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Review

Composting of waste algae: A review

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ABSTRACT

Although composting has been successfully used at pilot scale to manage waste algae removed from eutrophied water environments and the compost product applied as a fertiliser, clear guidelines are not available for full scale algae composting. The review reports on the application of composting to stabilize waste algae, which to date has mainly been macro-algae, and identifies the peculiarities of algae as a composting feedstock, these being: relatively low carbon to nitrogen (C/N) ratio, which can result in nitrogen loss as NH_3 and even N_2O; high moisture content and low porosity, which together make aeration challenging; potentially high salinity, which can have adverse consequence for composting; and potentially have high metals and toxin content, which can affect application of the product as a fertiliser. To overcome the challenges that these peculiarities impose co-compost materials can be employed.

Contents

1. Introduction

There is growing global interest in the role that algae can play in renewable fuel, food and materials generation. Algae are a diverse group of uni- and multicellular photoautotrophs. They are essentially biological solar panels that fix CO_2 for growth and the production of intracellular storage compounds (Chisti, 2007). They have a higher photosynthetic efficiency than other biomasses, and can be cultivated in simple open saline ponds so their production does not compete for arable land (Mata et al., 2010).

However uncontrolled growth of algae in natural and engineered environments can be a serious concern. The evidence includes some notable examples:

- *Qingdao, China (2008):* The world's largest "green-tide" event, caused by extensive aquaculture (Liu et al., 2009). Algal biomass, dominated by *Enteromorpha*, covered about 400 km^2 along the coast. The algal biomass blocked the port channel

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Fig. 1. Green-tide of Qingdao, China, in summer of 2008 (from Liu et al., 2009).

(Fig. 1). In June 2008 alone, more than 150,000 tonnes of wet algal biomass was collected from the region. More than 10,000 workers and 1000 boats were hired for the operation (Wang, 2008).

- *Albury-Wodonga, Australia (2009):* Blue green algae outbreak in Lake Hume, which is located east of Albury-Wodonga. The outbreak extended 600 kilometres, almost covering the whole main channel of the lake (Lauder, 2009).
- Venice, Italy (annual): In the Venice Lagoon, about 10 million tons (wet weight) of *Ulva rigida* biomass are produced annually. Harvesting has been carried out to reduce negative impacts of the algal biomass, however, due to the high costs of such effort, only 40,000 tons are collected every year (Cuomo et al., 1995).
- *Patagonia, Argentina (annual):* Large quantities of green seaweed, linked to eutrophication, are cast ashore every summer on the Puerto Madryn beaches (Eyras et al., 1998). This algal biomass interferes with recreational uses of the beach, and therefore must be periodically collected and disposed. It was estimated that about 8000 tons of seaweed are collected every year (Eyras and Rostagno, 1995).
- *Wuxi, China (annual):* Since 1981, cyanobacteria populations (Microcystis and Anabaena) have increased in Taihu Lake, Wuxi, China. Annual blue-green algae blooms in the lake have clogged intakes at municipal waterworks, interrupted domestic and industrial water supply, and caused losses in fish cultures (Pu and Yan, 1998).
- *The Mediterranean (annual):* The marine plant posidonia (*Posidonia oceanica*) beached in tourist zones represents a great environmental, economical, social and hygienic problem" (Cocozza et al., 2011). In many places the material is collected and disposed of in waste dumps (Castaldi and Melis, 2004).

Waste algae has been directly applied as soil conditioner and/or fertiliser in many coastal regions of the world (Castlehouse et al., 2003; Cocozza et al., 2011; Haslam and Hopkins, 1996). Here we review composting as a technology for waste algae stabilisation, which could potentially improve existing land application strategies. Composting is defined as the biological decomposition and stabilization of organic substrates under conditions which allow development of thermophilic temperatures as a result of biologically produced heat, with final products sufficiently stable for storage and application to land without adverse environmental effects (Polprasert, 1996). It is an aerobic process whereby organic carbon is oxidised to CO_2. Composting has been widely applied for managing household and food waste, but, while the opportunity to compost waste algae has certainly been recognised and the application of algae compost as a fertiliser for horticulture has been demonstrated (Eyras et al., 1998), reports on composting algae are relatively scarce.

To date, most algal composting has been limited to stabilising macroalgae, particularly seaweed. The focus has been on composting material collected from green-tide events, like those listed above. *Ulva* sp. is the most important component of green-tide seaweed (Eyras et al., 2008) and so the stabilisation of that species has been most widely examined (Cuomo et al., 1995; Maze et al., 1993; Mendo et al., 2006).

In contrast to literature on the composting of macroalgae, there are few reports on composting microalgae. The degradation of *Chlorella* during composting has been reported (Kitano et al., 1998) and in recent years, a few studies on blue-algae composting have been carried out by Chinese researchers. Much of the blue-green algae that has been stabilised was collected from the aforementioned Taihu Lake (Jiang et al., 2012; Pu and Yan, 1998; Ren et al., 2012; Wang, 2008).

The aims of this review are to bring together literature on algal composting in order to (i) report the technologies for composting waste algae, (ii) assess the merits of composting for managing waste algae, and (ii) identify the peculiarities of algae as a composting feedstock. To the best of our knowledge, this is the first review on this topic.

2. Peculiarities of algae as a compost feedstock

Algae are characterised by a relatively low carbon to nitrogen (C/N) ratio. Additionally, algal biomass typically has high moisture content and, for algae grown in marine or brackish environments, high salinity (Cuomo et al., 1995; Jiang et al., 2012; Maze et al., 1993; Mendo et al., 2006). Algae can also have elevated metals content and blue-green algae can carry associated toxins. The physical and chemical characteristics of algal biomass to be stabilised by composting are summarized in Table 1. These characteristics and the role they play in the composting process as discussed below.

2.1. Carbon to nitrogen (C/N) ratio

The carbon to nitrogen ratio (C/N ratio) of the organic material to be composted is important as it affects the microbial compost

Table 1
Physical and chemical properties of algae or seaweed materials used for composting.

Materials	C[a] (%)	N[a] (%)	C/N ratio	Organic matter[a] (%)	Moisture (%)	EC (dS m^{-1})	Salinity[a] (%)	Ref.
Ulva sp.	5.78	0.68	8.5	13.7	39.4	–	1.4–4.7	Maze et al. (1993)
Ulva sp.	24.34	2.77	8.78	41.97	64.4	8.5–14.5	–	Mendo et al. (2006)
Green algae	26.3	3.6	7.3	53.3	75.2	–	–	de Guardia et al. (2010a)
Green algae	19.5	3.6	5.4	–	–	–	–	de Guardia et al. (2010b)
Blue-green algae	36.3	7.4	4.9	62.1	87.7	–	–	Jiang et al. (2012)
Blue-green algae	44.9	7.4	6.06	–	96.2	–	–	Wang et al. (2009)
Undaria pinnatifida	31.32	2.67	11.7	–	–	–	4.6	Tang et al. (2011)
Undaria pinnatifida	36.95	4.14	8.92	–	89	–	1.5–2.8	Tang et al. (2010)
Posidonia oceanica	36.0–46.2	0.6–1.0	36–81	–	55–65	12.5–15.8	–	Cocozza et al. (2011)

[a] Percentage by dry weight.