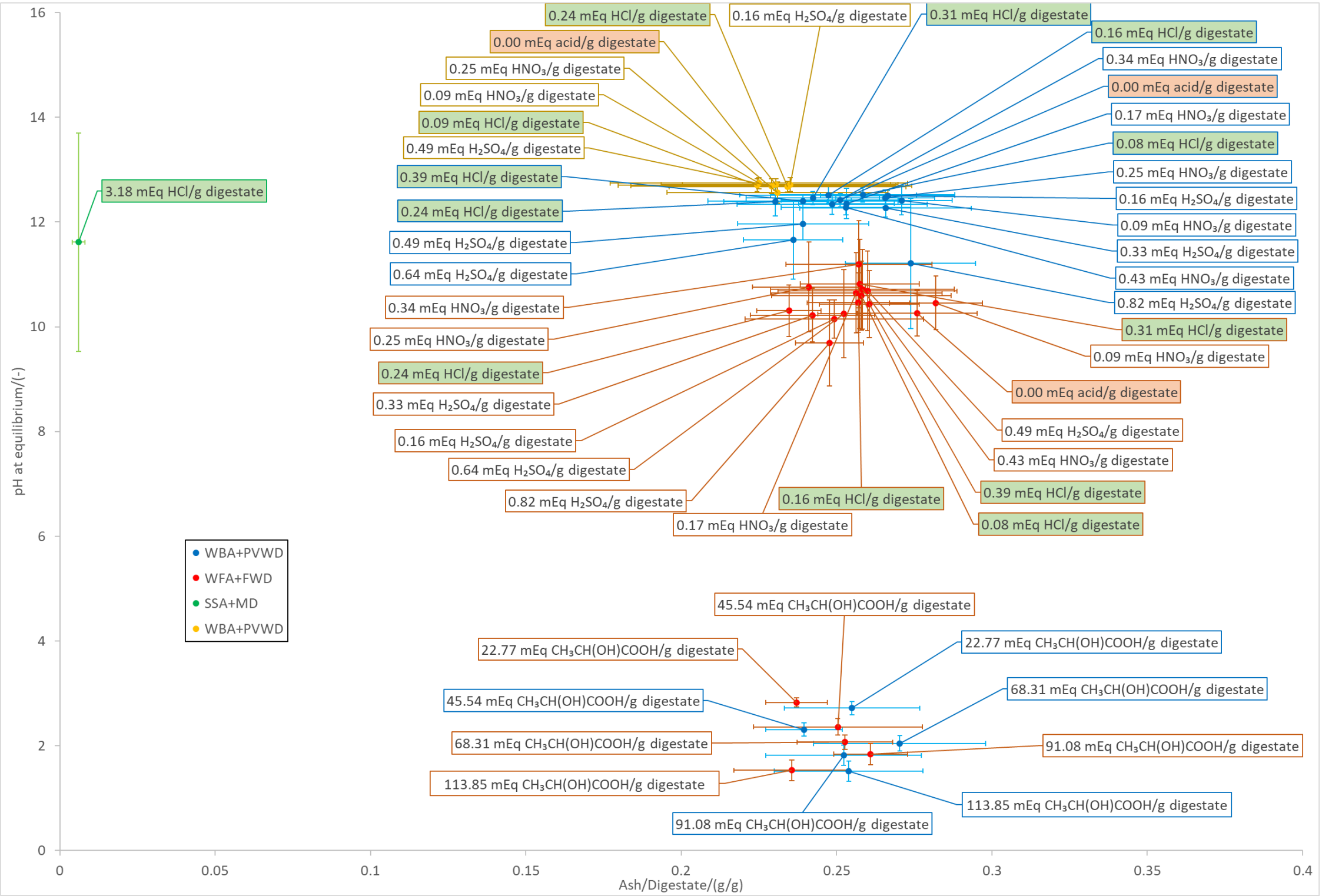
Aspen Plus® simulation of a combined process for the production of ammonium carbonate and a slow release fertilizer by ash-based treatment of the anaerobic digestate

In Europe, the current capacity of storage of manure and slurry is over 2.5 million tonnes and still governments continue subsidizing the management of these residues used as organic soil amendments and fertilizers. Other actions, such as derogation of the nitrate directive at a dedicated window of time and region, also alleviate the burden on the stakeholders of agribusiness as this allows the application of manure at a rate of 250 kg N/ha/y rather than 170 kg N/ha/y. It is therefore necessary to develop the downstream processing and valorization of this material with environmental technologies that minimize the emissions of GHG and phosphate leaching during storage and after land application and also reduce the cost of transportation. The anaerobic digestion combined with the wood ash based treatment has been demonstrated to address some of these issues by attaining a completive slow release fertilizer and production of ammonium sulfate. The process simulation by Aspen Plus® modelling for anaerobic digestion, which was originally developed by Rajendran et al. (2014), has been modified by including a stoichiometric-equilibria reactor to calculate the extent of the ionization of the molecules present in the anaerobic digestate. The refined model offers a more accurate prediction of the composition of the biogas because it delves into the chemical equilibrium of the gaseous stream and the anaerobic digestate. Additionally, the refined model allowed to assess the possibility of upgrading the gaseous stream to biomethane degree via manufacturing of ammonium bicarbonate. This processing pathway relies on the stabilization of the anaerobic digestate by means of biomass ash-based treatment. First of all, the titration of the manure digestate (MD) with the hydrochloric acid showed that a dose of 3.18 mEq/g would be required to attain the targeted pH of zero-point charge (pH_{zpc}), upon addition of the sewage sludge ash (SSA) in a ratio to the MD of 0.6 ± 0.2 %. The validation of the modelling is shown in the Figure below, which compares the results of the simulation with the empirical data found for the wood ash-based treatment of the anaerobic digestate employing different type of samples: wood bottom ash (WBA), wood fly ash (WFA), post-harvest vegetable waste digestate (PVWD), and food waste digestate (FWD). Secondly, the profiles of ammonia, carbon dioxide, and methane found in the biogas agreed with both the pH of the treated digestate and the processes described in for the simultaneously upgrading the biogas and the production of ammonium bicarbonate. The refined Aspen Plus® model needs to be further

developed to ensure the quality standards are attained in all output streams: stabilized anaerobic digestate, biomethane, and isolated added-value chemical fertilizers.

Caption of the figure below

Validation of the Aspen Plus® model by comparing the pH_{zpc} attained with the SSA-treatment of the MD with the experimental data of wood ash-based treatment of anaerobic digestate employing 4 different types of samples: WBA, WFA, PVWD, and FWD.


pH at equilibrium/(-)
Ash/Digestate/(g/g)
0
2
4
6
8
10
12
14
16
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
WBA+PVWD
WFA+FWD
SSA+MD
WBA+PVWD
3.18 mEq HCl/g digestate
0.24 mEq HCl/g digestate
0.00 mEq acid/g digestate
0.25 mEq HNO3/g digestate
0.09 mEq HNO3/g digestate
0.09 mEq HCl/g digestate
0.49 mEq H2SO4/g digestate
0.39 mEq HCl/g digestate
0.24 mEq HCl/g digestate
0.49 mEq H2SO4/g digestate
0.64 mEq H2SO4/g digestate
0.34 mEq HNO3/g digestate
0.25 mEq HNO3/g digestate
0.24 mEq HCl/g digestate
0.33 mEq H2SO4/g digestate
0.16 mEq H2SO4/g digestate
0.64 mEq H2SO4/g digestate
0.82 mEq H2SO4/g digestate
0.17 mEq HNO3/g digestate
0.16 mEq H2SO4/g digestate
0.31 mEq HCl/g digestate
0.16 mEq HCl/g digestate
0.34 mEq HNO3/g digestate
0.00 mEq acid/g digestate
0.17 mEq HNO3/g digestate
0.08 mEq HCl/g digestate
0.25 mEq HNO3/g digestate
0.16 mEq H2SO4/g digestate
0.09 mEq HNO3/g digestate
0.33 mEq H2SO4/g digestate
0.43 mEq HNO3/g digestate
0.82 mEq H2SO4/g digestate
0.31 mEq HCl/g digestate
0.09 mEq HNO3/g digestate
0.00 mEq acid/g digestate
0.49 mEq H2SO4/g digestate
0.43 mEq HNO3/g digestate
0.39 mEq HCl/g digestate
0.08 mEq HCl/g digestate
0.16 mEq HCl/g digestate
45.54 mEq CH3CH(OH)COOH/g digestate
22.77 mEq CH3CH(OH)COOH/g digestate
45.54 mEq CH3CH(OH)COOH/g digestate
68.31 mEq CH3CH(OH)COOH/g digestate
113.85 mEq CH3CH(OH)COOH/g digestate
91.08 mEq CH3CH(OH)COOH/g digestate
22.77 mEq CH3CH(OH)COOH/g digestate
68.31 mEq CH3CH(OH)COOH/g digestate
91.08 mEq CH3CH(OH)COOH/g digestate
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