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CLOSING THE LOOP: FEASIBILITY OF INDUSTRIAL SYMBIOSIS FROM FOOD PROCESSING WASTE

Nadia Mirabella[*1], Valentina Castellani[1], Serenella Sala[2].*

[1]*Department of Earth and Environmental Sciences, Piazza della Scienza 1, 20126 Milano, Italy.* nadia.mirabella@unimib.it .

[2] *European Commission, Joint Research Centre, Institute for Environment and Sustainbaility, Sustainability Assessment Unit , Via E. Fermi 2749, 21027 Ispra, Italy*

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ABSTRACT

Closed systems are the basis of so-called industrial symbiosis, in which the goal is to use wastes from one sector as an input for other sectors. In the context of bio-economy, the food industry generates a large amount of residues. Many of these, however, have the potential to be reused into other production systems, trough e.g. biorefineries. The present study, based on extensive literature review, presents feasibility and constraints of applying industrial symbiosis in recovering waste from food processing. Generally, food waste is not used as it is, but only after a transformation that allows to extract active ingredients with high added value. Mainstream sectors of application of functional ingredients derived from this transformation are the nutraceutical and pharmaceutical industry.

INTRODUCTION

In Europe, integrated product policy (EC, 2003), resource efficiency flagship initiative (EC, 2011) and the bio-economy communication (EC, 2012) are promoting the prevention of food waste (FW) in all the life stages. The production of FW covers all the food life cycle: from agriculture phase, up to industrial manufacturing and processing, retail and household. Up to 42% of FW is produced by households, 38% losses occur in the food manufacturing industry, and 20% is distributed along the whole food chain (agricultural food loss is not included in this estimation) (EC, 2010). In addition, FW is expected to rise to about 126 Mt by 2020 if additional prevention policy or activities are not undertaken (EC, 2010).

The large amount of waste produced by the food industry, in addition to being a great loss of valuable materials, also raises serious management problems, both from the economic and environmental point of view. Many of these residues, however, have the potential to be reused into other production systems, trough e.g. bio-refineries.

There are several studies in the literature which deal with the bio-refinery concept, i.e. with the use of biomass feedstock in substitution of fossil ones. Due to the well-known problem of land competition between food and biomass feedstock dedicated crops, a growing number of studies investigate specifically the use of residues as a secondary source of energy or raw

material (see, for instance, Ghatak, 2011; B. Kamm and M. Kamm, 2004 and Mahro and Timm, 2007). In fact, closed systems are the basis of so-called industrial symbiosis, in which the goal is to use wastes from one sector as an input for other sectors.

In order to systematize most recent research on the topic, the present study focus on the potential use of food waste coming from food manufacturing (FWm). The aim of this study is twofold:

- Reviewing the literature concerning the possible use of FWm for producing new products, reducing burden on virgin raw materials
- Assessing main constraints and limitation in a large scale implementation of FWm reuse/ recycling

The authors performed an extensive review of possible use of FWm in order to transform food waste in resource for production of new products, applying industrial ecology and eco-innovative approaches.

METHODOLOGY

Several keywords were chosen to obtain a large range of existing studies to be analysed. The keywords selected were: food waste; industrial ecology food; byproducts food waste; byproducts food industry; food processing waste; meat processing byproduct; biorefinery food waste; meat waste byproduct; dairy waste byproduct. No geographical restrictions were applied, and the search was limited to papers published from 2000 to 2012. The keywords were introduced with boolean operator "and" into the most important databases of scientific journals, such as Scopus, Cilea and SciDirect. Titles and abstracts from more than 1500 publications were screened and examined, and then relevant papers were selected based on a number of criteria and were used for this review.

Papers coming from fifty scientific journals were finally selected, plus two conference proceedings and one PhD thesis, for a total number of 107 papers reviewed. The journals mainly belong to food research, biotechnology, chemistry and waste management field. The 107 articles selected were classified into the following categories: fruits and vegetables; dairy products; meat and derivatives. Within the first category, the following subcategories were defined: apples; berries; citrus fruits; exotic fruits; potatoes; tomatoes; olives; other vegetables; and miscellaneous.

RESULTS

The literature review allowed identifying, for each of the food processing industries considered (fruit and vegetables, meat and meat products, dairy products) which are the most significant possibilities of FWm reuse. Table 1 illustrates the correspondence between the processing chains and waste potentially reusable in the fruit and vegetable sector. For more detailed results see Mirabella et al (2013).

The most promising sources of valuable compounds from fruits and vegetables are: olives, exotic fruits and tomatoes, which can provide several valuable compounds. According to the results of this review, researches mainly focus on antioxidants, fiber, phenols, polyphenols and carotenoids extraction, due to their high possibilities of application and potentials.

Concerning meat and derivatives, proteins are the most extracted substances, while lactic acid, proteins and peptides from dairy by-products are mainly obtained.

Table 1. Summary of the correspondences between manufacturing chains and reusable wastes in the fruit and vegetable sector.

	Apple	Berries	Citrus Fruits	Exotic fruits	Potatoes	Tomatoes	Olives	Other vegetables	Miscellaneous
Lactic acid								X	
Food additives				X					
Heavy metals adsorber									X
Functional Food				X				X	
Antimicrobials				X					X
Antioxidants	X			X	X	X	X	X	X
Carotene						X			
Carotenoids						X			
Cellulose			X						
Bioactive compounds				X				X	
Herbicide			X				X		
Phenols	X						X		X
Fibers	X	X						X	X
Rubber filler				X					
Phytochemicals	X								
Flavonoids	X	X						X	
Lipids							X		
Lycopene						X			
Animal feed			X		X				X
Pectins				X					X
Polyphenols		X					X		
Carbon adsorber							X		
Substrate				X				X	X
Carbohydrates							X		
Sugar syrup			X						
Various		X	X	X			X		X

DISCUSSION

The literature review about FWm recovery and industrial symbiosis in the food industry showed that the majority of the studies focus on restricted examples and pilot-scale laboratory experiences, while only few cases contain data about economic and technical feasibility on existing full-scale studies. In general, there is a lack of specific studies related to logistic aspects of industrial symbiosis, e.g. case studies with the characteristics and the quantity of food wastes produced by a company, the geographical distribution of other companies that could benefit from that wastes etc.

Furthermore, it was observed that the FWm are not used as they are, but they need further processing steps. This transformation implies high costs of capital investments in research and development; hence, it is essential to obtain valuable and high added-value products in order to justify the investment.

In this regard, an investigation to identify the type and amount of wastes, the potential for exploitation, the geographical location of producers, intermediaries (e.g. laboratories which could be involved in the transformation and valorization of wastes) and finally, the potential end-users will be necessary.

CONCLUSIONS

In order to promote an industrial symbiosis in the food manufacturing industry, feasibility studies are essential to classify the type and amount of wastes and to identify which industrial sector/activity might transform and use them. According to most of the reviewed studies, the functional compounds extracted from FW can be used as high value added ingredients in the pharmaceutical and cosmetic industry.

Nevertheless, since most of the recovery options involves deep transformation processes before the reuse of the extracted component, it is necessary to assess also the sustainability of the whole recovery process proposed, to avoid the risk of burdens shifting from an environmental compartment to another. For instance, some of the extraction procedures of compounds presented in this review may involve the use of potential polluting chemicals, such as solvents or additives. The benefits of recovery should not be undermined by environmental impacts caused by new production processes. Hence, it is preferable to promote direct reuse/recovery practices (i.e. the replacement of a virgin raw material) without the intermediation of manipulations and extraction from the waste product or to evaluate the processes for the bio-refinement adopting environmental assessment methodologies encompassing the entire life cycle of the by product (e.g. Life Cycle Assessment).

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