

Biodegradable Agricultural Waste Biomass Utilization

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INTRODUCTION

Biodegradation is defined as the decomposition of organic material by micro-organisms or their enzymes into smaller products such as carbon compounds (including CO₂, CH₄ and solids) and water [1,2]. Biodegradation can occur in the natural environment, e.g. in soils, or in a controlled environment such as during biological waste treatment. Composting and digestion are examples of aerobic and anaerobic biodegradation processes respectively, resulting in the formation of gases (e.g. CO₂, CH₄ and N₂O), water and compost or digestate. The estimation of nitrogen and carbon loss during composting process of olive tree lops and their contribution to the greenhouse effect has been experimentally and theoretically investigated by Charisiou et al [3]. Moreover, a recent study has been conducted [4] concerning the potential of agricultural waste biomass to contribute more significantly to global electricity generation by conducting an assessment of its potential for sustainable development. The aim of this paper is to approximate carbon and nitrogen footprints of the waste treatment phase and to find out what the best waste treatment option for the biodegradable agricultural waste biomass is by comparing home composting and anaerobic digestion.

METHODOLOGY

When compost is used as a soil conditioner to substitute other soil conditioners, this saves carbon and/or nitrogen from other sources. We used the method developed by Ref. [5] and combine the carbon content of soil conditioners with the shares of carbon that contribute to humus production to calculate the carbon credits. Substitution factors can then be derived for compost in comparison to other soil conditioners through equating the materials' humus-C and then standardising to compost. In order to take into account that the carbon dioxide emissions from the application of straw are biogenic and thus are cycled through agriculture on the short term, we set these biogenic CO₂ emissions to zero, valuing only the fossil carbon dioxide emissions from the use of peat. The systemic and combined perspectives take into account emissions of nitrous oxide from composting due to the necessity of nitrogen in the composting system. This is done based on the ratio of carbon to nitrogen in the composting input. In order to remain consistent, the fertilising effect of compost (through N in the compost) also has to be considered. We assume that the nitrogen in the compost can replace nitrogen from synthetic fertilisers, the most important of which are urea, ammonium nitrate, calcium ammonium nitrate and ammonium sulphate.

RESULTS AND DISCUSSION

Home composting occurs when bacteria and fungi degrade biomass under aerobic conditions at ambient temperatures (<35°C). Compared with industrial composting, here the biomass remains at lower temperatures, and is mixed less frequently. As a result, biomass degrades more slowly.

Table 1. Comparison of literature data on carbon and nitrogen emissions for home composting per kg carbon input assuming short-term carbon storage in compost (fruit, vegetable and greenwaste)

Source	C in CO ₂ [%]	C in CH ₄ [%]	C stored short-term [%]	N ₂ O emitted [g/kg C]
[6] [7];	47	1.32	44	1.16
[6] [7];	30	0.47	35	1.53
[8]; avg, 23 °C	47	0.02	53	3.86
[8]; best, 23 °C	35	0.01	65	1.32
[8]; worst, 23 °C	60	0.04	40	6.92
[8]; avg, 38 °C	49	0.21	51	0.83
[8]; best, 38 °C	38	0.11	62	0.05
[8]; worst, 38 °C	61	0.44	39	2.98

The data for home composting is based on a set of experiments carried out at OWS in Belgium [8], the goal of which was to quantify gaseous emissions from the system. The experiments showed a large variation in nitrous oxide emissions at temperatures of 23°C. In some of the 16 experimental vessels, the formation of N₂O seemed to have levelled off already at the end of the experiment (12 weeks), whereas in other vessels the emissions were still rising; at this point approximately 50% of the carbon originally embedded in the input material had been degraded and the rate of carbon dioxide and methane emissions had slowed down.

Biogas yield is influenced by several process conditions, and variation up to $\pm 25\%$ have been recorded [9]. Process controlling parameters such as temperature, retention time, volumetric loading, technology deployed (viz., continuous versus batch, single versus two stage digestion, slurry feeding cycle and stirring technology, etc.), and degree of pre-treatment of feedstock are important. Feedstock type is also important, e.g., fat, proteins and sugar contents have high methane yield [10]. On the other hand, inhibitors such as ammonia and lipids in waste streams from abattoirs can significantly derate yield [11]. Stage of energy crop harvest, weather and soil growth conditions may also affect biogas yield. Whereas theoretical calculations of biogas yield on the basis of fat, carbohydrates and protein contents are straightforward [12], accurate energy audit should be based on realistic data that can be validated against performance of full-scale plants. Analyses in this study for single feedstock digestion were based on biogas business planning data (Table 2) compiled by the Association for Technology and Structures in Agriculture (KTBL) in Germany.

Table 2. Estimated biogas yield and dry matter (DM) content of digestate by feedstock options adopted from [12]

Feedstocks	DM content feedstock (%)	DM content digestate (%)	Biogas yield (m ³ t ⁻¹ DM)	Methane Content (%)	Energy content (GJ t ⁻¹ DM)
Straw	86	81.6	341	51	6.2
Corn silage	35	11.1	576	52	10.8
Grass silage	25	9	492	54	9.5
Whole wheat plant silage	40	14.2	488	52	9.1
Food residues	16	4	592	60	12.7
Pomace	22	4.5	510	52	9.5
Slaughterhouse waste (paunch content)	15	7.4	403	55	8.0
Cattle manure	8	4.3	297	55	5.9

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