Research article

Reuse of Wastewater from Cassava Industry for Napier Grass Production

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Abstract Cassava industry plays an important socio-economic role in Thailand economy. The growth of the cassava processing industry has resulted in extensive water pollution, as it generates large amounts of wastewater with extremely high concentrations of organic pollutants from washing and extraction. The need for wastewater management from cassava processing was apparent and fit with green technology for reuse of wastewater for agriculture. Napier grass (*Pennisetum purpueum*), a perennial species, has become a priority source of biomass for alternative energy production in Thailand, as the National Energy Policy Council has raised the target of power production from Napier Grass to 3,000 MW under the 10-year alternative energy development plan (2012-2021) for Thailand. This study aimed to investigate the feasibility of using Napier Grass cultivation from cassava industry wastewater. Wastewater quality (effluent and influent) from cassava industry and its impact on soil chemical properties were studied at a site in Kalasin province, northeast Thailand to observe the effects of different concentrations (0%, 25, 50%, 75% and 100%) on germination test and Napier Grass biomass production. The wastewater characteristics were: pH of 7.2, EC 4 dSm^{-1}, BOD 119 mgL^{-1}, COD 1070 mgL^{-1}, TS 3230 mg L^{-1}, TKN 207 mg L^{-1}, TP 226 mgL^{-1} and water soluble K 1490 mgL^{-1}. The soil exposed to wastewater gave higher EC, more organic matter accumulation, higher total N, and available P when compared to soil without being exposed to cassava wastewater. The results showed that the wastewater concentrations significantly increased the Napier grass biomass. Therefore, wastewater from cassava industry can be used in Napier grass production as an example of application of green technology.

Keywords cassava production, wastewater quality, soil property, Napier grass biomass production

INTRODUCTION

Reuse wastewater in agriculture is gaining wider acceptance worldwide. It represents an agronomic option that is increasingly being investigated and taken up in regions with water scarcity, growing urban populations, and rising demand for irrigation water (Gatta et al., 2014; Meli et al., 2002; FAO, 2011). Many irrigated areas around the world are experiencing water shortages due to several factors, including climate change, and surface and groundwater pollution. Water scarcity poses serious economic, social, and even political concerns in all of its aspects. Under these circumstances, reuse of wastewater can help to mitigate the damaging effects of local water deficits (Gatta et al., 2014; FAO, 2010). Treated wastewater not only offers an alternative irrigation source, but also the opportunity to recycle plant nutrients (Chen et al., 2008). Its application might ensure the transfer of fertilizing elements, such as nitrogen (N), phosphorous (P), potassium (K^+), organic matter, and nutrients, into agricultural soil (Gatta et al., 2014). The cassava processing industry is considered to be one of the largest food processing industries in Thailand. However, the growth of the cassava industry has resulted in serious environmental pollution as it generates large amount of solid waste and wastewater with high organic content (Chavalparit and Ongwandee, 2008).

Together with the rice and sugarcane industries, the tapioca starch-processing industry has played an important role in Thailand's agricultural economy. Known as the world's largest producer and exporter of tapioca starch, Thailand produced over seven million tons of starch in 2004. Approximate annual revenue from tapioca starch export was 38,805 million baht or 1,060 million dollars (DOA, 2005). Tapioca is produced from treated and dried cassava (manioc) root and used in the food, paper, and toothpaste industries. Only 20% of the cassava root harvested in Thailand is delivered to starch-processing plants while the rest is used in the production of pellets and chips. Currently, Thailand has 92 tapioca processing plants with a total production capacity of native and modified starch at about 16,910 and 4350 ton/day, respectively (DOA, 2005). Normally, these tapioca-processing plants operate 24 hours per day from September to May each year.

The production of native starch from cassava root involves seven major stages. These are root washing, chopping and grinding, fibrous residue separation, dewatering and protein separation, dehydration, drying, and packaging. The production facilities experience a number of environmental problems such as the consumption of large volumes of water and energy, and the generation of high organic-loaded wastewater and solid waste. The starch extraction process requires a vast volume of water, which in turn produces large amount of wastewater. According to the study of Tanticharoen and Bhumiratanatries (1995), the production of one ton of starch from cassava generates an average of 20 m^3 of wastewater. Hien et al. (1999) reported the characteristics of wastewater from Vietnamese tapioca starch plants with values of 11,000-13,500 mg $CODL^{-1}$, 4200-7600 mg SSL^{-1}, and pH of 4.5-5.0. The approximate generation of wastewater and solid waste (fibrous residue and peel) from one ton of starch was 12 m^3 and 3 kg, respectively (Hien et al., 1999).

Thus appropriate wastewater management from cassava starch industry is needed. Reuse of such wastewater and its nutrients for agriculture fits with green technology. An appropriate class to consider for nutrient uptake is grass with high biomass. *Pennisetum purpureum* (Napier grass) is also known as elephant grass or Ugandan grass and is a species of perennial tropical grass native to the African grasslands and is cultivated extensively. Napier grass (*P. purpueum*) is a perennial plant that is also a priority source of biomass for alternative energy production in Thailand. The National Energy Policy Council, in its 10-year alternative energy development plan (2012-2021), has set a target to produce 3,000 MW of electricity from Napier grass. Napier grass has low water and nutrient requirements, therefore it can make use of uncultivated lands. Historically, this species has been used primarily for grazing. Recently, however, it has been incorporated into a pest management strategy. In addition to this role, Napier grass improves soil fertilityand protect arid land from soil erosion. They are also utilized for firebreaks, windbreaks, in paper pulp production and most recently to produce bio-oil, biogas and charcoal.

The perennial *Pennisetum purpureum* Schumach (Napier or elephant grass) readily crosses with the annual *Pennisetum americanum* (L.) Leeke (pearl millet) and the resultant interspecific hybrids are more vigorous than the parent species. Hence, several hybrid Napier grass cultivars (*P. purpureum* and *P. americanum*) have been developed (Premaratne and Premalal, 2006). Because of the high biomass production and very high forage quality for livestock, growth of these hybrids is widely promoted in subtropical and tropical countries including Thailand (Tudsri et al., 2002; Premaratne and Premalal, 2006). Recently, a very productive cultivar (Pakchong1) of this hybrid grass has been developed and marketed by Thailand's Department of Livestock Development. The Pakchong1 cultivar is claimed to have several advantages over other Napier grass cultivars, as it grows taller, has a higher content of crude protein, has an annual yield exceeding 500 ty^{-1}, and can be harvested 5-6 times per year (Jampeethong et al., 2014).

The nutrients wastewater from the cassava industry has the potential to contribute to crop production, including that of Napier grass. Nevertheless, there is a need for periodic monitoring, to avoid any imbalance in the nutrient supplies, which might cause an imbalance; such wastewater can also be a source of pathogenic organisms, enteric bacteria and viruses and potentially hazardous chemical substances such as salts, heavy metals, and surfactants. Hence, there is the need for further studies to investigate the feasibility of using wastewater from cassava industry for Napier grass production.

OBJECTIVES

The objectives of the study were: (i) to evaluate the effects of nutrients in the wastewater from cassava industry on qualitative and quantitative aspects of Napier grass production; and (ii) to assess the impact of the wastewaters on the soil properties.

METHODOLOGY

Water and Soil Sampling

Three samples of the wastewater from influent and effluent from biogas system at cassava industry were collected in sterile 1000-mL glass bottles, and transported to the laboratory in refrigerated bags. The samples collected were kept in a refrigerator at +4°C, and examined within 24 hours of their collection. Soil samples were collected in triplicate from each of 5 treatments before and after. All of the soil samples were taken from a 15-cm layer in each plot, from under the drippers, and they were air-dried, crushed, and passed through a 2 mm sieve before the chemical analysis.

Water Quality Analysis

The water samples were analyzed in triplicate, according to the international standard methods (APHA-AWWA-EF, 2005). The analysis included the physico-chemical parameters of pH, electrical conductivity (ECw; dSm^{-1}), total solids (TS; mgL^{-1}), biological oxygen demand over 5 days (BOD5; mgL^{-1}), chemical oxygen demand (COD; mgL^{-1}), Total Kjeldahl Nitrogen (TKN), Total Phosphorus (TP; mg L^{-1}) and potassium (K^+; mgL^{-1}).

Soil Chemical Analysis

The soil electrical conductivity and pH were measured ion 1:2 (w/v) and 1:2.5 (w/v) aqueous soil extracts, respectively. The pH and EC were measured using a digital pH meter in 1/2.5 (w/v) deionized water. Total N (total nitrogen) was measured by the micro Kjeldahl method (Jackson, 1973; Bremner and Mlvaney, 1982). Exchangeable phosphorous (Exch. P) was determined by using the Bray II extraction method (Schroth et al., 2003) and Exchangeable Potassium (Exch. K) was determined by 1 N Ammonium acetate and Flame photometry method.

Plant Growth Test

An experiment was carried out to investigate the effects of wastewater from cassava industry on germination and plant growth under greenhouse conditions at Khon Kaen University, Thailand, at (latitude of 16° 28' N and longitude of 102° 48' E) during the rainy season of 2014.

Napier grass plants were used in this experiment. The experiment was laid out in a completely randomized design (CRD) with three replications for each crop. Five-wastewater concentration treatments were used (T_1: tap water only, T_2: 25% wastewater concentration, T_3: 50% wastewater concentration, T_4: 75% wastewater concentration, and T_5: 100% wastewater concentration) were used. For five kilograms of 2 mm sieved air-dried of each soil sample were placed in each black plastic pots of 30 cm height and 25 cm diameter for each treatment. Wastewater was applied before planting in every three days until termination. Bud per stem, height, fresh weight, dry weight, yield of stem and root were recorded.

Statistical Analysis

The data obtained from different experiments were analyzed by using the one-way analysis of variance (ANOVA) function of Statistica 8 software (Version 8, USA) to test for variations ($p<0.05$) that were deemed significant between treatment groups and controls.

RESULTS AND DISCUSSION

The wastewater released from cassava industry characteristics were pH of 3.9, 7.2, EC of 1.5, 4.0 mS/cm, BOD of 633, 119 mg/l, COD of 4267, 1067 mg/l, TS of 4853, 3227 mg/l, TKN of 28, 207 mg/l, TP of 120, 226 mg/l and water soluble K of 1833, 4900 mg/l, respectively (Table 1). The result suggests that nutrients were high in wastewater. Therefore, it could be use for grass nutrient uptake.

Table 2 shows the effects of wastewater from cassava industry on soil properties. In the soil exposed to wastewater, the pH of the soil increased compared to the soil without exposure to wastewater. Similarly, the application of wastewater resulted in higher EC, N, P, K than the soil without exposed to wastewater. The exposed soil contained more organic matter accumulation and higher exchangeable K than the soil without exposure to wastewater. The noticeable increase of exchangeable K in the soil exposed to wastewater might be explained by the presence of high levels of organic matter in it. The soil exposed to wastewater had the higher total N content, whereas the soil without being exposed to wastewater had low value. The high total N content in soil by exposing to wastewater might be due to the fact that wastewater might enhance salt uptake and immobilization of N. The application of wastewater resulted in higher available P than the soil without exposed to wastewater. It might be due to the fact that the wastewater resulted in increasing available P in the surface layer. The soil exposed to wastewater gave higher exchangeable K^+ when compared to the soil without being exposed to wastewater. This might be the initial high content of these elements in the wastewater. Therefore, the results of this study show that soil chemical properties after being treated wastewater from cassava were better than the ones without application of wastewater.

Plant Growth Experiment

The biomass yields of the Napier grass plants grown on the amended soils have been determined using their height and weight data for plant stem and root biomass. The biomass of the Napier grass plants increased in the treatment using wastewater for all the samples. The highest yields were recorded for wastewater at 25% concentration (Tables 3 and 4).

Table 1 The wastewater from cassava industry characteristics

Wastewater Parameter (unit)	Influent	Effluent	Water quality standard for effluent discharge (MOST, 1996)
pH	3.9	7.2	5.5-9.0
EC (dSm^{-1})	1.5	4.0	-
BOD (mgL^{-1})	633	119	60
COD ($mg\ L^{-1}$)	4270	1070	400
TS ($mg\ L^{-1}$)	4850	3230	-
Total N ($mg\ L^{-1}$)	28	210	100-200
Total P ($mg\ L^{-1}$)	120	226	-
Total K ($mg\ L^{-1}$)	1830	4900	-

Table 2 Soil quality after apply wastewater from cassava industry

	Soil quality				
	pH	EC (dSm^{-1})	TN (%)	Exchangeable P (ppm)	Exchangeable K (ppm)
Before	6.12b	0.038c	0.008c	34b	44c
After (influent)	6.01c	0.091a	0.021b	48a	64b
After (effluent)	6.44a	0.065b	0.028a	43a	92a
F-test	**	**	**	*	**
CV (%)	0.45	3.12	8.04	5.18	2.79

Note: Mean (n=3) in the same column followed by the same lower case letters are not significantly different at p≤0.05

Table 3 The effects of wastewater from cassava industry (influent) on Napier grass production

Treatment wastewater concentration	Buds/ stem	Height (cm)	Stem fresh biomass(g)	Stem dry biomass (g)	Root fresh biomass (g)	Root dry biomass (g)
0 %)Control(	2.67	64.33	19.86^{b}	2.35^{b}	2.71^{c}	0.31^{b}
25%	3.67	72.68	43.30^{ab}	3.67^{ab}	7.09^{b}	0.50^{ab}
50%	4.33	77.00	50.87^{ab}	4.09^{ab}	8.02^{ab}	0.72^{ab}
75%	4.33	76.33	43.70^{ab}	2.22^{b}	7.00^{b}	0.28^{b}
100%	3.33	78.667	71.67^{a}	4.75^{a}	11.58^{a}	0.76^{a}
F-test	ns	ns	**	**	*	**
C.V. (%)	26.35	13.02	26.87	21.40	30.72	22.23

Note: Mean (n=3) in the same column followed by the same lower case letters are not significantly different at p≤0.05

Table 4 The effects of wastewater from cassava industry (effluent) on Napier grass production

Treatment wastewater concentration	No. Bud/ stem	Height (cm)	Stem fresh biomass (g)	Stem dry biomass (g)	Root fresh biomass (g)	Root dry biomass (g)
0 %)Control(	2.67	4.33	19.86	2.35	2.71	0.31
25%	3.67	76.33	35.26	2.87	5.47	0.38
50%	3.00	70.68	37.11	3.19	5.70	0.51
75%	2.67	72.33	33.39	2.60	5.44	0.39
100%	2.67	64.68	23.06	1.60	3.04	0.14
F-test	ns	ns	ns	ns	ns	ns
C.V.)%(	35.21	12.46	41.93	35.62	44.49	62.27

Note: Mean (n=3) in the same column followed by the same lower case letters are not significantly different at p≤0.05

CONCLUSION

Every wastewater application significantly produced maximum Napier grass biomass based on measured data. Therefore, wastewater from cassava industry natural can be reused to give enhanced Napier grass biomass production. The reuse of wastewater from cassava industry for Napier grass production considered the aspects of water reuse, nutrient reuse, and biomass production. The high biomass yield of Napier grass also makes it a possible potential feedstock in producing cellulosic ethanol, with the added benefit of water quality improvement and sustainable energy. This study suggests that through the cultivation of highly productive, low input, perennial and valuable plant species, benefits can be realized in the form of water quality improvement, water reuse, nutrient reuse, biomass production, and sustainable energy.

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