Sustainable Energy for Cashew Production Chain Using Innovative Clean Technology Project Developments

Pannir Selvam, P. V[1];
[2]Julio Nandenha;
[3]Brunno Henrique de Souza Santiago;
[4]Rosália Tatiane da Silva.
[1]Professor. PhD em Engenharia Ambiental; [2]Graduando em Engenharia Química; [3]Mestrando em Engenharia e Ciência dos Materiais e [4]Engenharia Agronômica
Grupo de Pesquisa em Engenharia de Custos e Processos - GPEC - DEQ/CT/UFRN[1, 2, 3 e 4]
Campus Universitário – Lagoa Nova, CEP: 59.072.970
Fone: (084) 215-3769 R-30 Fax: (084) 215-3770
e-mail: pannirbr@gmail.com e www. gpechp.cjb.net

RESUMO

O objetivo principal é desenvolver uma síntese de processo nova baseada no desperdício residual de biomassa para a produção de energia aplicada à planta processando de fruta com co-producão da calor e Energia Foram realizadas pesquisa bibliográficas sobre o estado atual da arte, desenvolveu se projeto de engenharia com o uso de software Super Pro Designer vs 4.9. Foram feitas simulações dos processos do pirolise rápida, gaseificação, biodigestão, incluindo a integração de sistema da produção de energia como a inovação do trabalho atual. Um estudo de três casos foi desenvolvido: primeiramente, o processo atual da energia convencional usando a combustões , outro com usar o pirolise e gaseificação combinados com cogeração , e último com o biodigestão. Os resultados sobre o investimento do projeto e a análise de custo foram obtidos usando o software Orc2004. Diversos parâmetros tecno-econômicos do estudo de casos selecionado que envolve a inovação processo foram obtidos e comparados, onde uma utilização melhor da energia e dos materiais foi observada com relação ao processo convencional. Este projeto que se realiza ainda na fase do desenvolvimento, envolve a integração energetica do processo. O projeto do sistema em pequena escala demonstra a viabilidade e sustenabilida energética nas cadeias produtivas de fruta, principalmente do caju, isto com a aplicação de tecnologia limpa que possibilitou melhoria significativa do ponto de vista econômico e ambiental usando o configuração ótima de sistema desenhados.

ABSTRACT

The main objective is to develop a new process synthesis based on the residual biomass waste for the energy production applied to the fruit processing plant with co-production of hot, cold thermal energy using biogas from the wood biomass and animal wastes. After carried out the bibliographical research about the current state of art technology, an engineering project had been developed with the use of the software Super Pro Designer V 4.9. Some simulations of processes of the fast pyrolysis, gasification, biodigestion, generation of energy have been realized including the system integration of energy production as innovation of the present work. Three cases study have been developed: first, the current process of conventional energy using combustion, another one with using combined pyrolysis and gasification, and the last one with biodigestion for combined power, heat and chilling. The results about the project investment and the cost analysis, economic viability and cash balance were obtained using software Orc2004. Several techno-economic parameters of the selected cases study involving process innovation were obtained and compared, where a better energy and materials utilization were observed in relation to conventional process. This project which is still in development phase, involves small scale energy integrated system design .The energy and the process integration cashew fruit production chain based on the clean technology process deign is made possible with significant improvement of the economy and ecology and optimum system configurations with viability and sustainability.

1. Introduction

Economic and ecological utilization of the biomass wastes from cashew nut production and cashew fruit processing is still not yet fully solved as several technical problems of solid and liquid effluent and energy generation are very complex system [1-2] The need to decrease the pollutants emitted by the cashew apple wasted as this is nearly 70 percent of total production in Brazil and this makes necessary to consider different alternatives of process and product design. The fundamental approaches in process analysis (synthesis, modelling, and design) have particular attributes, require different types of information and provide results applicable in several ways. The system design for small scale energy production from wastes integrated with small enterprise such as fruit production and processing industry involve dynamic system design and operation to attain economic and ecological of sustainable local development.

The main objective of the present work is to report our research study made on the system design, analysis and optimization tools which lead to the best value of the input variables and/or model parameters of the complex integerated biomass projects for fuel, food and protein feed production based on the total integral utilization cashew production chain. The use of computational modeling and dynamic simulation approach and the system design based on energy and environment concerns are also reported. The cashew production chain and fruit processing small industry generally produces a l significant amount of vegetable biomass solid wastes as well as the effluent from fruit processing industry. This leads to disposal and pollution problems. The fuel wood is the major source of energy for the most rural and low-income people in the developing world .The potential supply of fuel wood is dwindling rapidly, leading to the scarcity and environmental degradation. The waste can be used sucessfully to replace the fuel wood in both the cashewnut shell and cashew apple procesing[1-5].

2. Methods of generating energy from biomass wastes

Recent years have therefore seen considerable the effort devoted to the search for the best ways to use these potentially valuable sources of energy by 3 methods, it is possible to order them by the complexity of the processes involved: 1 Direct combustion of biomass, 2 Thermochemical processing to upgrade the biofuel; 3 Biological conversion: Anaerobic digestion for the gaseous fuel production [1-5].

The main product, of some of these processes is heat, which is presently studied for the use in the dairy industry to generate steam for pasteurization. For the other processes the product can be a solid, liquid or gaseous fuel: charcoal, liquid fuel bio oil and Biogas.

2.1 Combustion: The method used in the developing countries

The technology of the direct combustion is the most obvious way of extracting energy from biomass.This is well understood, straightforward and commercially available. The energy content of a cubic metre dry wood is 10 GJ. Bringing a litre to the boil should therefore require rather less than 400 kJ, equivalent to 40 cubic centimetres of wood. In practice, with a simple open fire we might need at least fifty times this amount: a conversion efficiency no better than 20%. [12] Combustion is cause of global warming and since wood contains less sulphur than oil does, less sulphate is discharged into the atmosphere. This means less acid rain and less acid in the environment.This process is now used to prove heat or roasting the cashew nut and sweet jams from cashew apple

2.2 Pyrolysis: The thermo conversion method

Pyrolysis is the simplest and almost certainly the oldest method of processing one fuel in order to produce a better one. Conventional pyrolysis involves heating the original material (which is often pulverised or shredded then fed into a reactor vessel) in the near-absence of air, typically at 300 - 500 °C, until the volatile matter has been driven off. The residue is then the char - more commonly known as charcoal - a fuel which has about twice the energy density of the original and burns at a much higher temperature. Fast pyrolysis of plant material, such as wood or nutshells, at temperatures of 800-900 degrees Celsius leaves as little as 10% of the material as solid char and converts some 60% into a gas rich in hydrogen and carbon monoxide. This makes the fast pyrolysis a competitor with conventional gasification methods but like the latter, it has yet to be developed as a treatment for biomass on a commercial scale. [10] Wood gasification is also called producer gas generation and destructive distillation. The essence of the process is the production of flammable gas products from the heating of wood. Carbon monoxide, methyl gas, methane, hydrogen, hydrocarbon gases, and other assorted components, in different proportions, can be obtained by heating or burning wood products in an isolated or oxygen poor environment [11]. This is done by burning wood in a burner which restricts combustion air intake so that the complete burning of the fuel cannot occur. [12].Some fast pyrolysis are used in remote rural for roasting the cashew nuts using wood as energy as low cost social technology in the north east part of Brazil where as the hot cashew nut liquid is used as energy source for fast pyroysis in the large scale processing of cashew nut processing , where the energy consumption is very high and there is an urgent need for cogeneration of energy and heat based on the residues for the production chain.

2.3 Anaerobic biodigestion: The bioconversion method for fuel production

The gas (Marsh Gas) obtained from the natural waste decomposition process is a mixture of Methane (CH_4) and Carbon dioxide (CO_2) and is commonly called as the 'Biogas'. Anaerobic digestion, like pyrolysis, occurs in the absence of air; but in this case the decomposition is caused by bacterial action. This is a valuable fuel which is in many countries produced in purpose built digesters filled with the feedstock like dung and efluent from the dairy. The input may be continuous or in batches, and digestion is allowed to continue for a period of from ten days to a few weeks. A well-run digester will produce 200-400 m^3 of biogas with a methane content of 50% to 75% for each dry tonne of input. The biogas-production will normally be in the range of 0.3 - 0.45 m^3 of biogas (60% methane) per kg of solid (total solid, TS) for a well functioning process with a typical retention time of 20-30 days at 32°C. The lower heating value of this gas is about 6.6 kWh/m^3. Often is given the production per kg of volatile solid (VS), which for manure without straw is about 80% of total solids (TS).. Biogas applications from animal wastes or a large centralized manure processing system are constrained by limited energy needs, storage complications, difficulties in exporting the energy, high capital requirements, and complexities in operation and maintenance. Despite the many constraints on economic application of biogas, many factors favor continued development and expansion of the technology related to the cashew production chain. These include: Reduction of odors; Improvement of fertilizer quality; Improvement of financial returns as the cost rises for the electricity and fuel that biogas use can offset. Recognition of unburned methane as a potent greenhouse gas that may contribute to climate change cause it is estimated to have 21 times the global warming potential of its primary combustion byproduct, carbon dioxide [2] .Many systems use engine waste heat in Europe, but mostly it is used for anaerobic digester heating (maintaining digester temperature around 100ºF). Biogas-fueled engine-driven chillers are probably not suitable for most operations that are needed for fruit processing that would like cooler temperatures than 42ºF to 44ºF for raw material and product storage ; even though the cooler temperatures are best obtained by an direct electric unit.

3. Materials and methods

Recently several software are made available that can be applied to biomass utilization process, which also focus on the computer aids for engineering economics. To use this one, several input data and mathematical model need to be developed first for material balance, preliminary design and process economics. These models and program were tied together into an integrated process design in easy to use electronics spreadsheet computer programs or process simulator. [6] A conceptual design of the bioconversion process was constructed using current laboratory and technical data. The flow sheet development was done using **SuperPro Design** process simulator and other subsystems. The key process economics parameters used for simulation are based on the data reported by our earlier research works. [6] Different process design and simulations were made.

Three scenes had been developed, in the first case study for small scale cashew nut processing units 5T/day, being first a system of pyrolysis for generation of biomass energy as charcoal and fuel gas and as the inovative integrated pyrolysis/gasification in separate reactor systems. This innovative system has maximum energy efficiency giving solid and gaseous fuel optimized for the fuel for combustion the micro-plant of the cashew production chain to meet the energy demand of this chain. The second case study was made about the use of combined pyrolysis and gasification and the third one about the potential of the anaerobic treatment of the residues as renewable energy source of methane gas, based on the concept of sustainable development and rationalized production without aggression to the environments. This technology is based on the energy conservation strategy and efficient energy use. In a confinement of 100 cows, a biodigestor can produce a volume of 118 m3 of biogas and a generating group of from 8-15kVA and this to assist with electric energy the demand of the fruit processing installation and water pump. The total demand of the biogas that working with these equipment is estimated to be 85,3 m3 of biogas, which can be supplied with rest by the biodigestor. In the third case study small scale f 500 L/day of cashew apple processing is considered as the basis for the design for energy and environmental conservation. This volume of the biogas is enough one to generate mechanical energy using internal combustion engine adopted with the gasoline Otto engine to run biogas and this to assist with electric energy to the demand of the fruit proceesing installation and the pump for the chilling. The system design of cogeneration involved the flow sheeting of several major components: Animal Production Facilities; Manure/Effluent Handling System; Digestor Tank; Heating & Mixing System Biogas Cleaning & Handling System; Biogas Storage; Energy using biogas engine; Waste heat recovery system; Heat pump system for chilling and hot water. The gas handling system removes biogas from the digester and transports it to the engine or burner needed for fruit processing unit.

The heat pump selected for this work is based on the innovative and well optimized design made possible recently by the research group in UNICAMP/Brazil which can run using R22 heat transfer refrigerent fluid. The use of ethanol and water mixture as heat transfer agent for heat pump to produce hot water, chilling and ice making has been also well studied by this group. We applies this UNICAMP/Brazil process to our cashew apple processing energy needs for fruit Jelly and Jam making from cashew.

4. Results

This system is used for fruit processing industry for the conservation using the heat for pasteurization the cashew apple juice . The main equipment used are anaerobic biodigestores, the combustion furnace , the heat recovery system using heat exchangers are used for food conservations.

The first case study made involves the pyrolysis system , making the charcoal, the heat is recovered from exit gas , where as the the second case study envolved combined pyroysis , using the charcoal for gasification that was be used for heat generation using heat engine for combined heat and energy recovery.

The main assumptions made in the model are related to the inferred value of the solids properties and the use of transfer coefficients for thermal and kinetics constants. The values of these constants assumed are validated by the simulation results comparing it to the real process published results. In the following Figure 1, the complex process scheme of the final case study made based on the design for Environment using computer software are outlined. In this work, we designed the flow sheet for the processing the waste and also the whole heat recovery system based on the biomass fuel heating in regard to recirculation of the hot water. From the results obtained, it was observed that the heat transfer thermal fluid is very important design components. In fact, the industrial thermal fluid heater may be a robust substitution for the hot water boiler typically used in a conventional heating system with the wood combustion, gasification and pyrolysis

We also designed the flowsheet (Figure 02) for the processing the animal waste using anaerobic bioconversion and also the heat recovery system based on the gas for heating and recirculation of the hot water. From the results obtained, it was observed that the biodigestor dimension is very important design components. In fact, for the small scale , the biogas combustion system appeared to be very simple that may be a robust substitution for the hot water boiler typically used in a conventional heating system , but with greater energy loss. All the system need the energy integration using the heat recovery .In the case studied cogeneration make the project more complex than the other simple system as shown below.

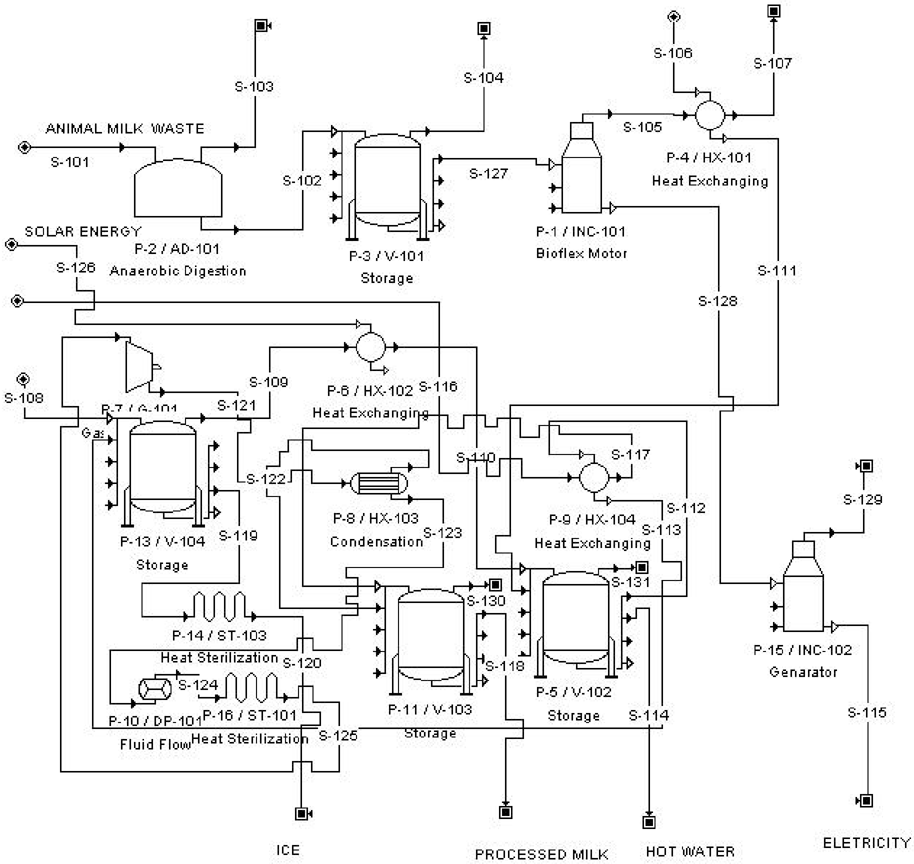

Figure 01 - Process flow diagram Cogeneration of energy using software SPD vs 4.9

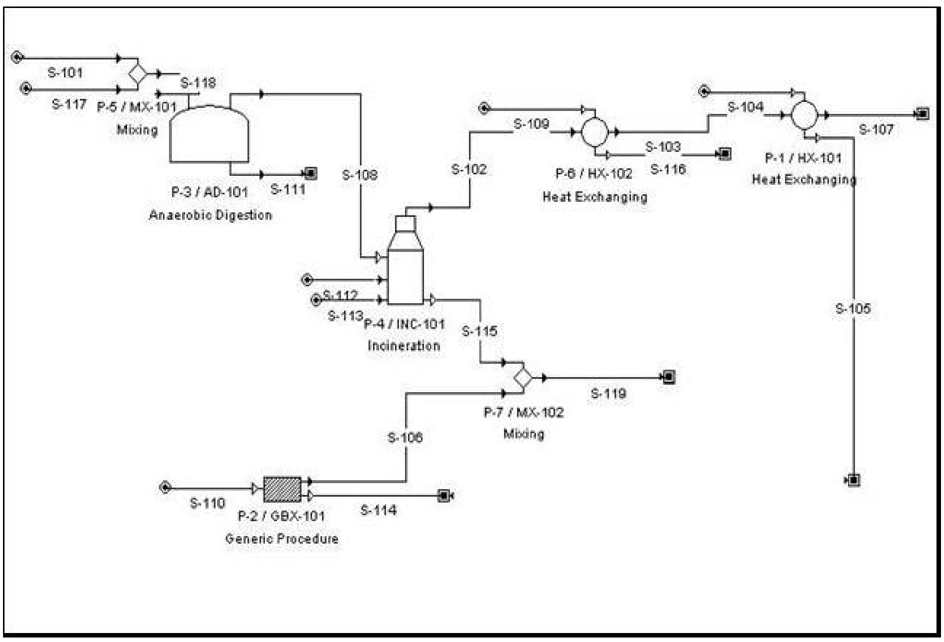

Figure 2 Process flow diagram of bioconversion process for energy using software SPD 4.9

4.1 "Optimum" Configuration of integrated Energy system

Obviously there are many, many permutations that are available for the combined use of the thermo conversion using pyrolysis and gasification as well as the bioconversion. Before we started the detailed case studies, we made with an energy audit of the animal and fruit system both in the production and processing units. Material balance of all the solid liquid flows and then made a tally of all of the energy uses that can be readily supplied using biogas. The energy and environmental audit is done using three case studies taking into account the energy consumed, the uncertainties of the biogas supply based on the scale and the efficiencies of biogas production. The entire integrated system requirement is first analysed and the process design was achieved from the result obtained by the process simulations and optimizations and the result of several techno economical parameters. Our result as well as the other studies shows that significant amount of residues from cattles, goats, poultry are required which are available plenty as by the data obtained by our research work which can be supplemented by the grater quantities of cashew apples waste and residues of the production chain. The result is that export or energy generated from biomass wastes can be made possible economically especially in the several tropical countries such as Brazil where hot climate can favour very well the biogas production. The integrated system design approach used in this made possible to determine whether the economics of selling electricity, fuel, the ice, the liquid fertilizer justifies the higher incremental capital cost of the engine-generator, the associated higher maintenance costs, and increased processing costs. The best optimized system has co-products together with the heat recovery using heat pump coupled to the low cost gasoline engine adopted to the biogas making the system designed more desirable ecology and energy sustainable related cashew processing and production chain

5. Conclusions

The present study allows the observation that the integration of the tools of process modelling with environmental and energy analysis using the results of each one of them in sequence real problems. This together with the process synthesis with the qualitative analysis and the flow sheet development with the quantitative and detailed process economic analysis are important step towards the solution the complex problems. With this methodology, the results obtained in an environmental analysis were used as the input information in a new modeling. The bioconversion process is shown to be better than the thermo conversion based on the environment and energy concerns related with the cashew production chain, where as from the resource availability and sustainability point of view thermo conversion shown to more sustainable with relation to bioconversion. The cogeneration system is too complex too complex to apply to rural energy , require trained man power to design and operate.

System design work for the energy production for production chain including the cashew nut an apple processing in the large and small scale was successfully carried out. The energy integration was made possible with the use of the dynamic simulation based on the computation models for the environments, several software tools for the system design, analysis. The optimization of the complex system integration had been for sustainable economical and ecological development were made possible. In the future, the present work models and methods should permit the sustainable energy for the small dairy units to be implemented with significant economical benefits with reduced risk for the sustainable production chain based on cashew

6. Key-Word: **Sustainable Developments, Clean Technology , Biogas e Thermochemical processing, Biomass , Cashew .**

7. Acknowledgments

The authors are greatfully acknowledged the 'Conselho Nacional de Desenvolvimento Cientifico e Tecnológico (CNPq)' their financial support and MCT fundo setorial de agronegocio

8. References

[1] Pannir Selvam, P. V. et al. **Process Biochemistry**. 18, (3),13, 1983.
[2] Carioca, J. O. B. et al. **Biotechnology Letters**. 7, (3), 213, 1985.
[3] Pannir Selvam, P.V. et al. II Seminário sobre Hidrólise Enzimática de Biomassas. Maringá-Brazil, 1985.
[4] Carioca, et al. **Energy from Biomass-Impact of Science on Society**, nº 148, 1988.
[5] Dale, Bruce E., **Biomass refining: protein and ethanol from alfalfa**, Ind. Eng. Chem. Res. Dev., Vol. 22, nº 3, p. 466-472, 1983.
[6] Rud, D **Estrategia Wen Ingeniera de Processo**. Ed. Alambra, Madri-Espana, 28, '76.
[7] Matley, J., (1984), **Modern Cost Engineering: Methods and Data.** Chemical Engineering, Mc Graw Hill Publications, V. 2, p. 265-269, New York.
[8] Nguyen, Q A., Saddler, J. N., (1991), **An Integrated Model for the Technical and Economic Evaluation of an Enzymatic Biomass Conversion Process**. ioresource Technology, Vol. 35, N. 3, p. 275-282.
[9] Hall D., Rosillo-Calle. **Biomass for energy. Renewable Energy. Sources for Fuels and Electricity**. Island Press 1992.
[10] Thomas, S. (1990). **Evaluation of Plant Biomass Research for Liquid Fuels** (Brighton, Science Policy Research Unit, University of Sussex), report, 2 vols.
[11] Williams, R. H. (1989) Biomass **gasifier/gas turbine power and the greenhouse warming, presented**. EA/OECD seminar, OECD Headquarters Paris 12-14 April '89
[12] Williams, R. H., and Larson, E. D.(1992). **Advanced gasification-based biomass power generation**, in B.J.Johansson, H. Kelly, A.K.N. Reddy and R.H. Williams (eds.),Renewables for Fuels and Electricity (Washington, D.C.,Island Press), chap. 17.