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Ecological engineering: from concepts to applications

Composting fish waste and seaweed to produce a fertilizer for use in organic agriculture

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Abstract

The fishing sector produces large amounts of waste in fish markets and processing industries. These by-products are mainly used in the manufacture of fish meal. However, there are other potentially valuable uses. One low-investment possibility is the elaboration of agricultural products by composting the fish remains with other marine materials such as seaweed.
The main purpose of this work was to obtain a fertilizer suitable for use in organic agriculture, by composting a mix of seaweed and fish waste.

Keywords: co-composting; drift-seaweed; fish offal; organic fertilizer; pine bark

1. Introduction

Since 1991 the total land dedicated to organic agriculture in Spain has grown exponentially to almost a million hectares. It is primarily dedicated to extensive crops (pasture, fodder, grains and legumes). Vegetable crops, tubers, vines and olive and nut trees also cover significant areas [1]. Organic agricultural production seeks to provide top quality food while respecting the environment and maintaining soil fertility through optimal use of resources. Organic agriculture promotes the recycling of nutrients to minimize the quantity of nutrients imported to the farm. If any product is to be used to maintain soil fertility it should not be synthetic. Organic matter is a key for maintaining fertility in the soil-plant system [2]. The demand for organic products in local and global markets is growing and is likely to gain significance in the future. However, organic fertilizer of sufficient quality to be used in this type of production is currently quite expensive, in spite of the increase in organic livestock farming.

The sea provides abundant resources, and one of them is the seaweed that reaches the coast by the action of tides and wind. The drift-seaweed washed up on beaches has been used for centuries as natural fertilizer in many coastal regions throughout the world [3]. Seaweed improves soil structure and provides it with trace elements and growth activators [4,5,6]. In areas where seaweed becomes a waste product due to eutrophication (Venice, Brittany, Peru,

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Argentina, etc), initiatives have been carried out to add value to it by looking to composting as an economically and environmentally viable biotechnology solution [7]. This would reduce the volume of seaweed on beaches and take advantage of its rich nutritive elements, particularly potassium, calcium and magnesium, to provide quality compost that is completely hygienic and free of contaminants such as heavy metals and phytotoxic compounds.

Fishing generates large quantities of waste daily in fish markets and fish processing industries (canneries, fresh and frozen fish processing plants, etc). Fish remains have also been traditionally used as fertilizer, given their wealth of nutritive elements (principally N and P) and their rapid decomposition. Composting initiatives using fish offal derived mainly from aquiculture have been carried out in various parts of the world in search of alternative and viable techniques for transforming fish waste into useful agricultural products [8,9,10].

A study was carried out in order to test if co-composting of seaweed and fish offal, along with lignocellulosic material for aeration and carbon, may provide a viable solution for recycling these natural marine sub-products and producing a quality organic fertilizer for use in organic agriculture systems.

2. Materials and Methods

2.1. Testing set-up

A compost pile was created using the windrow method in a plot of land in the municipality of Foz (NW Spain). Fish waste from the Pescados Rubén, S.L Company, which processes several varieties of extracted fish (mackerel, sardine, tuna, squid) into fresh and frozen fish products, were mixed with seaweed found on nearby beaches (primarily *Laminaria* sp. and *Cystoseira* sp.). To increase the C/N ratio in these materials, pine bark (particle size 10-35 mm) from a local sawmill were added. The various materials were spread in a trapezoidal pile 2 m wide at the base, 1 m high and 6 m long, with a total final volume of 10 m^3. To avoid lixiviation and nutrient washout, the pile was set on an impermeable base and sheltered above. The proportion of fish, seaweed and pine bark was 1:1:3.

The total duration of the composting process was four months. The compost pile was turned weekly during the first two months and every 15 days during the last two months. The temperature and O_2 levels were tested weekly to monitor the correct development of the process. Once the compost was considered mature, it was sifted using a 20-mm mesh screen.

2.2. Description of the materials

Table 1 shows the main physical-chemical and chemical characteristics of the materials used in the compost pile.

Table 1: General classification of the different materials (mean values and standard deviation)

	Seaweed	Fish waste	Pine bark
%:			
Humidity	80.30 ± 0.11	69.75 ± 9.01	62.75 ± 0.65
C	27.19 ± 0.35	46.22 ± 2.80	50.41 ± 0.02
N	1.15 ± 0.05	10.17 ± 2.29	0.16 ± 0.01
P	0.20 ± 0.02	1.80 ± 0.90	0.10 ± 0.01
K	5.03 ± 0.37	0.79 ± 0.46	0.17 ± 0.04
Ca	1.23 ± 0.17	1.86 ± 1.85	0.13 ± 0.00
Mg	1.15 ± 0.11	0.15 ± 0.04	0.08 ± 0.00
Na	4.80 ± 0.25	0.64 ± 0.16	0.44 ± 0.02
C/N	23.68 ± 1.31	4.79 ± 1.24	304.24 ± 11.84
E. C. 1:5	1.06 ± 0.02	4.81 ± 3.19	0.86 ± 0.02
pH 1:5	6.64 ± 0.06	5.89 ± 0.48	5.63 ± 0.04

2.3. Description of the final compost

The stability of the product was evaluated after two months. Stability was tested indirectly by the autoheating method [11]. The degree of stability (DS) was determined using the method in [12], which consists of two successive hydrolysis procedures that allow the resistant organic matter present in the sample to be estimated. The result can be expressed as the percentage ratio of resistant organic matter (ROM) to total organic matter (TOM), %DS = (ROMx100/TOM).

Phytotoxicity was determined by the test described in [13], using *Lactuca sativa* seeds [14].

Compost humidity was determined by drying at 105º C to constant weight. Carbon and nitrogen were determined after combustion in a Leco 2000 autoanalyzer. After acid digestion with H_2SO_4 and H_2O_2 30% [15], Ca and Mg levels were determined by atomic absorption and Na and K by emission. Levels of P were analysed using colorimetry [16]. The samples were subjected to microwave-assisted digestion with nitric acid (Microwave Labstation ETHOS 900) and the total concentrations of cadmium, copper, chromium, nickel and lead were determined by inductively coupled plasma-optical emission spectrometry (ICP-OES). The aqueous extracts (substrate/water 1:5 v/v) were also obtained using UNE-EN methods 13037 and 13038 [17]. The extracts were used to determine the pH, electrical conductivity, calcium, magnesium, sodium and potassium levels by absorption and atomic emission. Nitrates and ammonium levels were obtained using selective electrodes. All parameters were determined in triplicate and the data shown are mean values.

Data from these analyses were compared with the data for the reference materials CRM 279 and CRM 318. The recovery percentages were satisfactory.

3. Results

Four months of composting yielded approximately $3m^3$ of material, resulting from the decomposition of the initial 10 m^3, indicating a 70% reduction in volume. Stabilisation tests after two months of composting indicated that the compost product was stable. Autoheating showed the difference between the inside and outside Dewar flask to be less than 10ºC, which corresponds to a degree of maturity classified as V. This indicates that the compost was totally stable and that most of the biodegradable material had already been transformed [18]. The degree of stability was 66.7%, which suggests that more than half of the total organic matter was resistant.

The germination index in the compost was 81.1%, which according to Zucconi et al. [13] indicates the absence of phytotoxic substances or their presence in very low levels.

The final compost was adequate for use as organic fertilizer, particularly in regard to the NPK content, which was greater than 4% cumulatively. Unfortunately, the C/N ratio was greater than 20, which is considered high in current legislation [19] and should be corrected in the future (Table 2).

Salinity was also high (Table 3), mainly due to the saline content in the fish waste products (Table 1). The NH_4^+ and el K^+ ions are primarily responsible for this. If the compost is to be used as a substrate, recommended salinity should not surpass 0.65 dS/m in a 1:5 extract [20]. However used as a fertilizer or soil amendment, salinity would not be of concern.

Table 2: Mean values and standard deviation of the physical-chemical and chemical parameters of final compost sifted through a 20 mm screen

Parameter	Mean ± standard deviation
%:	
Humidity	38.08 ± 0.51
C	47.97 ± 0.15
MO	82.79 ±0.26
N	2.13 ± 0.11
P	0.63 ± 0.03
K	0.69 ± 0.06
Ca	0.44 ± 0.01
Mg	0.25 ±0.02
Na	1.19 ± 0.19
C/N	22.56 ± 1.24

Table 3: Mean values and standard deviation of pH, electrical conductivity and soluble elements of the final compost in a 1:5 aqueous extract

	1:5 Extract
pH	7.08 ± 0.07
E.C. dSm^{-1}	1.45 ± 0.01
NH_4^+ mgL^{-1}	171.00 ± 4.50
NO_3^- mgL^{-1}	20.64 ± 1.41
P mgL^{-1}	24.47 ± 1.12
K mgL^{-1}	107.22 ± 1.90
Ca mgL^{-1}	2.33 ± 0.91
Mg mgL^{-1}	0.79 ± 0.03

Heavy metal levels in the compost were very low with respect to the limits established by Spanish legislation regarding organic fertilizer products. The legislation [19] separates fertilizers into three categories according to content of heavy metals and establishes limits on their use (Table 4). The compost produced in this test falls within category A, indicating that there are no limitations to its use for this reason.

Table 4: Heavy metal levels in the final compost (mg kg^{-1}) as compared with limits established by Spanish legislation [19]

	Cd	Cr	Cu	Ni	Pb	Zn
Compost	0.80 ± 0.09	0.27 ± 0.18	4.20 ± 0.09	0.55± 0.38	4.83 ± 0.58	30.43 ± 0.44
Legal limits						
Class A	0.7		70	25	45	200
Class B	2.0		300	90	150	500
Class C	3.0		400	100	200	1000

4. Conclusions

Co-composting of fish offal with drift-seaweed and pine bark allows to reduce greatly the volume of fisheries by-products. In the course of two months from the beginning of the experiment, a stable product is obtained. This product might be used as a fertilizer in ecological agriculture systems, as it is of natural origin and has no limitations.

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