

Life Cycle Management in bioplastics production

Francesco Degli Innocenti^{a*}, Francesco Razza^b, Maurizio Fieschi^c, Catia Bastioli^a
^aNovamont, via Fauser 8, 28100 Novara; ^bNovamont, piazzale Donegani 4, 05100 Terni;
^c Studio Fieschi, Via G. Donizetti, 2, 10126 Torino
* Email: fdi@materbi.com

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ABSTRACT

The benefits of biodegradable and compostable (B&C) products are attained when the organic waste (OW) is composted. B&C products may improve the management of OW, so that greater and cleaner OW flows can be collected and composted. In this paper we show the case of the catering sector as an example of this. Disposable tableware is usually distributed at fast food restaurants and town festivals. The high rate of meal serving makes separate collection a very difficult task. The resulting mixed heterogeneous waste (food residues and plastic cutlery) cannot be easily recycled and is therefore landfilled or incinerated. Alternatively, with B&C cutlery the resulting waste is homogeneous (food and B&C plastic waste) and thus can be recovered by bio-recycling. This study shows that: (i) composting of OW is preferable (ii) the impact is substantially decreased when catering is carried out with B&C cutlery and total waste composted; (iii) the environmental advantage of B&C products is partly due to their nature; (iv) the main advantage is due to the creation of a homogeneous, biodegradable and recyclable OW. The use of B&C products turns a non-recyclable waste into a recyclable one. This study also indicates that comparative LCA studies should first identify the real environmental problem (in this case, the waste production) and then verify how different products and processes affect the problem.

Introduction

As a consequence of the development of new markets energy consumption and waste production are increasing at a fast rate. Emerging countries are needing more and more fossil resources whilst the developed countries are late and hesitant in introducing energy saving programmes and controlling the release of greenhouse gases. The amount of goods produced and packed is also growing, making waste disposal an emergency for several nations. These problems represent a powerful driving force which has stimulated much interest in a potential solution, bio-based and biodegradable polymers. At an industrial level, several biopolymers have been developed and biodegradable products are already present in the market (e.g. compostable bags for the at source collection of organic waste, packaging, mulch films for agriculture, compostable cutlery and tableware etc.) [1].

Since the biodegradable “green” products displace consumer products made with traditional polymers, the question soon arises whether the claimed environmental superiority of the biopolymer and bio-products is actually founded on fact.

Biodegradability and compostability can be verified thanks to a testing strategy which is well defined by the harmonised European standard EN 13432 [2]. The content of renewable carbon can be quantified by using the radiometric test described in the ASTM D6866-05 standard. The overall environmental impact of products and services can be determined by applying Life Cycle Assessment (LCA). LCA which is based on the ISO 14040 and ISO 14044 series of standards is currently advocated as an important means for performing comparison between products and services.

Since 1989, Novamont has been active in the bioplastics sector and is known for the production of Mater-Bi®, a family of materials containing renewable constituents [3]. The materials are available in granular form, in different grades and for a variety of manufacturing processes and products, such as films, injection moulded articles, foams. Mater-Bi is applied in different economy sectors: industry, agriculture, service and waste management. Since its establishment, Novamont has adopted precise strategies to identify products and instruments that guarantee concrete solutions aimed at linking the environment, agriculture and industry. In particular, LCA has been considered as an important tool to verify the real sustainability of bio-products [4]. It was also soon realised that the application of this methodology can be misleading if applied to merely compare the environmental impact of alternative products. A LCA approach focused on an “isolated” product does not take into account two things: (1) the framework: the possible role the products can play in a complex system and the overall impact of different systems - biodegradable product can be just “eco-advertising” or part of a chain whose benefit and consequences are much larger than the single product. (2) Evolution: the today scenario is not

necessarily (and hopefully) the tomorrow scenario. A product which is landfilled today (for lack of suitable infrastructures) could, due to forward looking decision makers, face a completely different waste management scenario. Therefore, the risk is to put under the microscope the single product, forgetting the interactions with the system and how the product would fit in an improved future scenario. As a consequence LCA studies, if merely applied to the products, can provide public opinion and the institutions with information which is scientifically correct but, nevertheless, potentially misleading.

LCA of serving meals with disposable cutlery: is biodegradability and compostability an advantage?

We have carried out a preliminary study on disposable cutlery as used in fast food restaurants, canteens and town festivals. We present this study as an example to clarify how, in our opinion, the LCA tool should be used when applied to biodegradable products. Details of this study will be published elsewhere.

We were interested in verifying whether it is preferable to use B&C cutlery in place of traditional plastic cutlery. The LCA study was not just a comparison of different products. The environmental problem of today's fast food restaurants is basically one of waste management. The choice towards one option or another should be dictated by the real overall advantages which are generated in global terms. The best solution is the one which engenders fewer problems to the environment. The search for the "ecological fork" or the "ecological knife" is a senseless challenge because such products do not exist. On the other hand, efforts must be made in order to identify the best waste management system, which will differ according to the type of waste, the way it is generated and the general conditions.

Waste management of fast food restaurants, town festivals etc. is today based on the collection of the mixed waste which is then disposed of according to the regional facilities. Since disposable tableware is distributed to the restaurant guests, a *heterogeneous* waste is generated. Together with food biodegradable waste (kitchen and guests leftovers, expired food, etc.) non biodegradable waste is produced: plastic cutlery, dishes, plastic or laminated paper cups, foam polystyrene containers, plastic bottles. In most case, the *heterogeneous* mixed waste is dumped in sanitary landfills. A very interesting alternative is to only use tableware that is compostable, similar to the food scraps. The mixed waste (food waste and cutlery waste) can then be collected as a whole *homogeneous* fraction and recycled by means of organic recovery, i.e. composting or anaerobic digestion followed by composting. Compost is a valuable soil improver.

Scope of the study

The main scope was to evaluate the consequences of two different systems of catering in fast food restaurants, town festivals etc. followed by two different waste treatment systems:

- serving 1000 meals using compostable disposable cutlery (Mater-Bi Y, a material containing a cellulose-based constituents and starch), collecting the total waste in a single homogeneous stream (compostable plastic cutlery and food waste) and compost it (see FIGURE 1)
- serving 1000 meals using traditional plastic cutlery, collecting the total waste in a single heterogeneous stream (not compostable plastic cutlery and food waste) and disposing it of by means of incineration with energy recovery and landfilling (see FIGURE 2).

The functional unit of this study is represented by the serving of 1000 meals, which generate an organic waste of 150 kg (on average 0,150 kg/meal) with the use of 1000 sets of disposable cutlery (TABLE 1). The study has been carried out following the Life Cycle methodology in accordance with the ISO 14040 and ISO 14044 series of standards. A critical review by an external expert (LCEngineering, Torino, Italy) has been performed according to the ISO 14044 requirements.

Results

TABLE 2 shows the Life Cycle Impact Assessment (LCIA) data referring to the treatment of 150 kg organic waste. This is the amount of waste which is generated by catering 1000 meals. Composting is compared with two different waste management scenarios: landfill after stabilisation and incineration in an 84:16 ratio (corresponding to the current situation in Italy). The LCIA results of serving 1000 meals using disposable cutlery made with different materials and coupled with different systems of waste treatment are compared in TABLE 3. In FIGURES 3A and 3B, the values of non renewable energy and greenhouse gases are shown respectively. The impact of cutlery, the impact of food waste and the total impact are shown. In this case, the end of life fate for the B&C cutlery is composting, while the traditional plastics are disposed of following the typical Italian scenario. It has been also carried out a sensitivity analysis regarding a hypothetical waste management scenario:

landfill after stabilisation and incineration in a 50:50 ratio (similar to Northern European countries; FIGURE 4).

Conclusions

The study shows that from an environmental viewpoint the preferred way of treatment of organic waste is composting. This is not surprising considering that organic waste is rather wet (it is also known as the “humid fraction” of the municipal solid waste). In the case of incineration with energy recovery, the high water content reduces the net calorific value and makes incineration of this fraction energetically unfavourable. The landfilling of organic waste is conducive of biogas formation, i.e. methane - a powerful greenhouse gas. On the other hand, composting is a real form of recycling of the humid fraction with the creation of a product whose use is particularly beneficial for the environment [5]. The possibility of composting the organic waste, obtaining high quality compost suitable for application in agriculture, depends on the quality of the feedstock. An organic waste which is contaminated with glass, plastics etc. i.e. with non biodegradable constituents, is not suitable for composting. A “clean” homogeneous feedstock can only be obtained if the “at source separation” of the different fractions is applied. Under this collection scheme, different bins are available at the fast food restaurant to collect the different waste streams in a separate way: plastics, glass, organics, etc. However, due to the large number of guests and the high rate of meals delivered, it is clear that the source separate collection of waste in fast food restaurants and town festivals is not a simple task. The other possibility is to distribute to the customers tableware which, like the food scraps, is compostable. The mixed waste (food waste and cutlery waste) can be collected as a whole homogeneous fraction and recovered by means of organic recovery, i.e. composting or anaerobic digestion followed by composting. The study presented shows that this option does improve the environmental impact of catering. The B&C cutlery shows good environmental profile in comparison with its non biodegradable counterparts, in spite of the higher mass (TABLE 1). The environmental performance of the B&C cutlery can be further on improved on condition that: (i) the mass per item (fork, knife, and spoon) is decreased, thanks to an improved design; (ii) the renewable fraction is increased and (iii) the environmental impact of the cellulose processing is decreased thanks to improved green chemistry technologies. However, the substantial environmental effect is that the use of compostable cutlery makes it possible to collect the mixed waste as a whole, homogeneous fraction, which can be recycled through composting or anaerobic digestion followed by aerobic stabilisation. Two fractions which otherwise cannot be recycled because they are in a heterogeneous mixture can be effectively recycled and this is the real environmental advantage which the present study has quantified.

This is a very good example of how LCA needs a wide approach and has to be performed including and studying not only the whole production chain, but also the products and processes correlated in the use and end of life phases.

References

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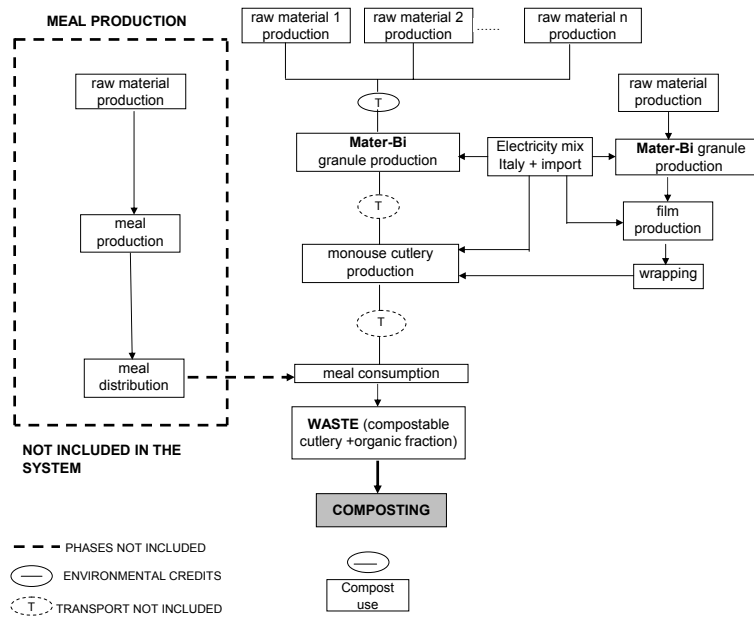


Figure 1: 100% composting of the homogeneous biodegradable waste (compostable plastic cutlery + food waste)

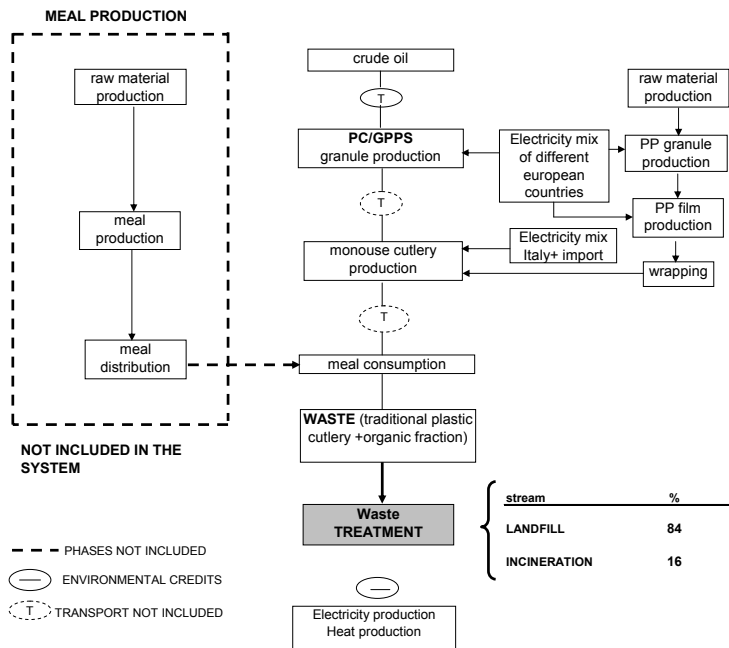


Figure 2: Disposal of the heterogeneous waste (non compostable plastic cutlery + food waste) following the traditional treatment routes. In particular, it has been applied the Italian scenario which is: sanitary landfill 84% and incineration 16%. However, a sensitivity analysis has been also carried out with a hypothetical disposal scenario: sanitary landfill 50% and incineration 50%, more similar to the conditions of the Nordic European countries.

Table 1. Waste production referred to the functional unit (serving of 1000 meals)

Material	mass (kg)		
	fork + knife	packaging ^a	Organic waste
Mater-Bi (YI)	15,70	1,4	150
Polycarbonate (PC)	13,68	1,2	150
General Purpose Polystyrene (GPPS)	11,78	1,2	150

^a Mater-Bi cutlery packaging is made with a biodegradable Mater-Bi NF type film; in all the other cases the packaging is made with polypropylene.

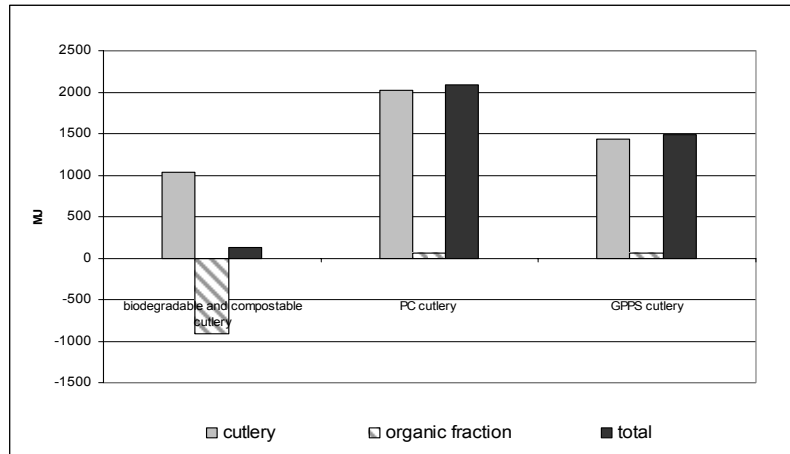
Table 2: LCIA results of different organic waste treatment options (food leftovers produced by serving 1000 meals)

Impact category	Unit	Composting with compost credits	Landfill (84%) and incineration (16%)
Acidifying compounds	molH ⁺ /g,max eq.	-1,97	1,28
Eutrophication compounds	g O ₂ /g,max eq.	-831	2790
Greenhouse gases	kg CO ₂ eq.	-26,5	11,1
Ozone depleting gases	kg CFC-11 eq.	-9E-07	4,8E-07
Photochemical ozone creation	kg C ₂ H ₄ eq	-0,00018	0,000191
Solid waste	kg	0	9,26
Resources en. non renew.	MJ	-912	60,8

Table 3: "Cradle to grave" LCIA results of catering 1000 meals using different cutlery and different waste treatments. B&C Mater-Bi cutlery is composted together with the organic waste. The cutlery made with traditional plastics is disposed of with the organic waste according to the Italian scenario (landfill 84%, incineration with energy recovery 16%). PC=polycarbonate; GPPS=general Purpose Polystyrene

Impact category	Unit	Cutlery type Waste treatment		
		Mater-Bi <i>composting</i>	PC <i>Landfill & incineration</i>	GPPS <i>Landfill & incineration</i>
Acidifying compounds	molH ⁺ /g,max eq.	5,85	16,38	11,25
Eutrophication compounds	g O ₂ /g,max eq.	789	4945	4207
Greenhouse gases	kg CO ₂ eq.	22,1	110,3	64,2
Ozone depleting gases	kg CFC-11 eq	7,65E-06	0,25E-05	0,21E-05
Photochemical ozone creation	kg C ₂ H ₄ eq.	5,7E-03	0,027491	0,002211
Solid waste	Kg	0,25	24,5	21,3
Resources en. non renew.	MJ	128	2080,8	1490,8

A



B

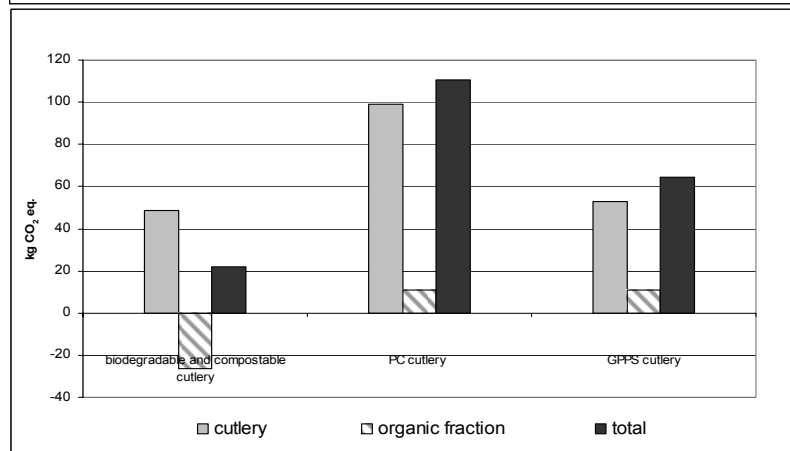


Figure 3: Non renewable energy (A) and greenhouse gases (B) produced by serving 1000 meals either with compostable or with traditional plastic cutlery. In the first case the resulting waste is composted, in second case the mixed waste is treated according to the current Italian waste treatment system (84% disposal in landfill and 16% incineration). Cutlery environmental performance is influenced by the mass (see Table 1).

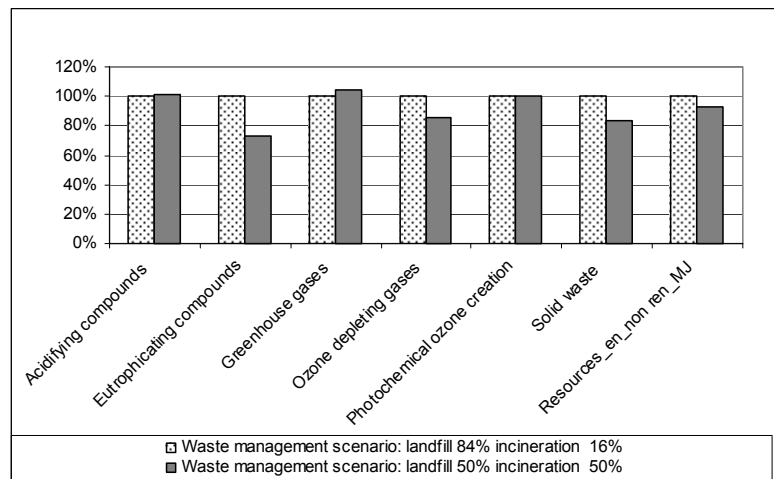


Figure 4: Sensitivity analysis to verify the effect of a higher incidence of incineration with energy recovery. The “Cradle to grave” LCIA results for PC cutlery disposed of by means of landfill (84%) and incineration (16%) together with organic waste have been set to 100% and compared with the normalised results of the 50% landfill and 50% incineration scenario.