CYPRUS UNIVERSITY OF TECHNOLOGY

**Environmental Bioprocessing Laboratory**
**Department of Chemical Engineering**
**Hydro-Aromatic Plants Laboratory**
**Department of Agricultural Sciences, Biotechnology & Food Science**
**30 Archbishop Kyprianou Str., 3036**
**Limassol, Cyprus**

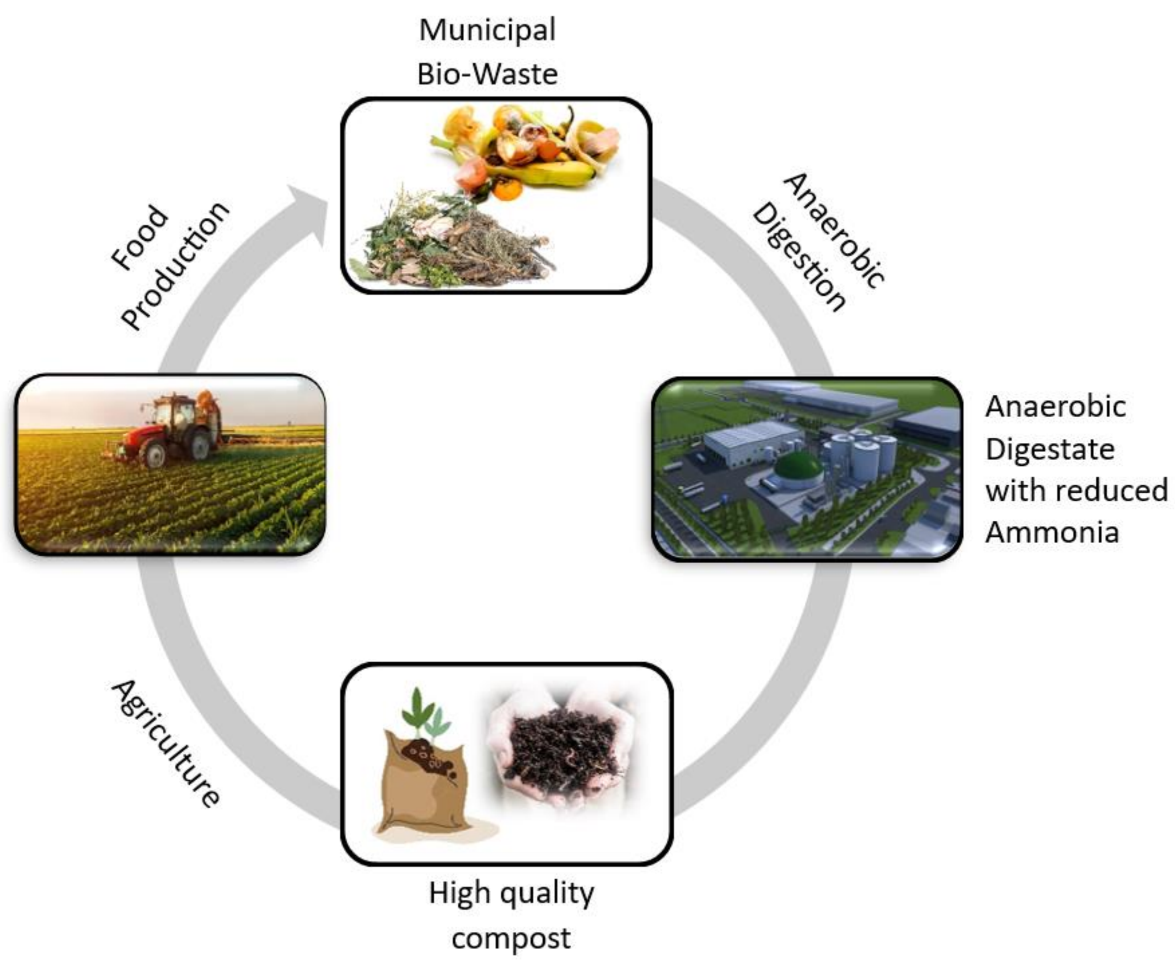
# Assessing the environmental merits of added-value commodities yielded via hydrolysis of municipal biowaste in agricultural and biochemical products

**M. Koutinas[1*], M. Christodoulou[1], M. Kallis[1], P. Photiou[1,2], E. Montoneri[3], I. Vyrides[1], N. Tzortzakis[4*]**

[1] Department of Chemical Engineering, Cyprus University of Technology, 30 Archbishop Kyprianou Str., 3036 Limassol, Cyprus
[2] Sewerage Board of Limassol – Amathus (SBLA), 76 Franklin Rousvelt, Building A, P.O. Box 50622, 3608 Limassol, Cyprus
[3] Università di Torino, DISAFA, Via Leonardo da Vinci 44, 10095 Grugliasco, Torino, Italy
[4] Department of Agricultural Sciences, Biotechnology & Food Science, Cyprus University of Technology, 30 Archbishop Kyprianou Str., 3036 Limassol, Cyprus
* michail.koutinas@cut.ac.cy, *nikolaos.tzortzakis@cut.ac.cy

## Introduction

Municipal Biowaste (MBW) is a valuable feedstock utilized as a renewable substrate for obtaining a wide variety of bio-based products (BPs), which have shown promising applications as chemical auxiliary in the chemical industry and agriculture. Current examples comprise the use of BPs for textile dyeing, detergents manufacturing and hydrocarbons contaminated soil washing [1-2]. The BPs employed incorporate the mixture of bioorganic molecules (containing aliphatic and aromatic C as well as several functional groups e.g. methoxyl, carboxylic acid, amide, ammine, etc) produced via chemical hydrolysis of MBW, aiming to evaluate at pilot-scale, in the sectors of MBW management and agriculture, i) replication of the BPs production process, ii) assessment of BPs quality and cost, iii) validation of BPs performance as fertilizers, plant biostimulants and anti-pathogen agents and iv) confirm BPs compliance with EU regulation for agriculture and environmental policy.




## Aim and Objectives

LIFE EBP project (LIFE19 ENV/IT/000004) includes two main objectives:

1) To demonstrate the environmental, economic and social benefits of new biobased products in the sectors of MBW management, agriculture and chemical industry in 5 EU countries (Cyprus, Greece, Spain, Italy, France).

2) Based on the results of the pilot project, to encourage joint ventures among stakeholders in the sectors of waste management, agriculture and chemical industry and promote industrialisation of BPs/IR production and uses in all EU countries to maximise the impact of project results.

## Results and Discussion

Addition of BPs in anaerobic digestion reduced the amount of ammonium in the digestate by 68% upon use of different MBW sources, inoculum and BPs content in fermentation, compared to control experiments where BPs were not added [2]. The microbial community and biogas production were not significantly affected by BPs addition. This supports the notion that supplementation of BPs assisted the fermentation process via combination of biological and chemical reactions, including the production of ammonia through the hydrolysis of protein by proteolytic bacteria and the oxidation of ammonia to $N_2$ by BPs. An additional goal of this study is to assess the environmental benefits of using BPs in agricultural trials employing green materials.

### Characterization of MBW

Green materials refer to plant-based residues which are rich in nitrogen, such as grass clippings, leaves, tree pruning and soil. These materials are essential for providing the nitrogen necessary for a healthy compost pile, which assists breaking down the organic matter in nutrient-rich soil. Herein, mature compost produced using green materials collected from different districts was obtained from local suppliers (samples S1-S3 and their mixture S mix) and their composition was determined. S mix constituted the mixture of the 3 different samples using 45% of S1 and S2 as well as 10% of S3. The analytical methods applied included monitoring of the organic carbon content (C), nitrogen content (N), pH, conductivity (EC), salinity, water holding capacity (WHC), total solids (TS), volatile suspended solids (VSS), chemical oxygen demand (COD), phytotoxicity (GI) and phosphorus content (P). The results obtained are presented in Table 1.

**Table 1.** Composition of MBW samples (S1, S2, S3, S mix) used for BPs production.

| | pH | EC (mS/cm) | N (%) | GI (%) | TS (% w/w) | VSS (% w/w) | C (%) | P (%) | $NO_3^-$ (mg/L) | $NH_4^+$ (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|
| S 1 | 7.7 | 3.47 | 2.02 | 66.9 | 73.86 | 77.83 | 54.5 | 14.4 | 14.8 | 10 |
| S 2 | 7.5 | 1.82 | 1.9 | 95 | 88.05 | 87.25 | 76.8 | 7.3 | 11.1 | 5.13 |
| S 3 | 7.6 | 3.81 | 1.33 | 45.6 | 84.88 | 80.72 | 68.5 | 4.4 | 27.7 | 6.75 |
| S mix | 7.6 | 2.68 | 1.66 | 72.1 | 81.27 | 78.31 | 63.6 | 10 | 10.4 | 4.83 |

Results indicated that the four different samples prepared exhibited carbon content higher that 50% and C:N ratio values ranging between 28-52 (Figure 1), which is acceptable for good quality fertilizer. C:N ratio in fertilizers is important affecting the rate at which the fertilizer will decompose and release nutrients into the soil. Fertilizers with high C:N ratio will decompose slowly and release nutrients gradually, while fertilizers of low C:N ratio will decompose faster and release nutrients more rapidly [3]. Phytotoxicity's germination index was 72.1% for the mixture, which is considered ideal demonstrating minor inhibition. Moreover, the ammonium content of S mix was 4.8 mg/L, which falls within an acceptable range given that concentrations exceeding 10 mg/L could harm plant roots.

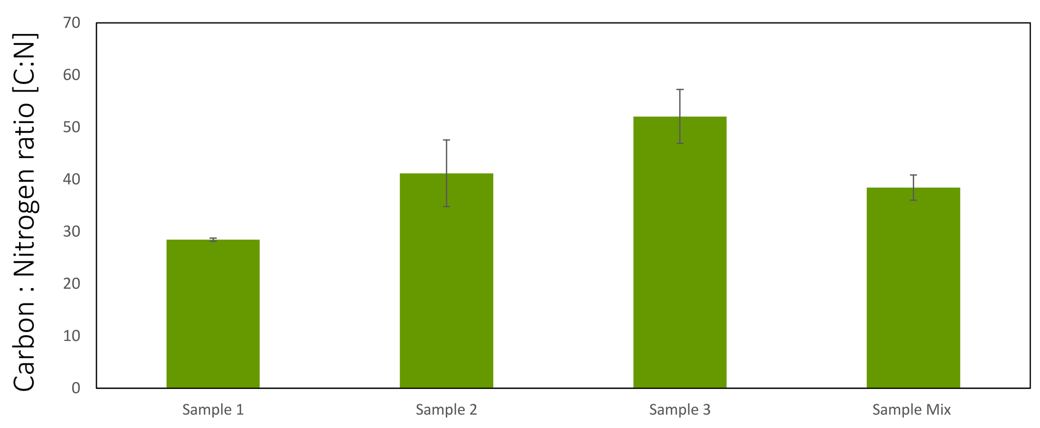



**Figure 1.** Carbon : Nitrogen ratio on different compost samples and their mixture.

### Agricultural application

Following characterization of each material, more than 100 kg of S mix were shipped to the facilities of Hysytech S.r.l. (Italy), which was subject to chemical hydrolysis producing BPs. The product was supplied to Cyprus University of Technology for application in agriculture. BPs were implemented on tomato crop in an automate climate control greenhouse. Fertile soil was purchased and transferred to the greenhouse farmland of the University's facilities. The physicochemical properties of soil were analyzed as presented in Table 2 and the analysis of BPs was performed as presented in Table 3. Subsequently, the experimental design was finalized (Figure 2) and preparation of the greenhouse area was conducted.

**Table 2.** Nitrogen, Phosphorus, pH and conductivity analysis of fertile soil.

| | N (%) | P (%) | pH | EC (mS/cm) |
|---|---|---|---|---|
| Fertile soil | 0.56 | 0.026 | 7.29 | 2.09 |

**Table 3.** Nitrogen, Phosphorus, pH, conductivity, humidity, organic matter, organic carbon and ash analysis of the BPs obtained via chemical hydrolysis.

| | N (%) | P (%) | pH | EC (mS/cm) | Humidity (%) | Organic matter (%) | Organic C (%) | Ash (%) | **C:N ratio** |
|---|---|---|---|---|---|---|---|---|---|
| BP | **4.21** | 2.39 | 9.06 | 6.67 | 27.31 | 68.09 | 39.49 | 31.91 | **9.38** |

Tomato (*Solanum lycopersicum* Mill cv. Elpida) seedlings were purchased at the 2-3 true leaf stage. Seedlings were grown in peat-based media in cubes and then they were transplanted in peat-based media and fertigated with diluted fertilizers (20-20-20) of EC = 1.8 mS/cm. Then they were let to grow for one week under controlled conditions to stimulate the root growth and plant establishment under greenhouse crop conditions. Following the process, the plants were transplanted in pot (9.5 Lt) filled with the relevant mixture (Organic input or BP input) and placed in tween rows while drip irrigation system was applied. After one week, for each plant, a string was applied to obtain the 1 branch pruning based in vertical orientation/growth system. In order to evaluate the initial effects of the applied BP into the mixtures and the relevant mask effects that could be obtained by applying relevant fertilization during the crop growing period, the 5 treatments were duplicated, as half plants are not receiving any additional fertilizers and the other half plants are receiving common fertilization for tomato.

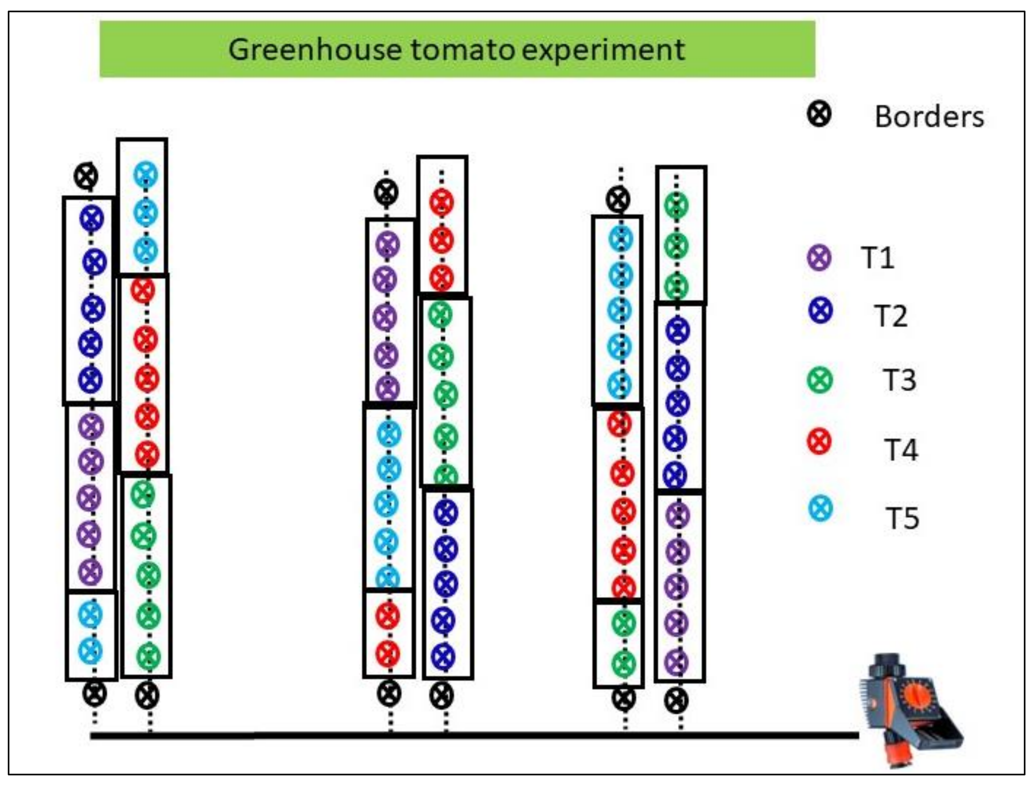



**Figure 2.** Experimental illustration of the experiment. T1 is only the fertilizer, T2 is the fertilizer with organic additive. T3 is the BP, T4 is the fertilizer and the BP and T5 is the fertilizer and twice the amount of BP.

## Concluding Remarks

Application of BPs in anaerobic digestion demonstrated that substantial reduction in the ammonia content of the digestate formed could be achieved via addition of less than 0.2% (w/v) of the biomaterial in the feed. Therefore, supplementation of the added value product proposed in anaerobic digestion could substantially improve the environmental sustainability of this major industrial process.

The current work performed in LIFE EBP project explores the use of BPs in agricultural trials, aiming to assess the added-value offered via use of the biomaterial for the cultivation of tomato crop.

Therefore, potential additional successful application of BPs in agriculture is expected to confirm that turning readily available complex MBW into a sustainable green feedstock for manufacturing value added renewable chemical specialties would be a real breakthrough achievement for the rising modern biobased chemical industry.

## FUTURE WORK

- The agricultural application will enable assessing the effect of BPs on crop production.
- Apart from the use of BPs for tomato crop cultivation in the greenhouse, open field trials will be additionally conducted to evaluate the use of the biobased product in pilot scale.
- Conducting LIFE EBP trials in 5 EU countries is expected to confirm the replicability of the value added product obtained by MBW under different conditions addressing important issues for the industrialization of the process.

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