O-STARCH-9

Environmental impact valuation model of cassava pulp utilization alternatives

Sivalee Trakulvichean[a], Pawinee Chaiprasert[a] and Warinthorn Songkasiri[b]

[a]Devision of Biotechnology, Faculty of Bioresources and Technology,
King Mongkut's University of Technology Thonburi, 49 Soi ThianThale 25,
Bang KhunThian Chai Thale Road, ThaKham, Bang KhunThian, Bangkok 10150 Thailand
[b]Excellent Center of Waste Utilization and Management (ECoWaste), National Center for Genetic Engineering and Biotechnology (BIOTEC), PDTI Building,
King Mongkut's University of Technology Thonburi, 49 Soi ThianThale 25,
Bang KhunThian Chai Thale Road, Tha Kham, Bang KhunThian, Bangkok 10150 Thailand
[b]Corresponding author; Tel.:+668-6909-4210; E-mail: warinthorn@biotec.ac.th

Abstract

Cassava pulp is solid waste produced approximately six million tons/year from the starch industry. High starch content (approximately 40-60% dry basis) and other nutrients in pulp cause environmental pollution. However, most utilization alternatives for pulps are not economically viable. The overall objective of this research is to assess economic and environmental impacts of various utilization alternatives using Total Cost Assessment (TCA) to later define an appropriate option(s) for the industry. The selected options are plant-supporting material, animal feed, biogas, and ethanol. This paper emphasizes on the development of environmental impact valuation model. The boundaries were scoped to gate-to-gate of a new plant with a receiving capacity of 600 tons/day of pulp (equivalent to pulps from a 200-ton starch factory). The model is mainly developed from the concept of Total Economic Value (TEV) and Life Cycle Impact Analysis (LCIA). Impacts on resource depletion and quality of life were evaluated based upon TEV, while general ecosystem impacts, i.e. global warming, acidification and eutrophication were evaluated based upon LCIA. The environmental impact is converted to economic value using the severity and the weighting impact factors. These weighting impact are compared to Global Warming Potential (GWP) using carbon credit price. One starch factory currently sells wet and dry pulps as animal feeds with an economic value of 44.4 million baht/year. The GWP of the option of plant-supporting material and fermented animal feed were calculated to be 19,440 and 13,340 kg CO_2 e/unit, respectively. The calculations were based on a 3-year operation period.

Keywords: Cassava Pulp, environmental impact valuation, environmental valuation model

1. Introduction

Cassava starch industry plays an important role in the Thai economy. Cassava can be processed into various products, such as cassava pellets and cassava starch, for many industries as diverse as animal feed, food, and paper industries. Thailand has approximately 70 native starch plants and more than 70 percent of cassava products are exported overseas (Department of foreign trade, 2010). Thailand, which is the third largest producer of cassava in the world, is the largest exporter of cassava starch in the world with 70% market share (Office of Agricultural Economics. Ministry of Agriculture, 2011; Ministry of Science and Technology, 2010). In 2011, the export value of native cassava starch products was approximately 40 billion baht. Although cassava starch industry has high economic value, the industry generates a large amount of solid waste, cassava pulps, from the production process.

The production of 1 ton starch generates approximately 1.4 tons of pulps (60% moisture content) (Chavalparit and Ongwandee, 2009). As an example, the production of 4.27 million tons of starch in 2009 generated approximately 6 million tons of pulps (Office of Agricultural Economics, Ministry of Agriculture, 2011).

Cassava pulp contains high starch content of approximately 40-60% dry basis. The starch loss in cassava pulp is accounted for 30 percent of the total starch loss. Incomplete drying of cassava pulp during rainy season generates strong odor as environmental pollution. As a consequence, cassava pulp is classified as waste by the Department of Industrial Works (DIW). DIW set the rules and procedures for waste management. For example, cassava pulp must be in possession as wastes within the plant not over a period of 90 days. If more than the period specified, the factory must inform and ask for permission from DIW. Further, the transportation of waste offsite must be reported. The starch factories are now in the process of finding best available alternatives for on-site cassava pulp management.

Thus, the objective of this research is to assess economic and environmental impacts of various utilization alternatives using Total Cost Assessment (TCA) to later define an appropriate option(s) for the industry. The selected pulp utilization options are plant-supporting material, animal feed, biogas, and ethanol. This paper focuses on the development of environmental impact valuation model. The research will later define an appropriate utilization option(s) for the cassava starch industry.

2. Methodology

2.1 Data collection and utilization option

Primary and secondary data were collected from literature reviews, survey, and field data. Data on the current cassava pulp utilization options were collected from a cassava starch factory in the East of Thailand. Interviews were conducted with 15 pulp buyers. This paper presents the application of environmental impact valuation model of the two utilization alternatives of animal feed and plant supporting material.

Data on fermented cassava pulp for the animal feed (beef and dairy cow) were collected from Baansuan Pirada Green Ranch Farm, Yasothon Province, Thailand. This farm has the pulp utilization capacity of 12-18 tons/month. Data on plant supporting material for the straw mushroom farm was collected from Baan Nongwa Farm, Chacherngsao Province, Thailand.

2.2 Boundary

The boundaries were scoped to gate-to-gate of a new plant with a receiving capacity of 600 tons/day of pulp (equivalent to pulps from a 200-ton starch factory).The calculations were based on a 3-year operation period. In each cassava pulp utilization option, the following factors were focused: machine/equipment, materials, waste management, regulatory compliance and testing for quality control process.

3. Result and Discussion

3.1 Current cassava pulp utilization option

Data on the current pulp utilization option of the Chonburi starch factory were collected during the period of January to December, 2012. The company sold the wet and dry cassava pulp for 48,300 and 5,400 tons, respectively. The total economic value from cassava pulp sold was approximately 31.7 million baht. The buyers used wet cassava pulp as animal feed and plant supporting material and used dry cassava pulp as a main ingredient for a cassava pellet production.

3.2 Concept of model development

Total cost of a cassava pulp utilization option composed of economic cost and environmental cost. Four tiers cost analysis is a tool to assess the economic cost in Total Cost Assessment (TCA). The concepts of Total Economic Value (TEV) and Life Cycle Impact Analysis (LCIA) are the selected tools to assess the environmental impact. Environmental cost is a function of environmental impact from resource depletion, health, ecosystem, and quality of life. Environmental impact of goods and service can be determined from the resource usage and depletion and the pollution as shown in figure 1. The resource usage and depletion are determined from inputs of a process, for example, material, energy, chemicals, and water. The pollutions are determined from outputs of a process, for example, wastewater, solid waste, chemicals, wave (from sound), and air pollution.

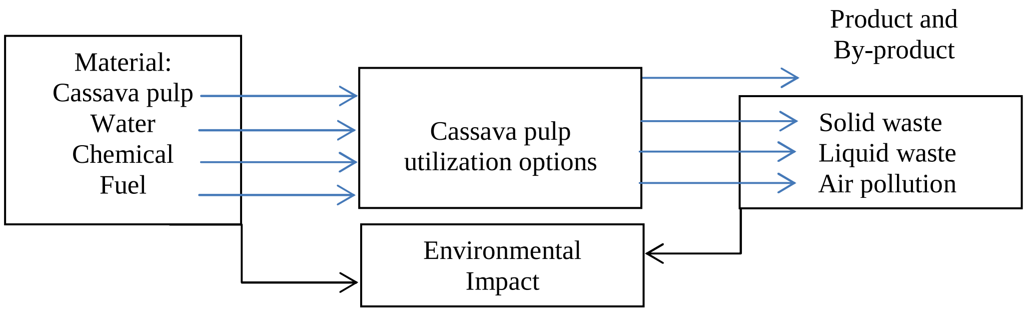


Figure 1 Environmental cost analysis boundary

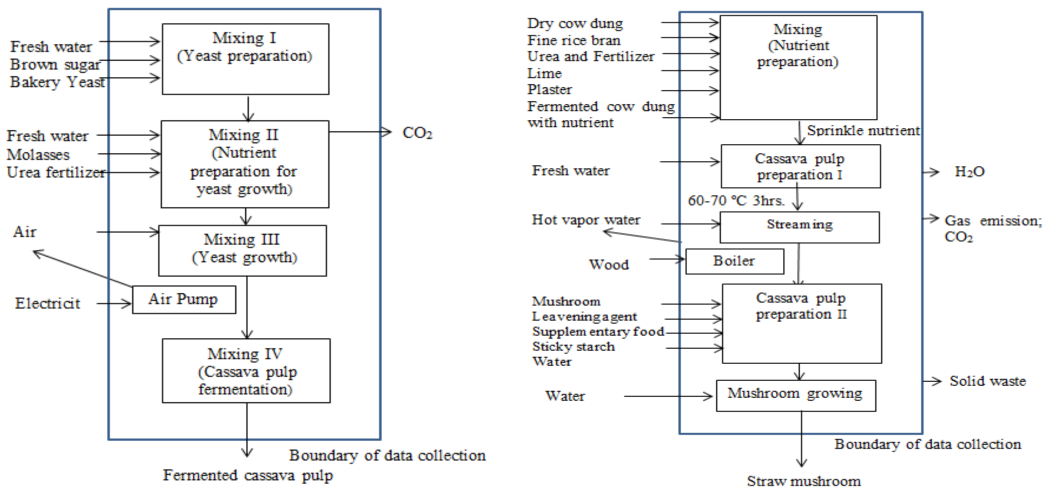
The impacts on resource depletion and quality of life were evaluated based upon the TEV method, while the general ecosystem impacts, i.e. global warming, acidification, eutrophication, were evaluated based upon the LCIA method. The environmental cost can be calculated from resource depletion, health, ecosystem, and quality of life, shown in eq.1.

$$\text{Env.cost} = \text{Env. Impact}\ \{\text{Resource depletion, Health, Ecosystem, Quality of life}\} \quad [1]$$

The environmental impact was converted to economic value using the weighting impact factors. These factors were grouped at least in regional and global of impact scales, e.g. Global Warming, Stratospheric Ozone Depletion (Denish ministry of the environment, Environmental Protection Agency, 2005).The environmental impact is relatively important in the process of weighting. The environmental impact inventory is compared to be the Global Warming Potential (GWP) through the carbon credit price (Gloria *et al*. 2007). The carbon credit price varied from 12-40 Euro/*EUA* (European Union Allowances) or *CER* (Certified Emission Reductions) (the Excise department of Thailand, 2012).

3.3 Case study on the cassava pulp utilization options of animal feed and plant supporting material

A process of cassava pulp fermentation for animal feed is shown in figure 2(a). Fermented cassava pulp is suitable to be animal feed. The protein content in the fermented cassava pulp is approximately 9% greater than in the fresh pulp (Baan Suan Green Ranch Farm, 2012). The cassava pulp fermentation by yeast requires 4 steps: yeast preparation, nutrient preparation for yeast, yeast growth, and cassava pulp fermentation. First, yeast was cultured using brown sugar and fresh water in yeast preparation step. In the second step, molasses, urea fertilizer and fresh water were mixed to support the yeast growth step. Then, the starter yeast was incubated under aerobic condition.



(a) **(b)**

Figure 2 Data collection boundary of **(a)** cassava pulp fermented with yeast for animal feed **(b)** plant supporting material

In cassava pulp fermentation step, 1,000 kg of fresh pulp was mixed with the starter yeast. All processes were done within the 250 m^3 cement pond (capacity 12-15tons/pond). Mixing was needed for at least 10 days. Life cycle inventory data analysis of the fermented cassava pulp for animal feed option is shown in Table 1.

Table 1 LCI data analysis of fermented cassava pulp

Input	Unit	Amount	Output	Unit	Amount
Cassava pulp	kg	1,000.00	CO_2 (burning)	kg	2.6E-02-3.6E-02
Dry cow dung	kg	24.00	Solid waste	kg	6,000.00
Fine rice bran	kg	3.00	Ash (5%)	kg	4.16-41.66
Urea	kg	0.60	Mushroom	kg	33.34
Lime	kg	2.00			
Plaster	kwatt/hrs	0.60			
Fermented cow dung with nutrient	kg	1.00			
Mushroom leavening agent	kg	9.60			
supplementary food	kg	0.80			
Sticky starch	kg	0.80			
Water	kg	4.00			
Wood (Kg)	kg	100.00			

Cassava pulp can be used as plant supporting material for straw mushroom cultivation. The mushroom cultivation requires 3 steps that are nutrient preparation; cassava pulp preparation and housing preparation (figure 2(b)). First, the nutrient for mushroom growth was prepared by mixing of dry cow dung, fine rice bran, urea fertilizer (15-15-15), lime, plaster, fermented cow dung together. Next, cassava pulp was prepared in mushroom house. Leavening agent, supplementary food, sticky starch were sprinkled on the top of cassava pulp as nutrients for straw mushroom cultivation. The housing preparation step was completed by sterilization with steam. The steamed temperature was 60-70ºC. The mushroom harvesting capacity was approximately 200 kg per 1 mushroom house. Life cycle inventory data analysis of the plant supporting material option was shown in table 2.

Table 2 LCI data analysis of plant supporting material

Input	Unit	Amount	Output	Unit	Amount
Cassava pulp	kg	1,000.00	CO_2 (process)	Kg	0.2934
Yeast	kg	0.34	CO_2 (elec.)	Kg	7.56E-05
Brown sugar	kg	0.69	SOx (elec.)	Kg	1.78E-08
molasses	kg	7.70	NOx (elec.)	Kg	5.04E-07
Urea fertilizer (46-0-0)	kg	6.27	Fertilizer	Kg	1,000.00
Water	kg	0.17			
Electricity	kwatt/hrs	0.40			

Total cost was calculated from economic and environmental cost. Table 3 presents the total cost of cassava pulp utilization options per 1 ton cassava pulp. The economic cost was calculated from machines, equipment, and material cost. The total economic cost of fermented cassava pulp and plant supporting material were calculated to be 6.59 and 927.56 baht/1 ton pulp utilized, respectively.

Table 3 Cost of cassava pulp utilization options per 1 ton cassava pulp (data were collected on 10/5/2013)

	Fermented cassava pulp (Baht/ton)	plant supporting material(Baht/ton)	Reference
Economic cost			
Fixed cost	6.52	255.56	Interviewed
Machine or Equipment e.g. Cement pond, pump, mushroom house			
Variable cost			Interviewed
Material	0.07	672.00	
Utility (electricity)	0.00 (0.0003)		
Total Economic cost	6.59	927.56	
Environmental cost	12.41*	18.00*	Calculated from Cai. Y.H. et al, 2012, Thongkratok. R. et al , 2010, Bergerson and Lave, 2002, EPA
Total cost	19.00	945.56	
Price (Thai market)	3,000.00-4,000.00	2,560.00	

The environmental cost was calculated from environmental impact. This impact was converted to economic value using the weighting impact factors. The environmental impact inventory is compared to be the Global Warming Potential (GWP) through the carbon credit price (Gloria *et al*. 2007).The GWP of fermented animal feed and plant supporting material were calculated to be 13,340 and 19,440 kg CO_2e/unit, respectively (figure 3).

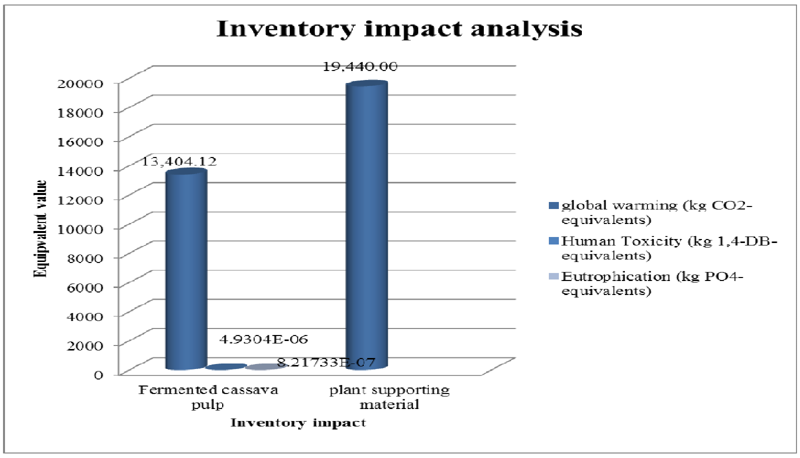


Figure 3 Inventory impact analysis of cassava pulp fermented with yeast and plant supporting material

Thus, the total cost of fermented cassava pulp and plant supporting material options were 19.00 and 927.56 baht/1 ton cassava pulp utilization, respectively.

4. Conclusion

The total cost of each cassava pulp utilization option was calculated from the economic and environmental cost. The environmental impact valuation model for the cassava pulp utilization alternatives is determined by the TEV and LCIA methods. The environmental impact valuation model is a function of the environmental impacts. It can be calculated from resource depletion, an ecosystem, and a quality of life. The environmental impact from LCIA is converted to the economic value using the environmental impact and the weighting impact factors. These weighting impacts are compared to the Global Warming Potential (GWP) using carbon credit price in the market.

Acknowledgements

This research was supported by the Thailand Research Fund through the Royal Golden Jubilee Ph.D. Program (Grant No. 2.B.KT/52/N1) to Ms. Sivalee Trakulvichean and Dr. Warinthorn Songkasiri. We gratefully acknowledge Choncharoen Co. Ltd., for the information support.

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