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Exploitable fish waste and stranded beach debris in the Emilia-Romagna Region (Italy)

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ABSTRACT

Within Circular Economy principles, this paper analyses and estimates exploitable marine residues, such as fish waste and stranded debris in beaches and their potential valorisation scenarios.

The Emilia-Romagna Region (Italy) has been chosen as a case study. Based on the sold fish, about 200 Mg/year of fish waste are produced at the five major fish markets of the Region. Including all regional fish processing plants and retail trade, the estimated availability of fish waste increases up to 30,000 Mg/year.

Stranded beach debris collected by mechanical cleaning operations are currently deposited in landfill. About 63,000 Mg/year of sieved debris are collected each year, out of which the recoverable fractions consist of 19,000 Mg/year of organic material, 8,000 Mg/year of shells and 5,200 Mg/year of stones.

Classification and valorisation routes for these residual biomasses are proposed and their applicability to other regions discussed. In order to investigate the possible use in anaerobic digestion plants and the effects on biogas production, Biochemical Methane Potential (BMP) assays have been carried out with fish waste samples and with organic material found in marine debris. Salt content in driftwood has been quantified to assess its potential use in Combined Heat and Power (CHP) plants. Proposed valorisation routes for shells and stones include the production of calcium carbonate (cement industry, wastewater treatment and mulching) and the application in building industry, respectively.

1. Introduction

Since 2011 the European Union has been promoting circular economy policies (EU Commission, 2011, 2015; McDowall et al., 2017). The main goal is to limit and avoid as much as possible the production of waste, by recycling secondary raw materials (EC Commission, 2015; McDowall et al., 2017) and recovering biomasses for their utilisation in accordance to the pyramid of value. That is why more and more research projects and industrial initiatives are aimed at identifying residues to be exploited in further processing and thus to add value. Residual biomasses from agriculture, agro-industry, urban solid waste and forestry are worldwide studied and quantitatively evaluated in order to understand their potential capacity to produce biofuels, bioenergy and biobased materials (Brosowski et al., 2016; Li et al., 2017; Lin and He, 2017; Meyer et al., 2017; Nunes et al., 2017; Ozturk et al., 2017; Parajuli et al., 2015; Pokharel et al., 2017; Roberts et al., 2015; Roman-Figueroa et al., 2017; Thomas et al., 2017; Turrado Fernandez et al., 2016). There is an abundant literature about terrestrial residual biomasses, but few information are available on marine residual biomasses; the majority of papers focus on macro and micro algae cultivation and harvesting for biofuels production (Akunna and Hierholtzer, 2016; Allen et al., 2013; Chiodo et al., 2016; Debiagi et al., 2017; Ge et al., 2016; Han et al., 2014; Karray et al., 2017; Lee and Lee, 2016; Reyes and Labra, 2016; Ruiz et al., 2013; Uggetti et al., 2016). Recently, attention has been paid to wastes from fish processing. The high lipid and protein content make them interesting for biomolecule extraction such as polyunsaturated fatty acids, enzymes and pigments (Baiano, 2014; Ciriminna et al., 2017; Enascuta et al., 2018; Lopes et al., 2015; Sabtecha et al., 2014) or for biofuel production (Adeoti and Hawboldt, 2014; Andersen and Weinbach, 2010; Ward and Løes, 2011; Yahyaee et al., 2013), even if, currently, the most common valorisation strategies for fish wastes are protein supplements for animal feed or biogas production through anaerobic digestion process (Arvanitoyannis and Tserkezou, 2014; Bermúdez-Penabad et al., 2017; Eiroa et al., 2012; Solli et al., 2014). In this last option,

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Nomenclature

AD	Anaerobic Digestion	MSD	Medium Size Debris
BMP	Biochemical Methane Potential	SSD	Small Size Debris
CHP	Combined Heat and Power	TS	Total Solids
EC	Electrical Conductivity	VS	Volatile Solids
ERDF	European Regional Development Fund		

using fish waste as single substrates is widely discouraged because it could generate process's inhibition due to both low C/N ratio that leads to an excessive ammonia production, and high contents of lipids and proteins that produce and accumulation of long-chain fatty acids (Labatut et al., 2011).

World per capita fish consumption is increasing and reached 20 kg in 2014 (FAO, 2016). European consumption is following the same trend with 4.5 million tonnes landed in 2014 (EUMOFA, 2016). In northern Europe, caught fish is quickly processed onboard in so called "factory ships" and its wastes immediately dumped at the sea. In the Mediterranean area the majority of fish and shellfish processing operations are carried out in shore-based facilities based in ports and fish markets (Archer et al., 2001). Although estimations of waste quantity depend on species, period of the year and final product, the edible portion ranges from 40 to 70% of the raw fish. The remaining is discarded and includes heads, viscera, frames, lugs, flaps and skin (Archer et al., 2001; Kim, 2014). Fish wastes are becoming more abundant and their quantification at local and regional level must be pursuite, given that they will surely take a relevant role as a source of future biofuels (Kafle et al., 2013; Msangi et al., 2013; Ward and Løes, 2011).

Marine debris deposited on beaches are conventionally defined as "any persistent, manufactured or processed solid material discarded, disposed or abandoned in the marine and coastal environment" (Coe and Rogers, 2012; Galgani et al., 2010). Increased relevance has been attributed to marine debris, mainly related to plastic litters, because of their role in polluting marine environment and food chain (Derraik, 2002; Zhou et al., 2016). Driven by winds and storms, part of marine debris reaches shores and continuously accumulates on beaches throughout the year, affecting tourism because of the visual and physical environment degradation and consequent loss of attractiveness. Consumers move to other beaches and/or coastal areas and/or plan holidays in different countries on the basis of the cleanliness of beaches. For this reason, periodic cleaning operations, although expensive, are widely conducted in touristic beaches at the European level in order to keep these portions of coast free from garbage and other debris and guarantee healthy recreational activities (Acoleyen et al., 2013). The sand or fine pebble fraction is recovered and usually redistributed on the shore, while there are no specific regulations and obligations for the other fractions which are currently landfilled. Moreover, the identification and the quantification of the original debris composition is poorly investigated, with the main focus on man-made polluting materials like plastics, glass, aluminium cans and micro-plastics (Browne et al., 2015; Iñiguez et al., 2016; Poeta et al., 2016). Only recently, the increasingly occurrence of enormous amount of driftwood brought by storms on the shore of Tuscany (Italy) has raised up attention from local authorities and Italy finally classified this material as a non-hazardous waste suitable for energy production (Bruschi and Pacciani, 2017). However, the origin of this material requires particular attention for sand and chlorine content that could cause rapid wear of blades and dangerous emission, respectively (Cotana et al., 2016; Long et al., 2012a; Wei et al., 2005).

The paper aims at: (I) providing a quantification of fish wastes concentrated at main ports and scattered at the Emilia Romagna regional level; (II) providing a quantification of beach debris collected and processed at regional level; (III) identifying the main fractions constituting beach debris and providing their individual quantification; (IV) providing an analytical characterization of the most promising residues, based on both quantification and analytical results; (V) addressing valorisation strategies for each fraction and (VI) proposing a new methodology to classify these residues.

1.1. Local background

1.1.1. Fish wastes

Fish wastes can be produced at different levels: in aquaculture activity, fishing activity at the sea, fish markets, fish processing industries or retail trade and restaurants. Not counting retail trade and restaurants, largely dispersed onshore and inland, all other waste producers can be considered as waste concentrators. Aquaculture in the Emilia-Romagna Region is almost totally focused on shellfish farming in open sea water. In particular, the Sacca di Goro, with 1,300 hectares dedicated to clams production (mainly *Tapes Philippinarum*), represents one of the most important aquaculture systems in Europe, generating about 30% of European clams production (Malorgio et al., 2012). Also, mussel farming represents a relevant activity for the region with 20,000 Mg produced on average every year (Osservatorio Pesca, 2015). However, shellfish farming activities do not generate residues because shellfish are generally marketed entire. Fish farming activities are rather small in the Region, with an estimated 1000 Mg/year of both marine and freshwater fish bred products (Osservatorio Economia Ittica, 2016). Due to the scarcity of fish farming, only 48 fish industries are active in the region and mostly at small size (only 8 having more than 3 employees) (Infocamere, 2016). At the regional level, about 350 fish retail shops are operating. Being scattered in the territory, no data have been collected and they are considered in the paper only for general estimations. Finally, the EU's Common Fisheries Policy was reformed in 2012; one of the main changes was to eliminate the practice of throwing unwanted catches overboard while at sea, a practice known as 'discarding'. This brought to the EU Directive on the obligation of landing of accidental and undersize catches (EU Commission, 2013). This directive is not yet implemented in Italy, mainly because of the lack of dedicated infrastructures to receive and to store these wastes at the harbours (Tasselli et al., 2015).

The last report on the marine economy in Emilia Romagna (dated 2012) shows about 22,000 Mg/year of fish and shellfish captured or collected at the regional level, out of which 6,000 Mg/year are sold through auctions at the five main Ports: Goro, Porto Garibaldi, Cesenatico, Rimini and Cattolica (Malorgio et al., 2012). Consumption data indicate that the Emilia Romagna Region is not self-sufficient and about 112,000 Mg/year of fish products are imported (Malorgio et al., 2012). The Port of Rimini is the largest in the Region, with a total of 110 vessels (2012 data), most of them small and used for local fishing. The fleet follows a fishing calendar, annually defined by the Italian Ministry of Agriculture, Food and Forestry to promote stock recovery. The wider fish market in the Region is also located in Rimini, with more than 60 vendor