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Use of *Manihot esculenta*, Crantz Processing Residue as Biofertilizer in Corn Crops

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Abstract: This research is about the use of *manipueira*, a liquid extract obtained from the cassava processing as biofertilizer in crops and its effects on soil as well as on subterranean waters. The physical-chemical characterization of the effluent showed the following results: pH (23°C): 3.6, cyanide: <0.05 mg L^{-1}, COD: 7,747.00 mg L^{-1}, $BOD_{5\,days}$: 5,660.00 mg L^{-1}, total phosphorus: 36.80 mg L^{-1}, nitrogen: 167.00 mg L^{-1}, sedimentary solids: 48.00 mg L^{-1}, total solids: 6,024.00 mg L^{-}. Despite the physical-chemical composition of the subterranean waters there was a pH increase from 4.8 (monitored area) to an average of 7.0 (control area). Other parameters analyzed (except sedimentary solids) showed a significant increase in COD, BOD, phosphorus, nitrogen and total solids in the control area, showing that the effluent may contaminate the subterranean waters. However, the increase in the organic substances, potassium and phosphorus in the soil presents a potential of being used as a fertilizer reflecting in final crop production.

Key words: *Manipueiria*, biofertilizer, soil, wastewater, corn, crops

INTRODUCTION

The Cassava (*Manihot esculenta* Crantz) also known as manioc or yucca, is a tropical shrub widely grown in Brazil, Africa and the West Indies (Lahai *et al*., 1999; Okogbenin *et al*., 2003; Pequeno *et al*., 2007). World production of cassava in 2002 was 184.8 million ton a growth of 17.3 million ha, with Brazil representing 12% (23.0 million ton/1.74 million ha) out of total (Filho and Alves, 2004). The Brazilian production of cassava, harvested in 2006, was estimated at 26.64 million ton a growth of 1.97 million ha, with an average yield of 14.04 ton of roots ha^{-1}, a quantity 2.5% higher than 2002 (IBGE, 2006).

Cassava cropping is an activity of great economic and social importance in Santa Catarina State, where it is developed predominantly by family farming. In Santa Catarina state, approximately 612000 ton of root of cassava is produced in an area of 32,400 ha. There are around 350 devices of flour and 40 industries producers of manioc and starch in the state (Dufloth *et al*., 2005). The products have many uses: for starchy foods such as tapioca and farina, animal feed and for use in the textile, paper, packing, mining, chemicals and pharmaceutical industries (Zaffaroni *et al*., 1991; Nakason *et al*., 2005).

The tubers contain hydrocyanic acid, which must be removed by washing, exposure to the air, heating and pressing. Thus, the cassava processing generates solid and liquid residues that are toxic for the environment (Cumbana *et al*., 2007; Jyothi *et al*., 2005), producing in average, 2.62 m^3 ton^{-1} of the residues generated from washing and 3.68 unit m^3 ton^{-1} from the water residues of flour production (Horsfall *et al*., 2006; Isabirye *et al*., 2007; Martínez-Bustos *et al*., 2007). The pollutant potential of an effluent is measured by the amount of oxygen needed to oxidize the organic matter, the Chemical Oxygen Demand (COD) and the amount of oxygen necessary to stabilize the organic matter by microorganisms and enzymes the, Biochemical Oxygen Demand (BOD). Liquid effluents contain many nutrients, suitable to increase soil fertility, as opposed to the water carried by them, which is pollutant to the environment (Horsfall *et al*., 2006; Khang and Wiktorsson, 2006; Nitschke and Pastore, 2006). The cassava varieties are classified according to

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their cyanide content, the major substance that makes cassava a toxic root. Young cassava leaves can present up to 600 mg kg^{-1} of cyanides; the peeled pulp presents 20-50 mg kg^{-1} of cyanides (Aryee *et al*., 2006).

The *manipueira* is a Brazilian native name meaning the liquid residues from the cassava roots. This effluent containing 5-7% of starch in weight basis, glucose, cianidric acid, carbohydrates, proteins and lipids (Charles *et al*., 2007; Horsfall *et al*., 2006). It also contains N, P, K, Ca, mg, S, Fe, Zn, Cu, Mn and B, showing potential as fertilizer (Menoli and Beleia, 2007) and biocide (Coulin *et al*., 2006; Marco and Kishimba, 2006). Thus, the use of *manipueira* as fertilizer (fertirrigation) can covert a dangerous residue in a profitable product at low cost, reducing environmental impact and improving cultivation of some crops. Some studies suggest the use of *manipueira* to produce biogas, citric acid and organic insecticide (Marco and Kishimba, 2006). Therefore, the aim of this research was to evaluate the potential of the *manipueiria* as a biofertilizer in maize crops, in order to develop procedures to reduce environmental impact of the cassava effluents at low costs.

MATERIALS AND METHODS

The experiments were guided in 3 fields of test. The 1st (area 1) corresponding 1.5 ha was irrigated with 7,200 m^3 of *manipueira*. The 2nd area (area 2) with 2.0 ha, was located 200 m distant from the first area, was fertilized with N, P_2O_5 and K_2O in 5:20:20 proportion. The 3rd field (area 3 or control area) was not fertilized. The fields test are located in Santa Rosa do Sul, Santa Catarina state, between the Southern parallels 25°57'41" and 29°23'55" and the Western meridians 48°19'37" and 53°50'00", predominated by the Atlantic Forest. The climate is mesotermic with temperatures ranging from 6-36°C and rain distributed throughout the entire year; rainfall ranges from 1.200-1.660 mm $year^{-1}$, with well defined seasons (Dufloth *et al*., 2005). The soil from the study area is classified as Dystrophic Quartz Red-Yellow Sands and topography ranges from gently to hilly plan undulating. The soils are limited for agricultural use due to low natural fertility, high acidity, low capacity of water retention and moderate tendency to eolian erosion. The soils are exceedingly well drained, with hydraulic conductivity (K) in order from 10^{-3} to 10^{-4} cm s^{-1} (Dufloth *et al*., 2005).

The collection of effluents for physical-chemical analyzes (characterization) was performed in alternated schedules 8 times every morning. Samples were homogenized and several parameters measured: pH (potentiometry), cyanides (spectrometry), COD (open reflux method), BOD (incubation at 20°C), total phosphorous (spectrometry), total nitrogen (volumetry), sedimentary solids and total solids (Imnhoff cone). All analysis were performed according to the Standard Methods for the Examination of Water and Wastewater (Greenberg *et al*., 1985).

The effluent was applied right on bare soil in the period coincident the harvest of cassava, in the months of June and July (60 days). In total 7,200 m^3 of effluent were applied in an area of 15,000 m^2, which corresponds to a deposition of 0.48 m^3 m^2 of soil and a daily volume of 8 L m^2. The application was performed by flooding via irrigation channels with a slope of 1.5%. The area concerned is situated in a plain, with a contemptible slope.

Three monitoring wells (50 m distant from one another; PVC; 3-4 m of depth) were constructed to mark the collection points of underground water and to prevent collection points from closing. A 4th monitoring point (located between area 1 and 2) was used, corresponding to the standard area and representing the point used to collect the water used for the cassava processing. The samples were collected with a suction pump directly from the monitoring wells, a depth ranging between 3 and 4 m, because groundwater is very close to the soil surface.

Soil analysis took place in 30 different points in the control area; in each point samples at three levels depth were collected: 20, 40 and 60 cm, respectively, 0-20 cm, 20-40 cm and 40-60 cm. Samples were mixed and homogenized. A sample of the standard area was also collected. All samples were analyzed for pH, texture, organic matter, specific ions (P, K, Al, Ca, mg, Na), Cationic Exchange Capacity (CEC) and SMP index.

Finally, the maize cultivated in area 1 (biofertilized) and in area 2 (with regular fertilization) were compared to determine the effectiveness of the *manipueira* as a fertilizer. Holes (5×5×5cm) were prepared for planting the seeds with 1 m distance between lines and 0.5 m between holes. With the aid of a manual seeder, 3 grains of maize were placed in each hole. This procedure was adopted in both studied areas (control and monitored).

The number of spikes, number of plants, bedding, height of plant, height of spike, mass of the aerial part and mass of grains were used as variables for comparison in both areas (biofertilized and regular fertilized). Data was analyzed using student's t-test for 5.0% for significance level.

RESULTS AND DISCUSSION

Table 1 presents the results of the effluent analysis. All results are out of the allowed maximum parameters, except for the cyanide parameter, according to the Brazilian liquid effluent emission legislation (Brazil, 2002).

Table 1: Chemical analysis of the raw effluent used as biofertilizer. The maximum allowed values for total phosphorous and total nitrogen were values for launching in lakes and estuary

Parameters	Result	Maximum allowed[1]	Minimum detected
pH (23°)	3.6	6.0-9.0	0.1
Cyanide (mg L^{-1})	<0.05	0.2	0.05
COD (mg L^{-1})	7747	-	5.0
$BOD_{5\ days}$ (mg L^{-1})	5660	60.0	1.0
Total phosphorous (mg L^{-1})	36.8	1.0	0.1
Total nitrogen (mg L^{-1})	167.0	10.0	0.1
Sedimentable solids (mg L^{-1})	48	1.0	0.1
Total solids (mg L^{-1})	6024	-	0.1

[1]According to the Santa Catarina State (Brazil) Environmental Legislation for liquid effluent emission

The pH of the effluent is significantly low in comparison to the maximum allowed (6.0-9.0): fermentation of the residues can cause the formation of CO_2 and organic, ascetic and lactic acids, contributing for its reduction and production of strong odors (Bradbury, 2006; Horsfall *et al*., 2006; Cumbana *et al*., 2007; Isabirye *et al*., 2007), also being able to affect the quality of the ecosystem.

Cyanide (CN^-) is another important component in the effluent; therefore, besides being toxic and volatile, it can be dissociated when dissolved in water with pH equal or higher that 8.0, forming HCN or free cyanide (Bradbury, 2006; Cumbana *et al*., 2007). This could explain the very low level of cyanide in this study (<0.05 mg L^{-1}), because the pH of the effluent was below 8.0 (3.6) and formation of the cyanide ion did not occur. The pH of the environment can avoid poisoning because it interferes with the reaction rates of the metabolism (Agbor-Egbe and Mbome, 2006; Bradbury, 2006; Cumbana *et al*., 2007).

In addition, the microbial development in substratum containing cyanides (with anaerobic metabolism) could detoxify cyanides by splitting the radical in carbon and nitrogen, explaining the effect of the effluent from the cassava processing on residual water (Agbor-Egbe and Mbome, 2006; Isabirye *et al*., 2007).

Results also presented high COD and BOD in the effluent, 7.747 and 5.660 mg L^{-1}, respectively. The high demands (COD and BOD) can represent risks to fauna, flora and surface or underground waters (Horsfall *et al*., 2006; Isabirye *et al*., 2007). High concentrations of Phosphorous (P) and Nitrogen (N), 36.8 and 167.0 mg L^{-1}, respectively show that the *manipueira* can be used as a biofertilizer (Johnston and Richards, 2003; Lemercier *et al*., 2008). Other elements like potassium, magnesium, calcium, sulphur, iron and micronutrients confirm the use of *manipueira* as a biofertilizer (Lenis *et al*., 2006).

Regarding total and sedimented solids both are out of the maximum values allowed by the Brazilian Law, 48.0 and 6.024 mg L^{-1}, respectively. However, these levels could be easily reduced by physical or biological processes (Oboh and Akindahunsi, 2005).

Table 2 presents the soil analysis after application of diluted *manipueira* (control area, 1-20, 20-40 and 40-60 cm). Results are presented in accordance with the periods of analysis. SM1 is the first analysis carried out during the application of the *manipueira* and SM2 is the second analysis, 150 days after SM1. All results were compared to the SM0 analysis (area 3), without application of neither fertilizers or *manipueira*.

Regarding the soil, there was a small increment in the organic substance content at the 0-20 cm layer. The organic substance content is related to the nitrogen content and the effluent launched over the control area presents high amounts of nitrogen. Difference between the organic substance content in the ground and in the effluent is because the microorganisms can consume nitrogen as an energy source (Barber, 1968; Ye and Thomas, 2001; Näsholm and Persson, 2001). In addition, the organic substance can be labile.

Contents of P, K and Al increased considerably with the application of *manipueira* in the layers 0-20, 20-40 and 40-60 cm (SM1 and SM2) compared with the area without application (SM0). The increase in P and K availability also increased the development of maize plants and fruits. The observed pH of the ground in the control area was lower in all analyzed layers comparing to the area 3 (SM0), i.e., without *manipueira* application. However, pH of underground waters presented high values. Low contents of Ca, mg and Na in the biofertilized soil are probably due the organic acids leaching them. In addition, the microorganisms can incorporate Ca (Barber, 1968; Lechaire *et al*., 2002).

There was also a reduction in the cation exchange capacity of area 1 regarding area 3 (SM0) associated with the reduction of the organic substance content (20-40 and 40-60 cm layers) and pH of soil. This fact explains the difference between the pH of soil and pH underground waters. Part of the absorbed nitrogen could be carried by the rains. The nitrogen converted into soluble nitrates and in contact with underground waters, rivers and lagoons can cause serious public health problems.

It is known that the capacity for accumulation of N in the soil is limited because of the limited cation exchange capacity of Brazilian soils (Costa *et al*., 2004; Liang *et al*., 2006; Bortoluzzi *et al*., 2006). The *manipueira* used in the soil influences the ionic balance (Horsfall *et al*., 2006; Isabirye *et al*., 2007). This could explain the small variation of the organic substance observed in the control area relative to the standard area.

Table 3 present the results of the analyses of the underground water. Monitoring wells PM1-PM3 were located in area 1 that was biofertilized and well PM0 (area 3) was located in an area that did not receive any kind of fertilizer.

Table 2: Results of soil analysis the control area (SM0) and the test area after application of diluted *manipueira* (SM1) and after 150 days of the first analyze (SM2) in the three depths

	Depth (cm)								
	0-20			20-40			40-60		
Samples	SM0	SM1	SM2	SM0	SM1	SM2	SM0	SM1	SM2
Texture (clay%)	4.00	4.00	5.00	5.00	4.00	4.00	4.00	4.00	4.00
pH	6.00	4.70	4.70	5.40	5.00	4.80	5.40	5.30	4.70
SMP index	6.40	5.80	5.50	6.10	5.70	5.60	6.10	5.90	5.90
P (ppm)	3.40	37.40	50.00	3.70	13.20	35.90	3.40	5.10	9.70
K (ppm)	52.00	166.00	165.00	51.00	177.00	250.00	58.00	184.00	205.00
Organic matter (%)	1.00	1.00	1.20	1.00	0.80	0.90	0.80	0.50	0.90
Al (cmol L^{-1})	-	1.30	1.20	0.30	1.00	1.00	0.40	0.80	1.20
Ca (cmol L^{-1})	3.90	0.70	0.80	2.50	0.50	1.50	2.50	0.80	1.00
Mg (cmol L^{-1})	1.60	0.30	0.80	1.30	0.20	1.50	1.40	0.20	0.90
Na (ppm)	8.00	6.00	2.00	8.00	3.00	2.00	11.00	4.00	3.00
H +Al (cmol L^{-1})	2.48	4.27	5.60	3.26	4.67	5.11	3.26	3.90	3.90
pH $CaCl_2$	5.30	4.20	4.00	4.70	4.30	4.20	4.70	4.50	4.20
Sum of bases (cmol L^{-1})	5.67	1.45	2.03	3.97	1.17	3.65	4.10	1.49	2.44
CTC	8.15	5.72	7.63	7.22	5.84	8.76	7.35	5.39	6.34
Saturation of bases (%)	69.53	25.38	26.63	54.91	19.99	41.65	55.72	27.63	38.47

Table 3: Results of underground water analyses at the first sampling (August 2004) and second sampling (February 2005) for the monitoring wells

	Results 1st sampling				Results 2nd sampling				
Parameters	PM0	PM1	PM2	PM3	PM0	PM1	PM2	PM3	Minimum detected
pH (20°C)	4.8	6.8	7.6	4.7	4.8	6.6	6.8	7.5	0.1
COD (mg L^{-1})	<0.5	111.0	122.7	4,441.4	<0.5	91.4	132.2	97.2	0.5
BOD_{5days} (mg L^{-1})	<1.0	51.0	27.0	1,817.0	<1.0	-[1]	-	-	1.0
Total phosphorous (mg L^{-1})	<0.1	0.2	0.2	12.0	<0.1	<0.1	<0.1	1.3	0.1
Total nitrogen (Kjeldahl) (mg L^{-1})	0.4	2.8	8.0	112.4	0.4	7.5	3.8	63.9	0.1
Sedimentable solids (mg L^{-1})	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.7	<0.1	0.1
Total solids (mg L^{-1})	30.0	291.0	998.0	1,761.0	30.0	455.0	825.0	375.0	1.0

[1]BOD analysis was not possible because the presence of chlorides in the samples

Table 4: Numbers mean of the maze and plant productivity at control area and biofertilizer area (2004 harvest)

Variables	Control area	Biofertilizer area	t-test
No. spikes	57.60	54.60	Not significant
No. plants	59.20	58.10	Not significant
Bedding	0.00	0.00	Not significant
Plant height (m)	2.16	2.68	Significant at 1%
Spike height (m)	1.12	1.44	Significant at 1%
Aerial part mass (kg)	10.50	11.13	Significant at 5%
Grain mass (13% humidity) (kg)	353.80	470.81	Significant at 5%

The physical-chemical characterization of underground waters shows the pH values for the monitoring wells of the area 1 (PM1-PM3) presented high levels in comparison to the monitoring well of area 3 (PM0). However, as explained above, these results are bellow the pH needed for the cyanide to dissociate and form HCN and free cyanides (pH = 8.0).

Except for the sedimented solids, all analyzed parameters were raised: COD, BOD, nitrogen, phosphorous and total solids presented higher levels for the control area when compared with the standard area (PM0). These results show that the application of the effluent as used in this study can cause contamination. However, the *manipueiria* has been used as biofertilizer indiscriminately by farmers for >10 years in region and adjacent areas, a fact that could justify such high results in analyses of the underground water given an accumulative effect.

Finally, Table 4 presents results corresponding to the productivity of the maize and mass of the aerial part, achieved in the 2004 harvest, in area 1 (biofertilized) and area 2 (regular fertilization), respectively. It was observed that the fruits harvested in area 1 were more developed and healthier when compared with fruits of area 2. Grains presented greater productivity for each parcel and mass of the aerial part were better developed in comparison to area 2.

The productivity of the maize cultivated in the area biofertilized with *manipueira* showed interesting and promising results regarding maize cultivated in the area fertilized with inorganic fertilizer. In the biofertilized area, plants presented an increase in productivity of the grains and healthier fruits, superior growth and significantly superior mass of the aerial part, showing the potential of *manipueira* as an organic biofertilizer and insecticide.

According to Table 4, the variables height of plant, height of spike, mass of the aerial part and mass of grains had presented statistical differences of 5% significance level (t-test). Regarding number of spikes, number of plants and bedding, there was no significant variation.

CONCLUSION

The chemical composition of *manipueira* supports its potential as a biofertilizer regarding content in potassium, nitrogen, magnesium, phosphorous, calcium, sulphur, iron and micronutrients in general.

The research presents risks of underground water contamination due to variations observed in the physical-chemical parameters showing that a daily pre-treatment (for example, through the aeration forced and lagoons of stabilization) of this effluent before its application can be an alternative to avoid contamination. The biofertilized soil presented significant improvement in fertility function of the application of *manipueira*. Content of P and K in the biofertilized soil resulted in a significant increase in productivity of maize and mass of the aerial part of the plant.

Finally, the use of *manipueira* as fertilizer is an interesting alternative to agricultural reuse of an effluent, transforming it into an organic supplement to cultivate species; it is an economic way to compound fertilizers and to reduce environmental impacts, since the ideal doses the for each type of soil and crop are respected.

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