. (100 B&C carrier bags)

	Unit	Stage 1	Stage 2	Stage 3	Stage 5	Stage 6	Total
GWP	Kg CO2eq	3.12	0.03	0.59	-2.56 (A) -1.93 (B)	0.6 (A) 0.17 (B)	1.78 (A) 1.98 (B)

Stage 1: production of Mater-Bi pellets; Stage 2: pellets transportation; Stage 3: conversion into bags; Stage 5: reuse as (A) bin liner for bio-waste (B) bin liner for residual waste; Stage 6: composting (A) or (B) incineration & landfilling.

Production of Mater-Bi pellets (Stage 1) and Reuse (stage 5) are the most relevant stages (Table 5) in the carbon footprint. The main greenhouse gas emissions for Stage 1 (Mater-Bi granule production) come from raw material production whose contribution accounts for about 95%. Impacts of Stage 3 are due to electricity consumption for producing carrier bags. Such impacts depend, therefore, on the electricity mix and consumption (in this study the Italian electricity mix was considered). Both Scenario A and Scenario B of Stage 5 show negative impacts thanks to the avoided impacts generated by the replacement of bin liners. The avoided impacts depend on the material used for bin liners production. Carbon footprint of Stage 6 is affected by biological mineralization (Scenario A) or incineration (16% incineration in Scenario B) of fossil feedstock carbon.
In order to better understand the relevance of LCA results, they must be put into context. Total yearly emissions for a reference year in a reference region are generally used to calculate normalisation factors [19]. To this end, the absolute values shown in Table 5 were normalised to the total consumer carbon footprint for the EU 27+2. According to the Denkstattös study [20] the GHG emissions for 2007 were estimated to be 13.7 tonnes CO_2 eq. per capita. Therefore the impact (in percent) caused by the use of 100 B&C carrier bags in a year represents about 0.013% of the overall impact of the "2007 average EU 27+2 citizen". This is a very low carbon footprint.

5 Conclusions

The B&C carrier bags do not generate significant greenhouse gas emissions in relative terms. Carbon footprint of 100 B&C carrier bags (which can be approximately considered the number of bags consumed by a citizen in a year) is less than 0.02% of the overall carbon footprint of an equivalent person.

By supplying B&C carrier bags, retailers not only offer a service to customers but also a product that can improve overall waste management systems and processes.
Carrier bags are frequently used as waste bags by householders who exploit this "second use" option. Traditional carrier bags are made with non-biodegradable polymers and are therefore unsuitable for the collection of bio-waste. Bags for bio-waste must be B&C in order not to contaminate the organic waste stream and subsequent organic recycling. In another paper in this book, we showed how plastic contamination of organic waste can affect organic recycling and increase the overall environmental impact [18].

Unfortunately, some householders are prone to use non-biodegradable bags for bio-waste. No official data are available to us, but this has been confirmed by several conversations with composting managers operating in Italy [21].
This risk of improper use of non B&C bags for bio-waste collection is overturned if householders are only provided with B&C carrier bags. B&C carrier bags are multi-purpose waste bags, fit for both the collection of residual and bio-waste. For bio-waste the use of B&C bags is a very important factor because it creates a homogeneous waste, where both the content (kitchen waste) and the container (B&C bag) share the same ódegradabilityô and the quantity and quality[1] of marketable compost may significantly increase as a result. If used in this way the B&C and compostable bags can definitely be considered as ñsustainableò because they play an essential role in a farseeing waste management project which goes well beyond the ówaste issueô, and gives a real contribution to solve some problems of present time, that is the progressive removal of organic matter from land, the decrease of soil fertility and increasing desertification.
It is also important to mention that the biodegradability of a carrier bag should not become an excuse or a justification for littering. Notwithstanding the above, biodegradability can reduce the environmental impact in case of uncontrolled release and, therefore, represents an important feature of carrier bags which should be evaluated from an environmental point of view, since a certain degree of littering seems unavoidable. B&C plastics, thanks to their intrinsic biodegradability, present a lower environmental risk.

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1 Industrial composting plants producing high quality compost are continuously supplied with loads of bio-waste. In such plants the quality of the input waste is measured in terms of ópurityô, that is to say by the lack of contaminants such as plastic and glass. A contaminated bio-waste will produce contaminated compost whose economic value and utilization are compromised with consequent interruption of the positive recycling loop of organic matter.

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