CHALLENGES IN THE ANAEROBIC DIGESTION OF HOG MANURE

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BACKGROUND

Anaerobic digesters using hog manure as a primary feedstock have operational requirements different than those using dairy manure as a result of the diet of hogs as compared to dairy cattle. The mechanisms needed to facilitate the anaerobic digestion of hog manure are well understood and, as a result, many hog digesters are successfully operational in Europe. However, the extensive use of chemicals in hog barns needs to be assessed on a case-by-case basis in order to manage and/or mitigate their presence in the manure and, subsequently, the digester. This is of particular concern when disinfectant chemicals and antibiotics are used as they can be highly detrimental if present in a biogas plant.

Anaerobic digestion is a highly complex process containing an immeasurable quantity of biological and physiochemical reactions. These processes take place at the same time, inducing many different interactions between chemicals and microorganisms. While it is normal to have certain inhibiting substances in an anaerobic digester, such as ammonia, if the concentration of toxic substances reaches a critical level, anaerobic digestion and biogas production will stop. Consequently, an understanding of the toxic and inhibiting factors present in a biogas plant and their interaction with the digestion process is crucial for achieving optimal biogas production and economic returns.

An anaerobic digester is essentially a bioreactor containing several kinds of microorganisms, supplied through the introduction of sewage sludge or manure. Each microorganism has a different anaerobic metabolism and is sensitive to diverse physiochemical conditions. Consequently, the state of the biocoenosis depends on the composition of the substrates and how microorganisms themselves convert the given substrates. An abundance of nutrients and optimal environmental conditions result in the growing and reproduction of microorganisms, which in turn allows for a high conversion rate of substrates. However, if this conversion of substrates results in a lack of nutrients or an increased concentration of a critical chemical, some microorganisms will starve or be inhibited. Therefore a bioreactor is seen as a closed system where all components, whether chemical or biological, participate in one or more reactions to maintain system equilibrium.

In the fields of microbiology and environmental engineering, laboratory research is performed regularly to define the most important processes. As Genesys Biogas Inc. has found, these processes can be replicated by computer simulation.

WHY MATHEMATICAL SIMULATION?

As a result of relatively low energy prices in Canada, Biogas project developers were forced to use high strength feedstock in order to achieve adequate energy production, ultimately pushing biogas systems to their limits. Consequently, some equilibriums in the digestion process are shifted to a critical level that could endanger the methanization process or even the operation of the entire biogas plant. Predicting these cases of system decline or failure is essential for project financing. Traditionally, predicting either relies on time-consuming and expensive lab-tests.

To reduce costs and time, Genesys Biogas Inc. developed a mathematical model to simulate the anaerobic digestion process in order to predict the biogas yield and stability of the entire digestion process. The model is based on the Anaerobic Digestion Model No.1 (ADM1) of the IWA task group and the simulation is done with a program known as Aquasim. Genesys Biogas Inc. further developed ADM1 with several processes and adjustments concerning high strength substrates.

So far, biogas composition, biogas yields, pH, and levels of organic acids predicted by Aquasim have matched lab results quite closely. Aquasim further allows the identification of ammonia inhibition as a cause for increasing acetate concentration in the lab test.

RELIABILITY OF THE ANAEROBIC DIGESTION MODEL

The extended ADM was compared to different laboratory results to determine the accuracy of the computer modelling.

BMP Tests

The energy content of a substrate is usually determined by a laboratory batch digestion study, known as a Biochemical Methane Potential test (BMP). Genesys Biogas Inc. simulated BMP tests of two different high strength substrates:

- Substrate 1, a by-product from a milk processing plant.
- Substrate 2, a by-product of a down-stream process in the Bioethanol production.

Figure 1. **Simulated biogas production compared to measured biogas production in the laboratory for the BMP test of substrate 1.**

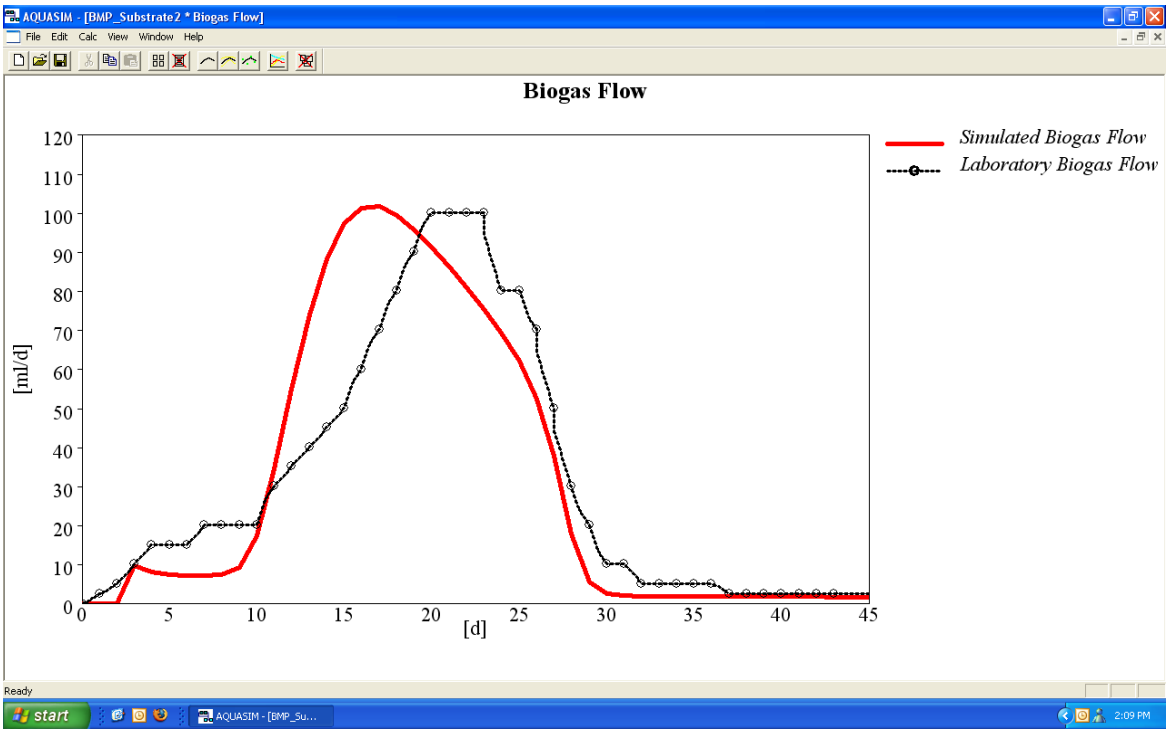
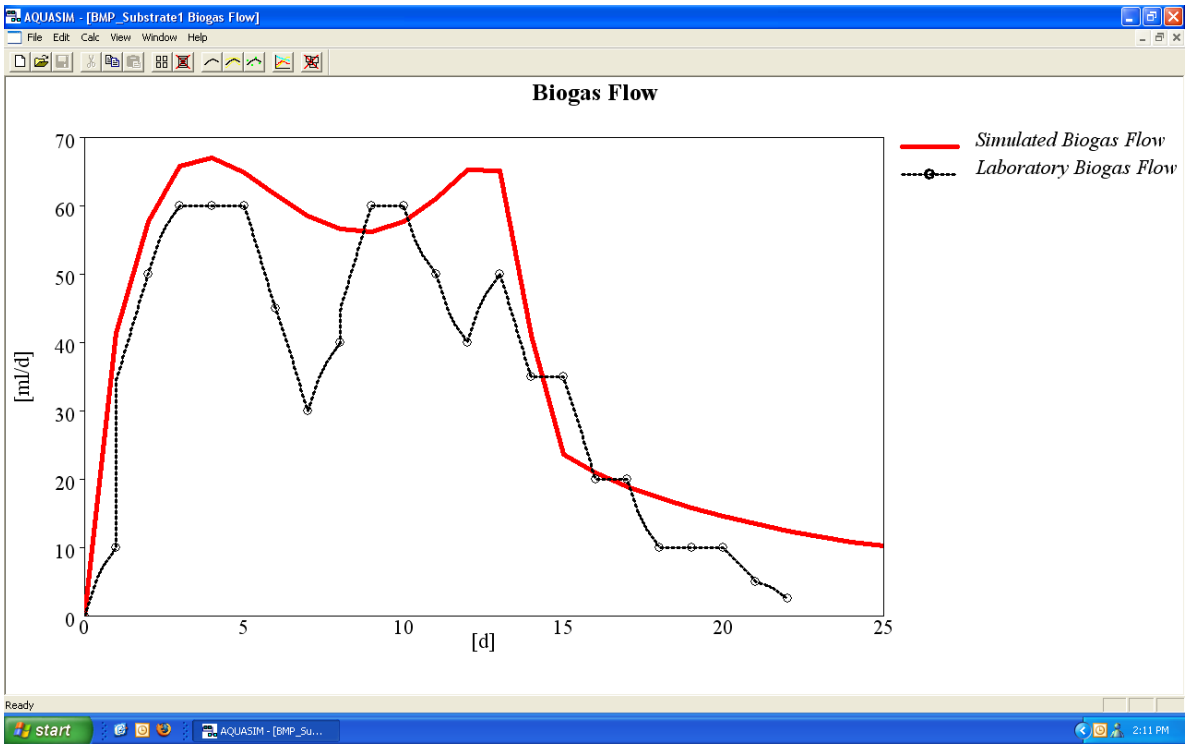


Figure 2. **Simulated biogas production compared to measured biogas production in the laboratory for the BMP test of substrate 2.**



Semi-Continuous Flow Digestion Study

The model was used to simulate a semi-continuous flow study of a Bioethanol by-product over 45 days. Prediction of levels of organic acids, biogas yield and pH are compared to lab results (Figures 3, 4 and 5).

Monitoring Study of Fepro Farm's Biogas Plant

Fepro Farm's biogas plant has operated on dairy manure for several years. The process is under steady state conditions. Based on the available data from the laboratory, values of organic acids and pH were compared to the simulation by Aquasim (Figures 6 and 7).

Figure 3. Simulated concentration of acetic acid and propionic acid compared to measured concentrations in the laboratory for the 4L semi-continuous flow reactor over 45 days.

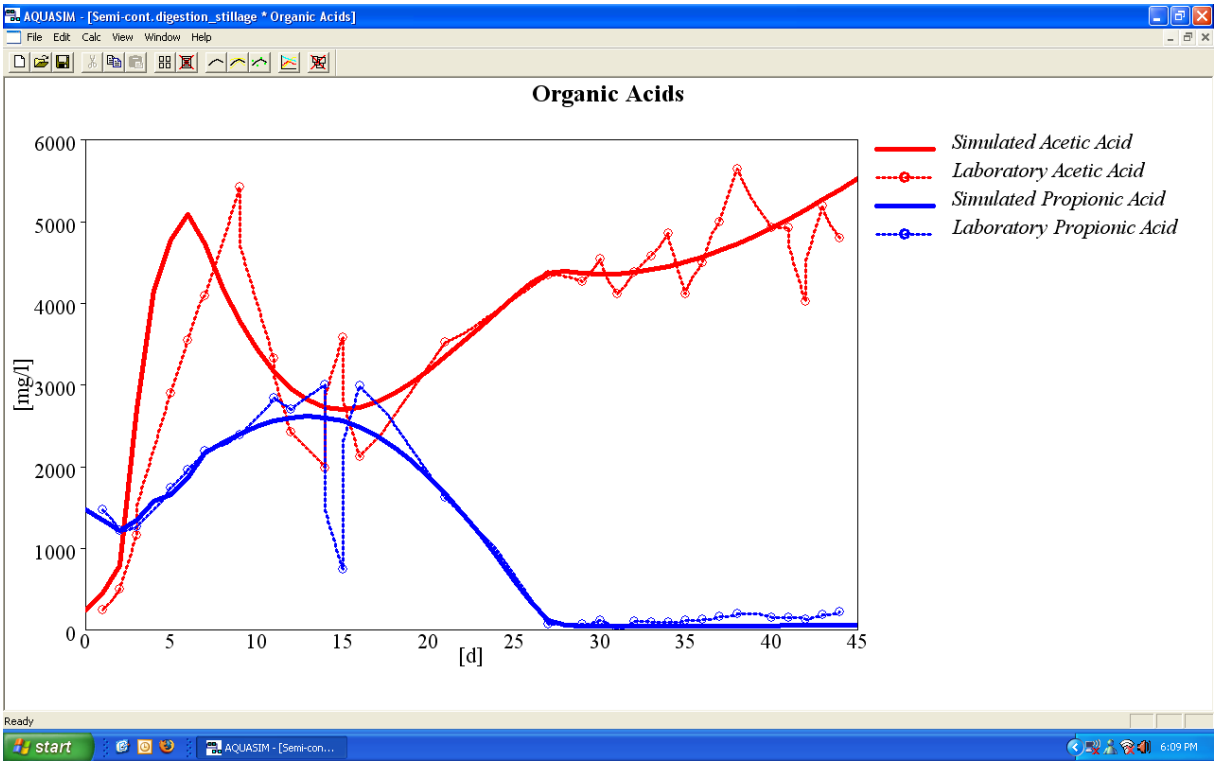


Figure 4. **Simulated pH values compared to measured pH in the laboratory for the 4L semi-continuous flow reactor over 45 days.**

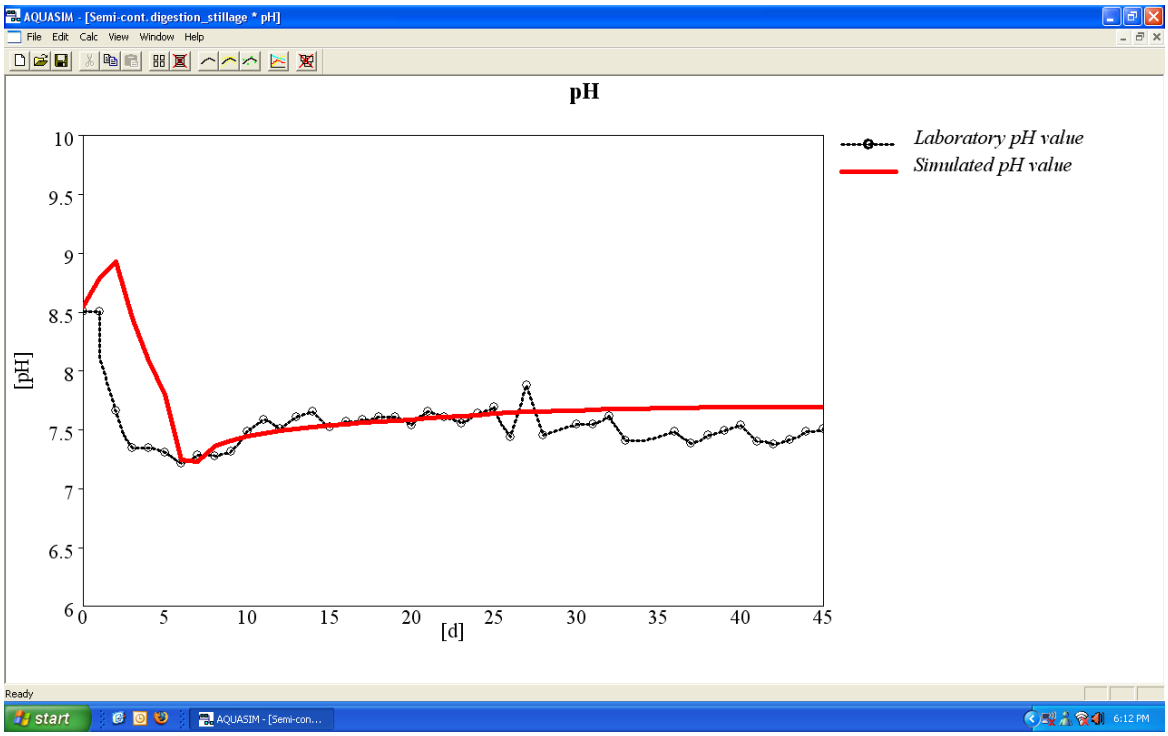


Figure 5. **Simulated biogas flow compared to measured biogas flow in the laboratory for the 4L semi-continuous flow reactor over 45 days.**

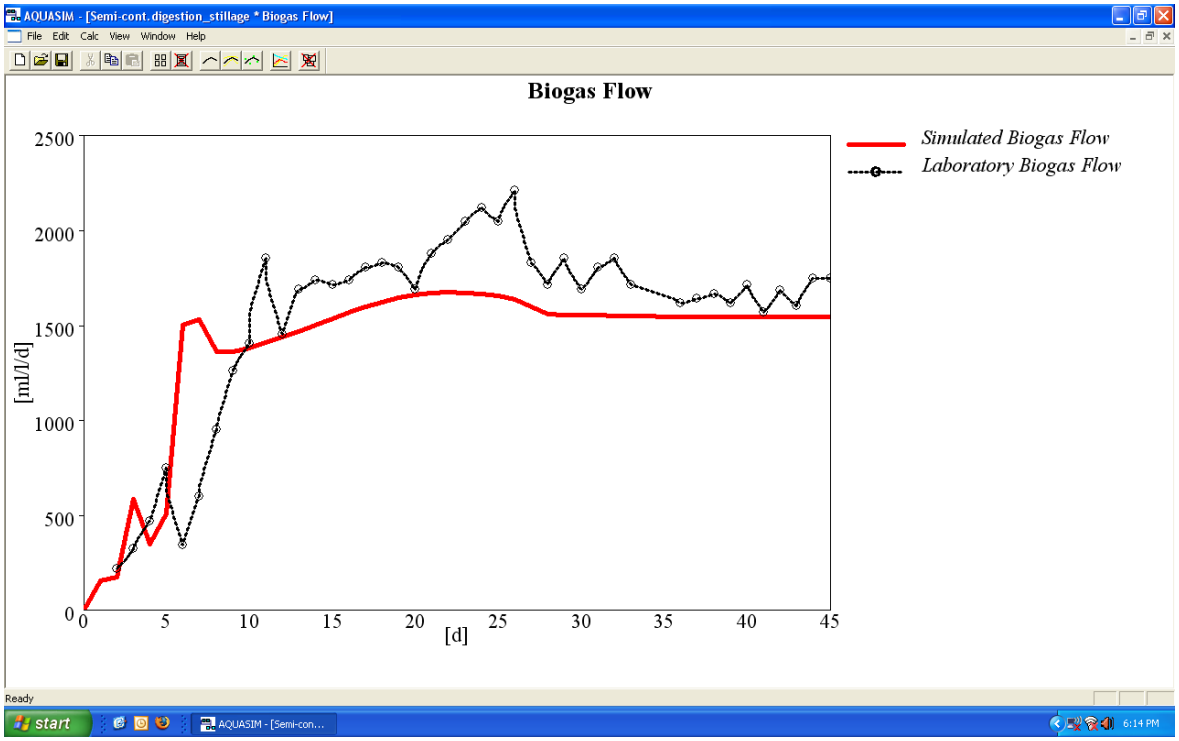


Figure 6. **Simulated concentration of acetic acid and propionic acid compared to measured concentration in the laboratory for the Fepro Farm's biogas plant over 200 days.**

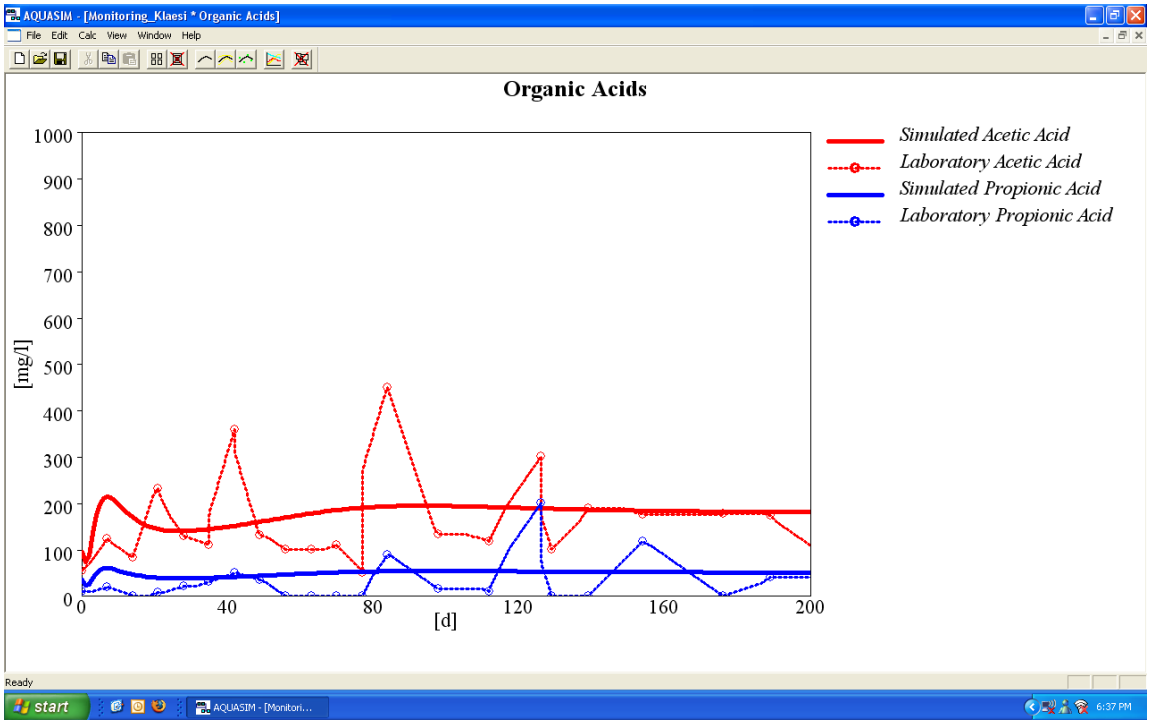
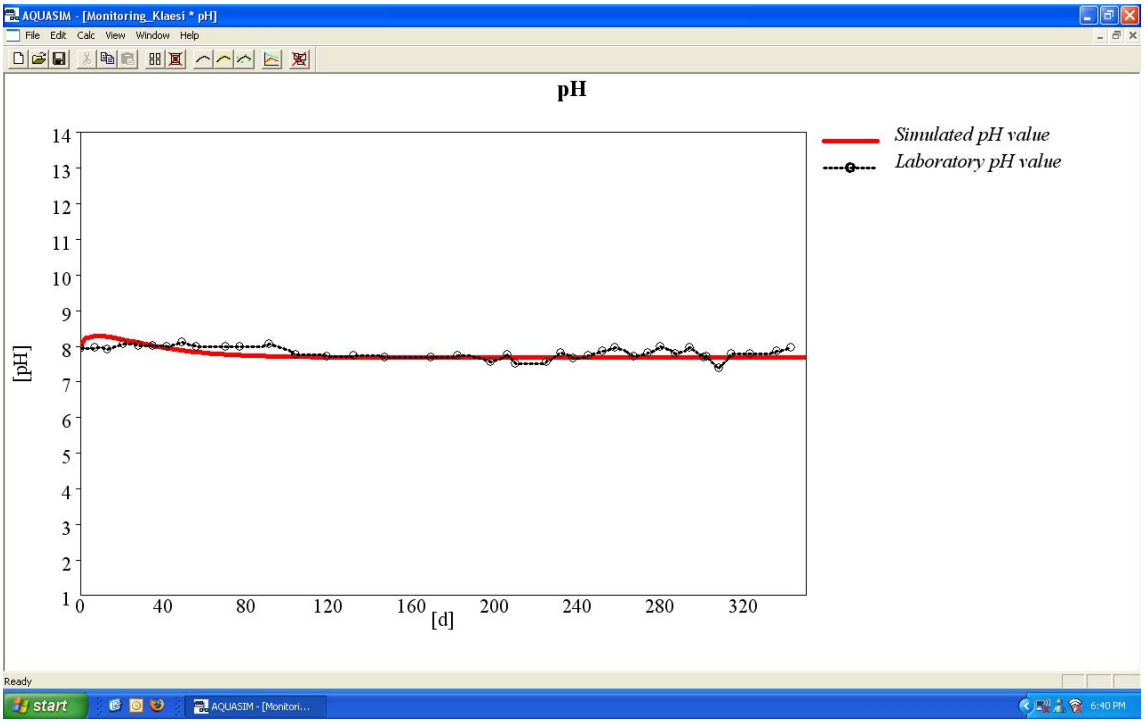


Figure 7. **Simulated pH values compared to measured pH in the laboratory for the Fepro Farm's biogas plant over 340 days.**



DISCUSSION / OUTLOOK

The modelling of the biological and chemical processes during anaerobic digestion creates a new opportunity to predict the potential and limits of high strength substrates. The enhanced model developed by Genesys Biogas Inc. produces an accurate description of the properties of potential biogas system substrates. This tool provides the opportunity to choose the most useful substrates in your area without time-consuming lab tests. Consequently, it reduces evaluation cost during project planning.

The main benefits for our clients are:

- Evaluation of new substrates with unknown behaviour
- Reduced cost for substrate evaluation
- Time benefit with few or no lab tests
- Process stability verification
- Prediction of critical components
- Establishment of operational safety margins
- Predicting steady state conditions including biogas yields of industrial organic by-products and its interactions with other substrates present
- Performance optimization of existing digesters
- Yield analysis and substrates behaviour of complex interactions in a digester
- Early warning systems for critical digester feed rates and problematic substrates
- Optimizing digester feeding regime, optimizing substrate blending in single stage and multiple stage digestion

Due to the immense number of biological and chemical processes within an anaerobic digester, this enhanced model has a great deal of potential for continued development. As a result, Genesys Biogas Inc. continues to refine the model in order to increase the accuracy of simulation and the diversity of its application.