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AgroCycle – Developing a circular economy in Agriculture

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Abstract

Continuing population growth and increasing consumption are driving global food demand, with agricultural activity expanding to keep pace. The modern agricultural system is wasteful, with Europe generating some 700 million tonnes of agrifood (agricultural and food) waste each year.

The Agricultural Centre for Sustainable Energy Systems (ACSES) at Harper Adams University is involved in a major research and innovation project (AgroCycle) on the application of the 'circular economy' across the agri-food sector. In the context of the agrifood chain, the 'circular economy' aims to reduce waste while also making best use of the 'wastes' produced by using economically viable processes and procedures to increase their value . Led by University College Dublin, AgroCycle is a Horizon 2020 collaborative project with 26 partners. AgroCycle will address such opportunities directly by implementation of the 'circular economy' across the agri-food sector.

The authors will present (a) a summary of the AgroCycle project and (b) the role played by Harper Adams in the project in evaluating the potential for small-scale anaerobic digestion (AD) technology that can be applied on farm to provide local heat, energy and nutrient recovery from mixed agricultural wastes.

Keywords: Circular econom [1]y; anaerobic digestion; waste valorisation; nutrient recovery

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1. Agrocycle and the circular economy.

Europe is generating 1.3 billion tonnes of waste annually, of which 700 million tonnes are agricultural waste [1]. Given the projected one third increase in world population by 2050 [2], best estimates indicate a need to increase agricultural and food production by two thirds by 2050 to feed an additional 2 billion people to adequate levels of nutrition [3]. This need is compounded by the impacts of climate change on agricultural systems; higher temperatures and changes in global precipitation patterns increase the likelihood of reductions in crop yields and the proliferation of weeds and pests on agricultural land [4].

The above challenges present a major opportunity for the development of a circular economy (CE) using innovative technologies and profitable business practices to address the utilisation of agricultural wastes, by-products and co-products. The development of a CE requires the adoption of closed loop systems which work towards the goals of improved economic and environmental sustainability [5]. The development of such systems is a move away from traditional linear production models that operate via of the conversation of natural resources to products and then wastes [6]. Although there has been a focus on recycling and reducing the impacts of wastes at the end of these linear systems, it has not been effective with increasing levels of wastes not being recycled and ending up in landfill [7]. The CE aims to develop a model that has no net effect on the environment, ensuring that there is a reduction in natural resource use and waste production [6], effectively reducing the wastes to process and designing their utilisation into the systems as valuable co-products.

In the transition towards a circular economy, there is a need to collect and share data, produce exemplars, make innovation investments and facilitate business collaborations [7]. Transition is required at a supply chain level rather than individual company level due to the overarching system development required [6]. This requires evaluation and re-design of existing production systems, incorporating integrated technology solutions that enable the development of the biogeochemical and technical aspects of the circular system. In this context AgroCycle [8] will perform an integral analysis of the agrifood value chain, including livestock and crop production, food processing and retail sector (Fig. 1), providing mechanisms to achieve an increase in the recycling and valorisation of agricultural waste by maximising the use of by-products and co-products via the creation of new sustainable value chains.

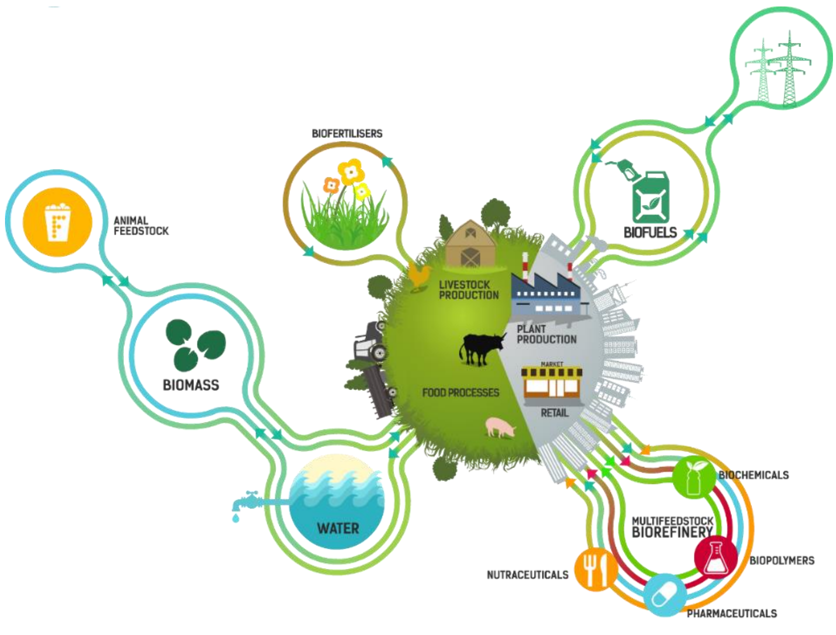

Fig. 1. AgroCycle innovations in the agricultural production chain [8].

AgroCycle is a three-year project with 25 partners from the EU, Hong Kong and mainland China, with the consortium comprising academic institutes, industrial partners, technology providers, economic experts in the agricultural sectors, associations of farmers, end–users of the technologies and associations of the technology providers and policy makers.

The project will develop:

- Pilot case studies to demonstrate the technical feasibility of valorisation technologies
- New business models to demonstrate the economic opportunity for the technologies and processes
- Sustainable value chains analysis, management practices guidelines and policy recommendations
- Joint stakeholder's platform and a series of knowledge exchange activities.

The main objective of the AgroCycle project is to further develop, demonstrate and validate novel processes, practices and products for the sustainable use of agricultural waste, co-products and by-products. Systems under study will be tested and evaluated from technical, environmental and socio-economic perspectives, including their impact on the sustainability of agricultural systems, thereby contributing to the creation of sustainable value chains in the farming and processing sectors. A key aspect is identifying ways to reduce inputs for the same production levels, focusing on waste reduction and recycling nutrients and other processing by-products. Levels of sustainable extraction rates for wastes will be determined, as well as guidance on the optimal use of crop residues for soil improvement taking into account the need to maintain soil organic matter levels.

Specific objectives have been developed spanning all areas of the agricultural supply chain. These include the charicterisation and quantification of agrifood wastes and the feasibility of producing high value products, biofuels and energy from the wastes identified and are outlined below.

Objective 1: To map, characterise and quantify the available agricultural AWCB, including value chain mapping.

Objective 2: To demonstrate the technical feasibility of the production of biofuels from AWCB, over a range of bioenergy conversion technologies.

Objective 3: To develop and evaluate the effectiveness and impact of existing and new biofertilisers from crop residues, livestock effluents and bioenergy effluents.

Objective 4: To demonstrate a generic and modular design process for valorisation, treatment and recycling of nutritional agro-industrial wastewaters and animal effluents.

Objective 5: To demonstrate an integrated bioremediation process for the valorisation, treatment and recycling of pig slurry, this will involve the development of open-pond bioreactors that will be demonstrated at lab and pilot-scales.

Objective 6: To demonstrate the integrated multi-feedstock extraction of proteins, fibres and secondary plant metabolites (SPM) from horticultural waste streams.

Objective 7: To demonstrate the application of extracted biocompounds in nutraceuticals, active packaging, adhesives and coating applications.

Objective 8: To perform environmental and economic sustainability assessments through LCA/LCC.

Objective 9: To implement a joint stakeholder platform for knowledge exchange between stakeholders.

Objective 10: To define sustainable value chains and propose new models for business diversification.

Objective 11: To maximise the innovation impacts of the project for contributing to the uptake of the project results for growth and jobs.

2. Evaluating the potential for small scale anaerobic digestion technology that can be applied on farm to provide local heat and energy recovery from mixed agricultural wastes.

AgroCycle work at Harper Adams University is part of objective 2 and will evaluate the potential for using micro-scale AD technology on a broiler farm to provide local heat, power and nutrients (in the form bio-fertilizer) recovery. The waste litter from poultry production is one area that has been identified for potential benefit from the development of a novel AD system which takes into account the challenges that this waste stream provides.

In the linear poultry production concept, birds are fed grain which requires fertilization, they are housed in sheds which have oil, gas and electricity usage requirements as well as wood chip and straw for bedding. Feed production alone contributes to around 65% of the energy required to produce a bird gas and oil contributing up to 25% [9]. The AgroCycle CE approach aims to utilise wastes from the system to produce heat, energy and nutrients that can be utilized to offset raw material inputs.

While poultry litter, typically a mixture of chicken manure, wood shavings and straw, is rich in both carbon and nitrogen, it is not ideal for use in conventional AD systems due to the feedstock having a high dry matter content (typically 60%) with total nitrogen 30 kg N/t [10]. The high dry matter content would require significant water addition to enable processing in current dry AD systems which are designed to process materials with a range of dry matters between 20 and 40% [11]. An appropriate C/N ratio is also required for the anaerobic digestion process to work effectively which is in the range of 25:1 to 30:1, feedstocks outside this range can result in pH increases to levels toxic to the system [12]. Therefore broiler litter is not suitable as a feedstock in current systems without the addition of other waste streams to balance the nitrogen levels and the redesign of current commercial systems to counteract the high dry matter content. Any system developed for the processing of poultry litter also needs to take into account microbial safety factors, as the litter can contain *Salmonella*, *Campylobacter* and *Listeria* and there are regulations in place governing its use [13].

To address the problems identified above, Harper Adams will work with two industrial consortium members, (1) Carton Bros (Bracetown Business Park, Clonee, Co. Meath), who will provide poultry farm resources in Ireland and (2) Innovation for Agriculture (Stoneleigh Park, Warwickshire CV8 2LZ) who will provide agricultural resources in the UK. Ourselves and our partners have teamed up with other industry partners, including Enviroeye Engineering, PlanET Biogas, Portagester Systems and Keenan Alltech to investigate the development of a novel AD process to address the challenges that broiler litter presents. The expertise assembled covers areas from agricultural production (Carton Bros, IfA), environmental process engineering (Enviroeye Engineering), agricultural materials handling (Keenan Alltech) and AD (Harper Adams, PlanET Biogas, Portagester Systems).

A dry micro AD system will be designed and commissioned for deployment at a commercial broiler farm operated by Carton Bros. The design of a co-digestate mixture using broiler chicken litter and locally available feed resources from nearby dairy and crop farms for optimal efficiencies will be performed. This will address the challenges associated with the dry matter and nitrogen contents, and will run in a thermophilic temperature range to reduce the pathogen loading of final effluents.

Alongside the demonstration facility at the broiler farm a mini AD unit will be commissioned at Harper Adams University to further assess the digestibility of the mixed wastes and their effluents. These two demonstration units will form the basis of a novel two-phase AD system to fully utilise the agricultural wastes available on site alongside the poultry litter and wastes which will be provided by AgroCycle consortium members. The general concept is shown in Figure 2 below.

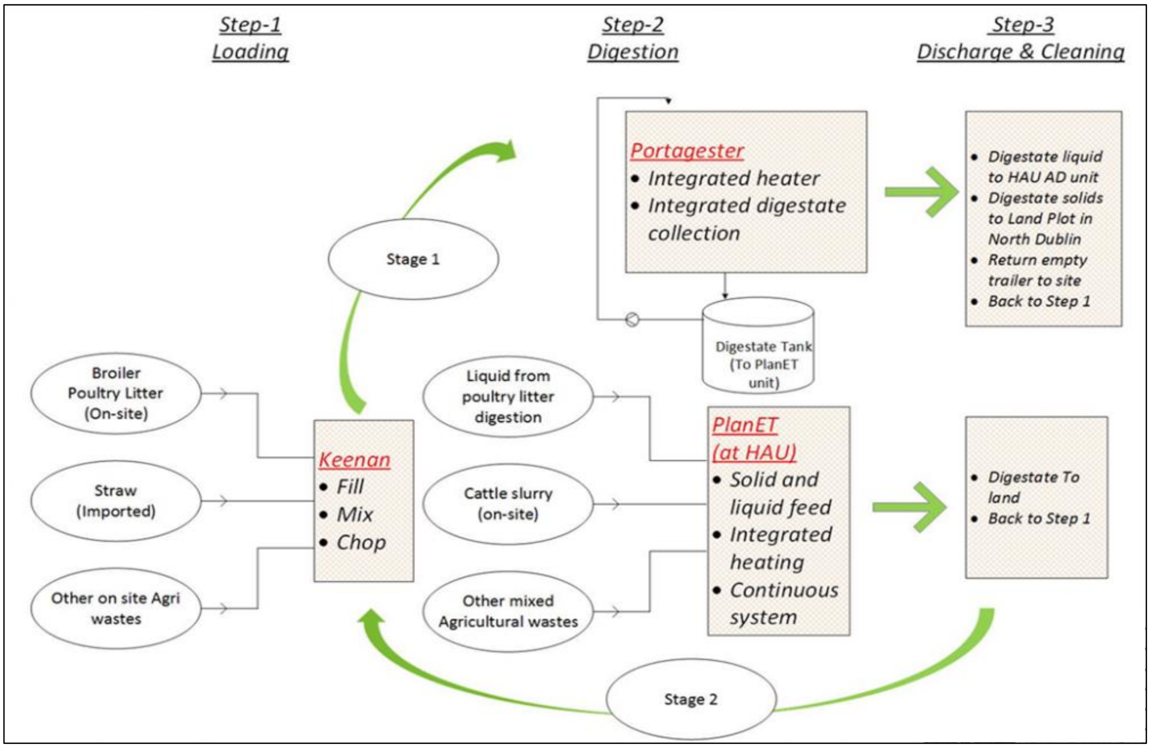

Fig. 2. Outline research concept for the treatment of mixed agricultural wastes including poultry litter from broiler production.

In addition, impact of AD digestate application on the microbiological communities in the soil (pathogens, beneficial soil microbes) will be researched. Importantly, contamination risks will be assessed at all stages, the bio-security chain will be kept intact, avoiding carryover of pathogens from one system to another.

The valorisation of mixed agricultural wastes via AD will be analysed from the three pillars of sustainability – social impact, environmental impact and economic impact following life cycle assessment methodology. This will be carried out following guidelines set out by the AgroCycle LCA protocol [14] and will allow for evidence based decisions to be made on whether the valorization pathway is beneficial, and therefore sustainable.

Once the novel system has been developed and results analysed a number of demonstration and knowledge transfer events will be organised to ensure that the best practice developed is communicated to relevant stakeholders.

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