A rapid food waste valorisation into organic fertilizer using a so called disruptive technology

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Key words/

Carbon, Nitrogen, phosphorus, Potassium. Nutrient release. Greenwaste compost, biowaste compost, residual nutrients, Emissions.

Abstract

A so called "disruptive" technology has been developed in Ireland which turns raw organic waste, in particular vegetable and food waste (canteen waste) into a agronomic product that is both pathogen free and stable with a consistency similar to humic soil conditioner and an aromatic characteristic similar to that of coffee grind, after around 24 hours. This aromatic product is Harp's BioNova. During the process, the food digester or biodigester does not require any freshwater or water connection and has little to no grey water discharge to the sewers, environmental conditions dependent. A cultivated and unique consortium of hydrolytic and mesophilic enzymes are added to the preconditioned chamber that aggressively breaks down the raw material. This chamber is controlled and monitored to maintain optimum mesophilic conditions throughout the 24 hour period.

During the processing of the food waste, emissions were minimal with theoretical reductions in Methane and Nitrous Oxide of 46-69% and 73% compared to traditional composting methods respectively [1-2]. We determined the nutrient profile, pH, electrical conductivity, heavy metals and other parameters of the Harp-BioNova product.

Initial controlled growth studies were conducted to ascertain the comparative growth performance of a model crop, grass when grown in soil treated with Harp-BioNova material and biowaste compost (BWC) and composted greenwaste (CGW), all applied at three rates. Overall the biomass from pots treated with Harp- BioNova material were higher than pots treated with a biowaste and greenwaste compost at comparative application rates on volume basis. Analysis of the material for agronomically important macronutrients, such as nitrogen, phosphorous and potassium, indicated higher uptake rates of these nutrients in BioNova treated pots over four harvests. Despite higher uptake the residual total N and available P and K were higher in the soil after the 4th harvest. The product produced from the food waste processing has a high potential as an viable organic fertilizer and fits in with the EU strong policy of Circular Economy and new EU Fertilizer Regulations which promotes organic fertilizer as against mineral fertilizer. The most substantial benefits of such a technology is both the very short turn around and the reduced emissions of GHG gasses released during the processing.

Introduction

A so called "disruptive" technology has been developed in Ireland which processes raw organic wastes, typically canteen waste from commercial sites, food factories and onsite canteens, into an agronomic product/ biofertilizer than can then used to enhance and treat the commercial premises landscaping. According to a report by the US Compost Council and ILSR (US Institute for Local Self-Reliance), on-site composting should be prioritised over large scale, decentralized composting sites. A life-cycle analysis performed by the EU by the European Environment Agency on the greenhouse gas emissions (GHG) from municipal solid waste management, also concluded that home composting has the best environmental performance as "direct emissions from home composting are negligible (very little methane is emitted) if composting is done well, largely due to there being no transportation involved" [3].

By incorporating Harp technology and removing the need for collection and transportation of organic waste demand for diesel powered heavy good vehicles can be eliminated, traceability can be improved, potential cross contamination of other recycling streams can be minimised and inefficiencies/emission losses in large scale composting sites can be mitigated. The Harp biotechnology does not require any freshwater or water connection and has little to no grey water discharge to the sewers, environmental factors dependent. The technology is fully automated to mechanically rotate the material while at the same time removing excess steam or vapour while drawing in fresh air for improved aeration. The raw material slowly passes through a reactor at around 55 to 75 degrees centigrade. A cultivated and unique consortium of hydrolytic and mesophilic enzymes are added that aggressively breaks down the raw material. A computerize PLC unit that controls internal environmental factors, such as moisture and temperature, which favor mesophilic breakdown of the substrate, ensures the material output achieves a pasteurization process of 70 degrees centigrade for a minimum of 1 hour before it is deposited from the unit. The biodigester reduces the organic mass by about volume of 70% on average.

The objective of the investigation was to determine the quality of the end product by the Harp process as evidenced primarily by release characteristics of N,P and K for use as an organic fertilizer using plant growth test and comparing it to a commercial biowaste compost, BWC (from brown bin) and a commercial greenwaste compost (CGW). Residual nutrients after four harvests (160 days) were analysed based on the total Nitrogen and soil test for Phosphorus and Potassium.

Materials and Methods

Emissions on a limited number of parameters, using colourmetric tube was outsourced to Axis Environmental Services, Limerick. Ireland. Sampling and analysis of dust was carried out in accordance with the methodology MDHS-14. Volatile Organic compounds monitoring was carried out by the standard method MDHS-96 using gas chromotography. Monitoring was also carried out on the outlet gasses (NH3, Mercaptans, Hydrogen Sulphide and Amines using colourmetric tubes [4].

The total organic carbon (TOC), N, P and K and other macro and micronutrients on treated foodwaste by the Harp process were analysed using industrial standard methods through independent labs across Ireland and the UK. The parameters for the Biowaste compost and greenwaste compost were evaluated from Prasad, M. and Foster, P. et al, 2008 [5]. We then evaluated Harp-BioNova, Biowaste compost (BWC) and Greenwaste compost (CGW) as an effective organic fertilizer by studying nitrogen, phosphorus and potassium release characteristic by measuring their plant/crop uptake, which was used as a model crop. The methodology for this study was based on Prasad et al.,2012 [6]. Composted green waste and composted biowaste (mostly foodwaste) were included for comparative purposes. Although the three materials were added at a similar volume basis (4,8 and 12%), the resultant addition rates of various nutrients were not equal, see table 1. There were four harvests of grass over a period of 5.5 months. Due to lack of growth after two harvests from CGW, this treatment was discontinued. Fresh weights, dry weights and the macronutrient & micronutrient analysis was done on all four cuts to determine nutrient uptake. Results of N,P and K uptake will only be presented here but other data secondary nutrients such as Ca, Mg and S will be available as supplementary information. In addition, at the completion of Harvest 4, composite soil samples were taken and the residual C (loss on ignition) and total N and "available nutrients"(Mehlich P and K) left in the soil were determined.

	Application Rate (Volume / ml)	Weight of Addition (g)	Dry Weight of Addition (g)	TKN (Addition g)	NH_4 (Addition g)	NO_3 (Addition g)	P (Addition g)	K (Addition g)	Organic Matter (g)	Organic Carbon (g)
BioNova (4%)	80	45.6	39.31	1.217	0.0168	0.0041	0.0481	0.4720	35.179944	20.439744
BioNova (8%)	160	91.2	78.61	2.435	0.0336	0.0082	0.0962	0.9440	70.359888	40.879488
BioNova (12%)	320	136.8	117.92	3.652	0.0504	0.0122	0.1443	1.4160	105.539832	61.319232
Greenwaste (4%)	80	46.16	20.22	0.472	0.0016	0.0025	0.0060	0.1707	9.1992264	5.3577912
Greenwaste (8%)	160	92.32	40.44	0.944	0.0032	0.0050	0.0120	0.3414	18.3984528	10.7155824
Greenwaste (12%)	320	138.48	60.65	1.416	0.0048	0.0074	0.0180	0.5120	27.5976792	16.0733736
Biowaste (4%)	80	49.6	45.19	0.616	0.0103	0.0096	0.0034	0.1117	10.392688	6.0548704
Biowaste (8%)	160	99.2	90.37	1.232	0.0206	0.0191	0.0067	0.2233	20.785376	12.1097408
Biowaste (12%)	320	148.8	135.56	1.848	0.0308	0.0287	0.0101	0.3350	31.178064	18.1646112

Table 1: Influence of application rates on the addition of total N and available macro nutrients and organic matter

Result and Discussion

The pH analysis for the Harp- BioNova material, at 5.5 is low for what would typically be expected for a compost, see table 2. The EC for the Harp-BioNova material is very high, potentially indicating high salt levels. The Organic matter content is very high compared to BWC and CGW 2 to 4 times higher than the BWC and CGW respectively.

Material	Code	Bulk Density (g/L)	Moisture %	Organic Matter %	Organic Carbon %	pH	EC (mS/m)
BioNova	HR0019	570	13.8	89.5	52	5.5	541
Greenwaste	HR0020	577	56.2	45.5	26.5	8.7	97
BioWaste	HR0021	620	8.9	23	13.4	7.8	212

Table 2: Comparative characterisations of treatments

		Ammonium-N		Nitrate-N	
Material	Code	Dry Sample (mg/Kg)	Fresh Sample (mg/L)	Dry Sample (mg/Kg)	Fresh Sample (mg/L)
BioNova	HR0019	427.4	210	103.8	51
Greenwaste	HR0020	79	20	122.5	31
BioWaste	HR0021	227.5	128.5	211.5	119.5

Table 3: Available nitrogen content of compost materials tested

		US EPA Limits	N/A	41	39	1200	N/A	1500	300	17	18	420	36	2800
		Europe PAS100	N/A	N/A	1.5	100	N/A	200	200	1	N/A	50	N/A	400
		Metals (dry)	Aluminum (Al)	Arsenic (As)	Cadmium (Cd)	Chromium (Cr)	Cobalt (Co)	Copper (Cu)	Lead (Pb)	Mercury (Hg)	Molybdenum (Mo)	Nickel (Ni)	Selenium (Se)	Zinc (Zn)
		Units	*ppm*	*ppm*	*ppm*	*ppm*	*ppm*	*ppm*	*ppm*	*ppm*	*ppm*	*ppm*	*ppm*	*ppm*
Date of Analsysis	Ref Code	Material												
26 Nov 2018	HR261118-FW-CX-US-01-S	Food Waste	430.0	1.0	0.1	2.6	0.1	8.5	1.0	0.1	1.0	1.6	1.0	29.0
24 Sep 2015	HR240915-FW-CX-IRE-01-S	Food Waste	360.8	0.8	0.1	2.4	0.2	46.0	6.6			3.5	0.5	207.1
17 May 2016	HR170616-FW-CX-IRE-01-S	Food Waste	122.0	6.7	0.1	0.7	0.1	10.4	0.2	0.1		0.6	1.0	32.4
11 Oct 2017	HR111017-FW-CX-IRE-01-S	Food Waste	261.3	0.5	0.1		0.2	42.0	6.2			3.2	0.5	197.1
10 Mar 2016	HR100316-FW-CX-IRE-01-S	Food Waste	95.8	0.5	0.1	0.6	0.0	5.0	0.9	0.1		1.0	0.6	24.7
20 Mar 2016	HR200316-FW-CX-IRE-01-S	Food Waste	2212.0	0.5	0.1		0.2	39.1	5.7			3.9	0.6	157.1
21 Sep 2016	HR210916-FW-CX-IRE-01-S	Food Waste	442.7	3.0	0.1	1.8	0.1	9.5	0.1	0.2		3.5	46.4	42.0
28 Aug 2019	HR280819-FW-CX-IRE-01-S	Food Waste	3451.0	0.8	0.1	2.4	0.2	46.4	6.6			3.2	0.4	197.1
18 Jun 2019	HR180619-FW-CX-IRE-01S	Food Waste		0.5	0.1	2.8		8.2	1.0	0.1		1.8		25.9
		Food Waste		0.5	0.1	2.8		8.2	1.0	0.1		1.8		25.9
19 Nov 2018	HR191118-FW-CX-IRE-01-S	Food Waste		0.4				7.7	1.0	0.1		1.7		24.9
		Food Waste		1.0	0.1	2.8		8.2	1.0	0.1		1.8		25.9
5 Aug 2020	HR050820-FW-CX-US-01-S	Food Waste		0.5				20.0						47.0
2 Jan 2019	HR020619-FW-CX-IRE-02-S	Food Waste			0.1	2.8		4.0	1.0	0.1		1.3		5.2

Table 4 : Table from the Harp Environmental Team on Heavy metal content of Harp-Bionova

The heavy metal content levels of the Harp- Bionova product are extremely low, see table 4. In the context of the new EU fertilizer regulations [7], we can see they are well within any tolerance or required levels.

During the processing of the food waste, emissions were minimal with ammonia <1 ppm, H_2S < 0.1 ppm, amines <0.5 ppm and mercaptans <0.5ppm. Much of the carbon is retained within the substrate in the form of organic carbon and therefore mitigating much of the carbon volatilization in the form of CO_2 emissions. Total Dust and Respirable Dust was a % of TWA limit <2.1 and 7.91 respectively. There was no change in Volatile organic Carbon after 8 hours reference was 0.278 mg/m3 (Report available as supplementary information) [4].

The data over the 4 harvests (2 harvests for CGW) over 160 days showed that the Harp BioNova material has a consistently higher fresh weight than the comparative compost treatments indicating sustained availability of nutrients from the material Fig 1).

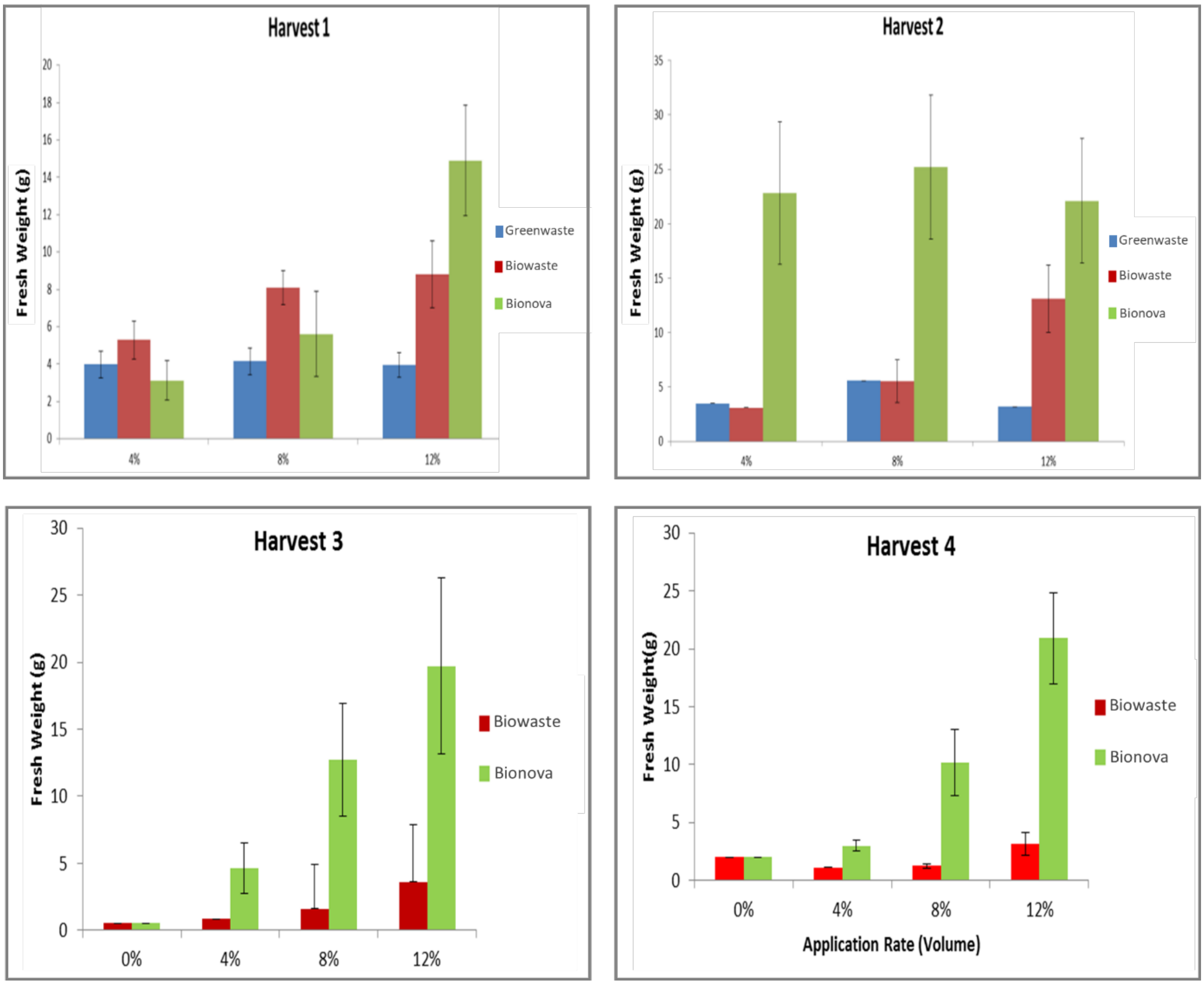

Figure 1: Comparative fresh weight recovery for compost and BioNova material over 4 harvest periods

As expected, nitrogen uptake (Fig., 2) effectively mirrored fresh weight returns. As the experiment progressed through the harvests, the impact of application rate and initial nitrogen application seem to have had an impact. In terms of recovered nitrogen from the grass samples harvested from each pot, the comparative nitrogen uptake in the Harp-BioNova pots to the biowaste pots was 12.5 times higher at 4%, 7.44 times higher at 8% and 4.6 times higher at 12% application rate.

There, the comparative efficacy in terms of nitrogen uptake is more pronounced at lower application rates. Given that there will possibly be agronomic and environmental constraints on applications at the tested higher rates. The performance at the lower rate of treated are significant. Uptake of P and K followed a similar pattern to N uptake.

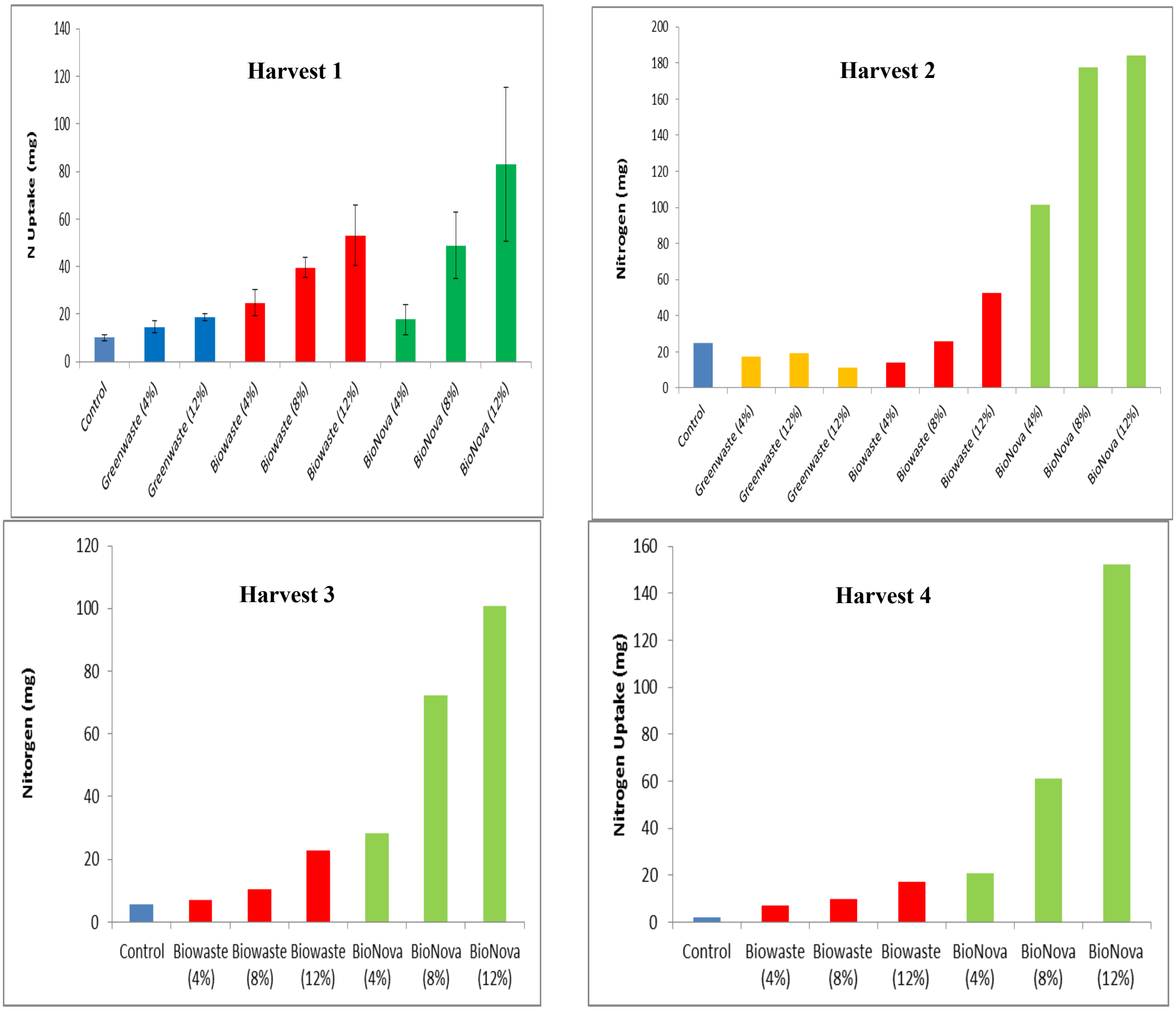

Figure 2: Comparative nitrogen uptake for compost and Harp-BioNova material over 4 harvest periods

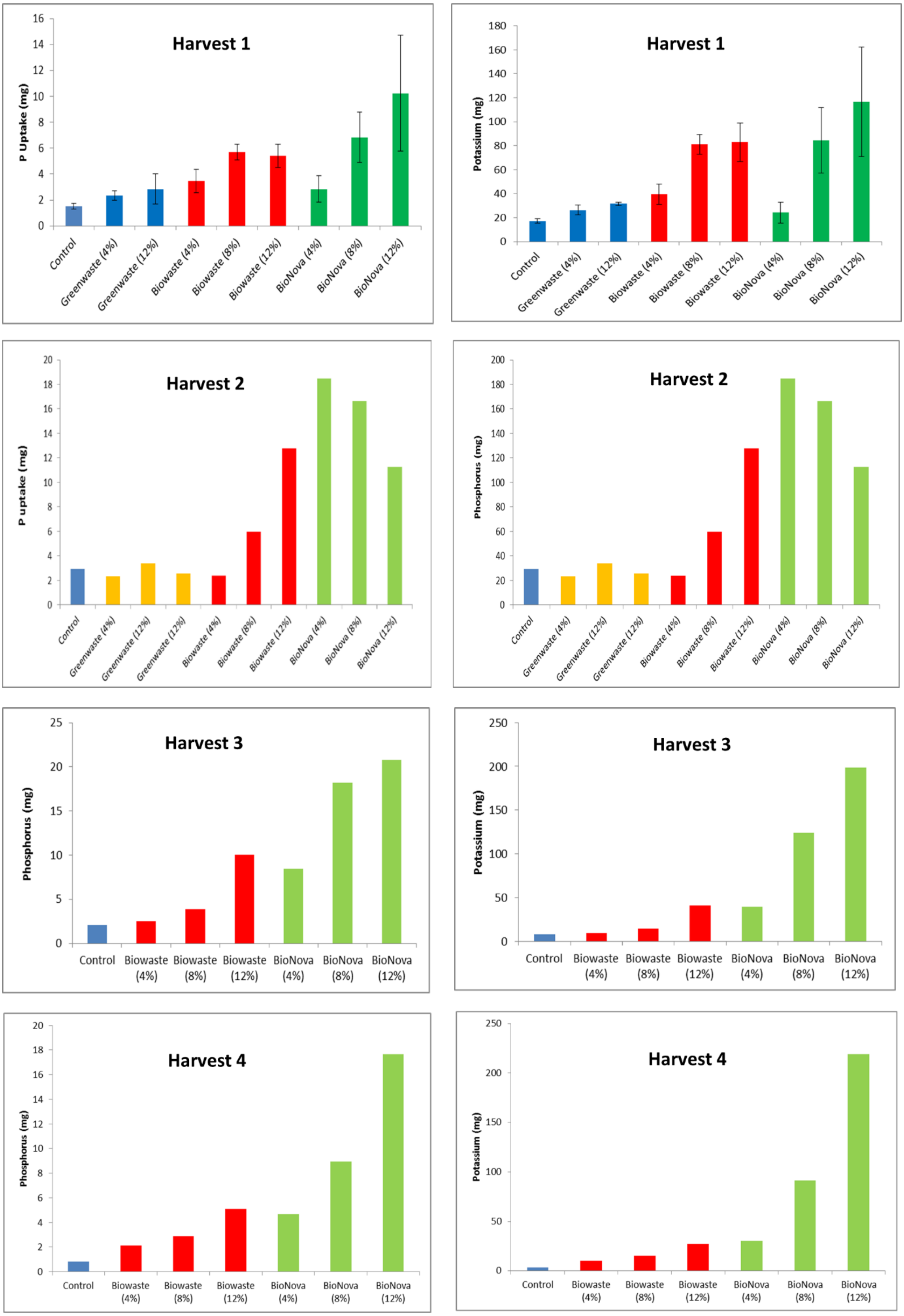

Figure 3: Comparative Phosphorus and Potassium uptake for compost and Harp-BioNova material over 4 harvest periods

With regards to phosphorus and potassium uptake, due to the application rates of P and K being variable between the three materials due to different P and K content despite the rates on volume basis being similar it followed a similar scenario to N uptake(Fig.3) Significantly more available phosphorus was present in the Harp- BioNova material than in the CBW or the CGW material. The recovery (uptake) of phosphorus and to a lesser extent potassium from materials subjected to the Harp treatment process may be beneficial from a purely agronomic and resource utilisation perspective. Given the lack of naturally occurring phosphorus resources within the EU, greater emphasis is being placed on technologies and processes for the recovery and utilisation of phosphorus from organic waste streams.

With regards to magnesium, calcium and sulphur uptake, similar to the scenario with nitrogen, it is an indication that the elements were available to be taken up by the plant. Data available as supplementary information.

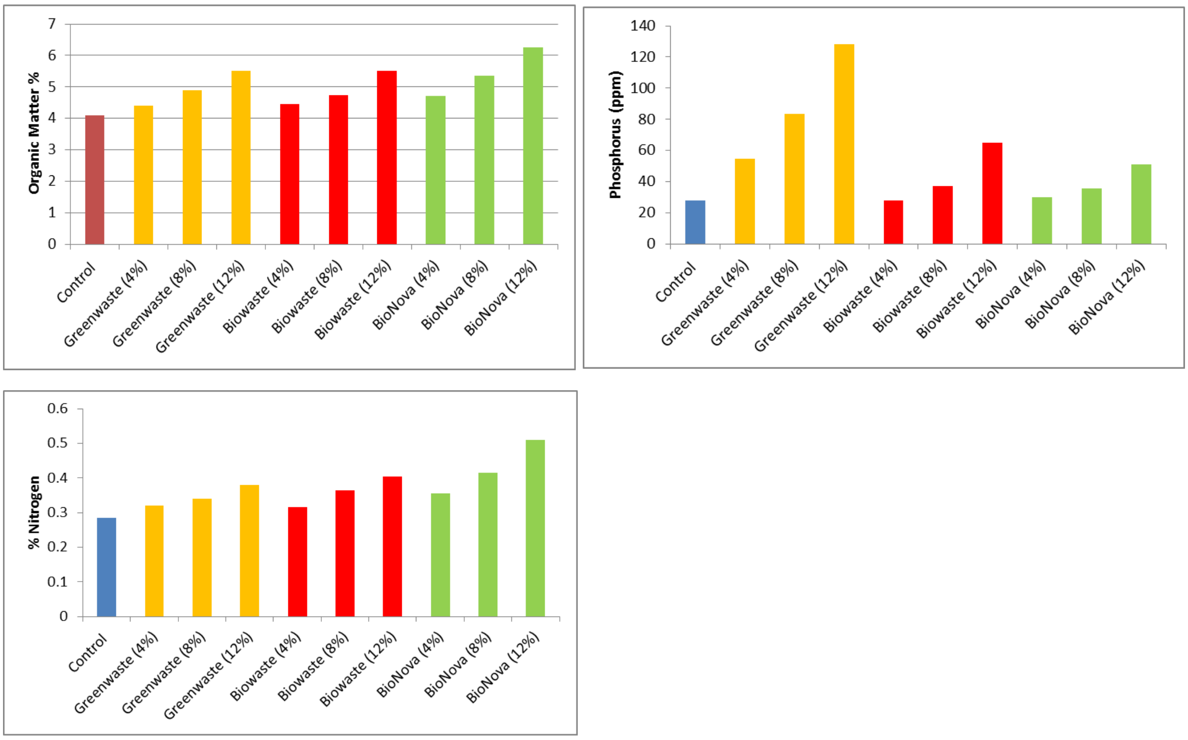

Figure 4: Post cropping soil content and characterisation analysis of Harp-Bionova and composts

In relation to the residual organic matter in the soil, the application of Harp-BioNova materials had a positive impact on organic matter levels, which was expected given the high organic matter content on the material. Despite the higher macronutrients uptake by plants during the cropping period, the fact that there is still residual nitrogen(total N), and extractable phosphorous left after cropping comparable to Biowaste compost is of interest and reflective of the comparatively high nutrient value of the Harp-BioNova material. (GW compost not comparable as only two harvests taken due to lack of growth and minimal nutrient uptake by grass occurred).

On average, food waste processed using this Harp technology achieve, a Total Organic Carbon (TOC) of over 45% (n=70). Comparing this to the Carbon content of a number of Bio-waste and greenwaste compost from Ireland, UK and Switzerland of 23% to 34% (Prasad et al., 2012). With over 70 analyses preformed on Harp-BioNova treated food waste, the median percentage N-P_2O_5-K_2O values are estimated at 2.8 – 0.8 - 1.5 or an NPK index of 5.1%, which meet the minimum nutrient limit of 4% in the EU Fertilizer Regulations 2019/1009 [7] and the minimum nutrient value for all fertilizer regulations across the Unites States [8].

Conclusion

In conclusion the product produced from the Harp food waste processing has a high potential as an viable organic fertilizer and fits in with the EU strong policy of Circular Economy, new EU Fertilizer Regulations which promotes organic fertilizer as against mineral fertilizer [7], and the need to reduce dependence on imported phosphate raw material with almost all comes from outside the Europe. The big benefit of the process is the very short turnaround time, lower C footprint and a lower GHG emission in relation to traditional aerobic digestion processes.

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