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Design of a producing plant of bio-fertilizer from Vinaza of sugar cane

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ABSTRACT

Vinaza, a by-product of the alcohol distillation originating of the fermentation of sugar cane molasses, presents difficulties of handling due to its great volumes of production and to the great amounts of organic matter that contains, which disables its unloading to the water sources. In base of this, the possibility of treating to vinaza, to turn it in a manageable bio-fertilizer liquid rich in phulvic and humic acids, is considerer. In this work it was elaborated basic engineering for the design of an industrial plant of bio-transformation and stabilization of vinaza in Venezuela from the collected data on a scale pilot, achieving the advantages of the fertilizing benefits of the vinaza of an optimal way, and turning to this last one, from an undesirable by-product to an important source of nutrients for the ground. For the resolution of the raised objective, the specifications of the raw material as of the produced bio-fertilizer, the required capacity of the plant and services, were identified. Later the operations involved in the process were considered and the mass and energy balances were made. These allowed estimating the dimensions of the involved equipments. The results showed an approximated capacity of plant of 7.000 m^3/year of liquid fertilizer based on the availability of vinaza, with a production system by loads and a time of residence of 30 days.

Keywords: Vinaza, Humic acids, Phulvic acids, bio-fertilizers

INTRODUCTION

Vinaza is an industrial by-product of the process of ethylic alcohol distillation, produced by biological fermentation of the raw material (molasses), that presents a dark coloration and a great turbidity. The generated volume of this product is elevated, since are produced approximately 13lts of vinaza for each one liter of alcohol obtained in the process. This by-product is highly corrosive and polluting of the water sources, presents in its chemical composition, high contents of organic material, potassium, calcium and moderate amounts of nitrogen and phosphorus, that give it an important commercial value with a great potential for diverse uses.

It is characterized by a pH value between 4 and 5 (Pande and Sinha, 1997), and due to its high organic material content has a high biochemical demand of oxygen (BDO) that oscillates between 7.000 and 20.000mg/lt.This value become it in a pollution agent of the environmental, since it requires high oxygen concentrations for the oxidation of the organic material that it has; therefore when are discharged to the rivers, it exhaust the dissolved oxygen affecting the flora and fauna present in that ecosystem..

Nevertheless, under rational conditions of handling, the mineral fertilization can be replaced partially or totally for vinaza depending on the requirements to the ground, due to its high concentration of potassium, essential nutrient required in great amounts principally by sugar cane crops.

Made studies (Gloria et al., 1973), have probed that the application of vinaza to grounds of sugar cane production, improved the pH of them, diminishes the interchangeable aluminum and increase the potassium concentration. Also it's improved the cationic relationship, mainly of calcium and magnesium. These results allow to conclude that vinaza is and excellent organic product enhancer of the ground and whose use in average dose oscillates between 20 and 130m^3/ha (depending of the ground requirements), allowing to obtain greater yields of the crop and enrich the nutritional condition of agricultural production units, in addition of the benefits in public health that it generates. Experiences carried out (Gómez J, 1991) in inceptisole grounds in the valley of Turbio river in Venezuela, point out that the best yields of sugar cane was obtained when was applied 50m^3/ha and 100m3/ha of vinaza. The evaluation of the vinaza as potassic fertilizer (Alfaro and Alfaro, 1996) in inceptisole grounds of Athenas, point out that when are applied 37m^3/ha of vinaza, the yield of sugar cane (MT/ha), was improved in 19% and 25% in comparison with those who used chemical fertilizers.

For all these reason, it is proposed to use the vinaza as a partial substitute of fertilizers to Venezuelan grounds. In this work is developed the basic engineering of a vinaza plant

METODOLOGY

The following investigation was divided in two stages: *Experimental* and *Design*. The experimental stage consisted of the development of tests on pilot scale, that allowed the characterization of the raw material obtained of the stills of the distillery; as well as by means of the application of 6 treatments, the identification of the conditions of reaction and characteristics of the obtained fertilizer. In the phase of design the data collected in the experimental phase were used to establish the capacity of the plant and the size principal equipments.

RESULTS AND DISCUSION

Experimental stage:

Before being able to raise any design, it must be necessary to identify the raw material to be employed as the products to be obtained, also must be identified the via to transform the raw material into a product. Because didn't known data about the process, was necessary to make laboratory tests that allowed to make the elementary analysis of the raw material. The data is showed in table 1:

Table 1: Raw material characteristics

Parameters	%
Nitrogen	0.22
Phosphorus	0.2
Potassium	1.27
Humification degree	20.59
Humic acids	19.75
Phulvic acids	0.84
No humic substances	74.42
Humification index (N/D)	3.61
C/N relation(N/D)	139.75

Source: Muzali, 2005 (N/D):No dimensions

Once evaluated chemically the raw material, the next step consisted in to determine the characteristics of the end product, for which were carried out the following tests:

Was placed in probe six (6) treatments denominated from T_0 to T_5, with a number of repetitions of 3 by treatment and in a factorial adjustment of 3 x 2 completely at random. All these treatments were put under the same process of bio-transformation of the organic matter in similar materials to humus, following the same methodology in each one. The purpose was to verify, applying the method of Ciavatta (Ciavatta et.al. 1990), that amounts of humic acids and phulvic acid could be reached. In addition the organic carbon was determined by the method of Walkley and Black (1934). Each treatment was carried out with different conditions of pH and amounts of applied activators, these conditions are shown in table 2.

Table 2: The activator and pH conditions employed for the treatment

Treatment	pH	Multi-enzyme (g/150L vinaza)
T_0	4.2	0
T_1	5.0	0
T_2	4.5	110
T_3	5.0	110
T_4	4.5	147
T_5	5.0	147

From these treatments the results shown in figures 1, 2 and 3 were obtained, where the humification degree is identified by symbol GH, the relation humic acid/ phulvic acids by symbol AH/AF and the index of humification by IH.

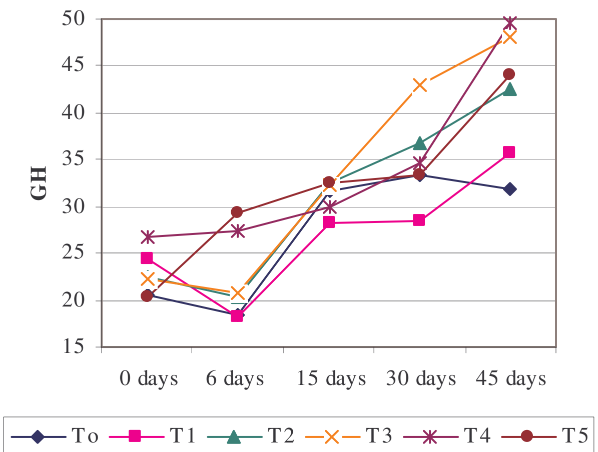

Figure 1: Humification degree obtained by treatments

When observing figure 1 is appraised that treatment three (T_3) presents an accelerated growth of humification degree until the 30 days of residence, having obtained an acceptable value of 43% of GH. This treatment is the only one that surpasses 40% of humification degree in that period. To the 45 days, the treatments T_3 and T_4 surpass 45% GH, a value some better, but that loses interest when considering that, in first place, besides to imply greater cost of investment since will require greater size of the equipment and/or reactors to use due to the increase of the time of residence, the production costs are increased to a value superior to 50%.

As far as the humification index, the only treatment that reaches the considered numerical value as matured product (IH‹1) is treatment T_3 to the time of 30 days with a value of 0,96. The other treatments are by outside this rank, being catalogued like immature or partially mature products.

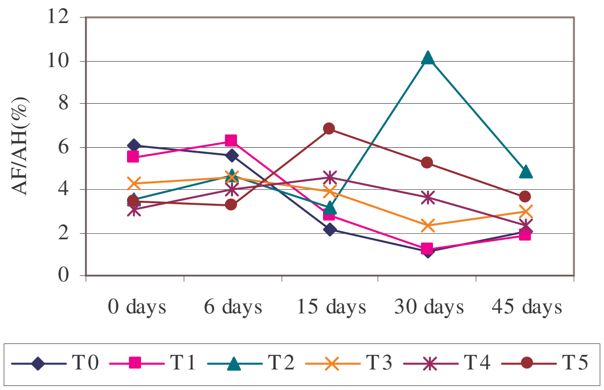

Figure 2: Relation humic acids/phulvic acids presents in the treatments.

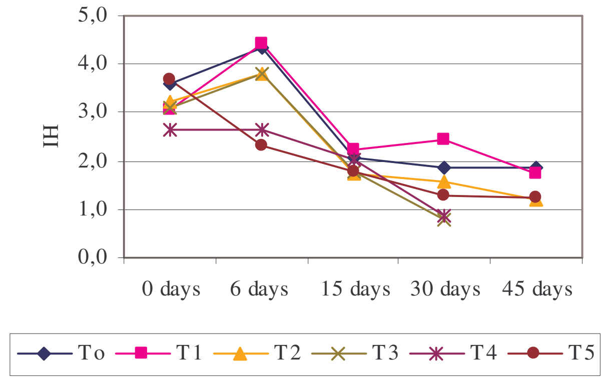

Figure 3: Humification indexes present in the treatments

By the shown in the previous figures, the humic liquid fertilizing product that adapts better to the exigencies of production according to the cost parameter and that represents a product of good quality as well is the obtained by means of treatment T_3 to the 30 days, reason why it was selected as the treatment which would be due to carry out to industrial level. It was observed in addition, that the total volume of bio-fertilizer obtained represents 50% of the volume of the raw material and catalyses employees joint, the proportions in which are present the components are shown in the table 3

Table 3: Characteristics of fertilizer products

Parameters	%
Nitrogen	0.45-0.5
Phosphorus	0.25-0.28
Potassium	1.45-1.5
Humification degree	43.04
Humic acids	42.08
Phulfic acids	0.96
No humic substances	33.7
Humification index (N/D)	0.78
C/N relation (N/D)	60-70

Source: Pimentel (2005) (N/D): No dimensions

Once identified the design bases, the next stage consisted in the design or engineering stage that allowed knowing the fundamental characteristics of the process

Design stage:

Initially was considered the vision of the plant that is desired to install. In this sense was settled down that the plant on industrial scale had to fulfill the parameters that were used on pilot scale, which are dictated next:

1.- It must follow the procedure proposed by Poglio (1989) where is guaranteed the bio-transformation and stabilization of the organic matter through two phases: one Catalytic and one Catalytic-Enzymatic.

2.- The adjustment of pH between the phases must be done for a better unfolding of the process of bio-transformation of the organic matter.

3.- It must stay in aerobic conditions, providing ventilation and constant agitation throughout the process to guarantee the appropriate work of the microorganisms (fungi and bacteria) that are in charge of the transformation.

Already known these aspects, an initial scheme is structured of which will be the industrial plant, which is shown in figure 4:

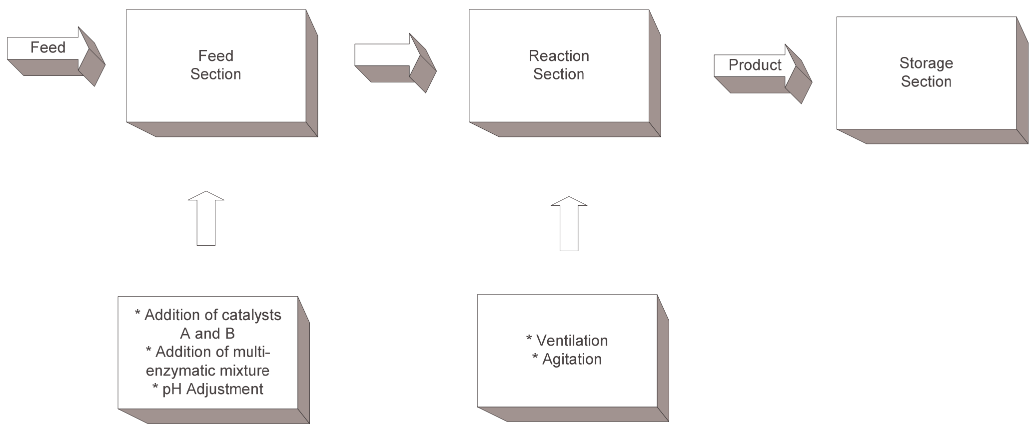

Figure 4: Initial scheme of the plant of production of Liquid Humic Bio-fertilizer

Then, being based on the size of the national market and on the measurement to represent an alternative that initiates the solution to the problem of handling of vinaza, came to define the capacity of the plant which was of 6.750.000 liters of liquid humic bio-fertilizer to the year, using for it smaller amounts of nitric acid and ammonium hydroxide in different concentrations for adjustment of pH and development of communities of microorganisms. Also will be used moderate amounts of commercial multi-enzyme that is the responsible of that the bio-transformation is carried out of accelerated way. In total 13.500.000 liters of raw material and annual supplies will be handled, that are represented in percentage in the proportions that are shown in the table 4:

Table 4: Percentage represented by the raw material and supplies in the bio-fertilizer production

Substance	%
Vinaza	98.33
Nitric acid	0.29
Ammonium hydroxide	0.79
Multi-enzyme	0.59

Later, it was come to define the processes required for the plant, reason why the block diagram of process was made along with its balance of mass, whose representation is in figure 5.Identified the processes, was come to quantify the required equipment, taking into account an analysis for the obtaining from the optimal number of required reactors based on the minimum required area. Obtaining like main product of this stage, the flow chart of process indicated in figure 6, which can be described of following form:

The plant will be constituted by two sections:

- Section of preparation of the activators.
- Section of reaction.

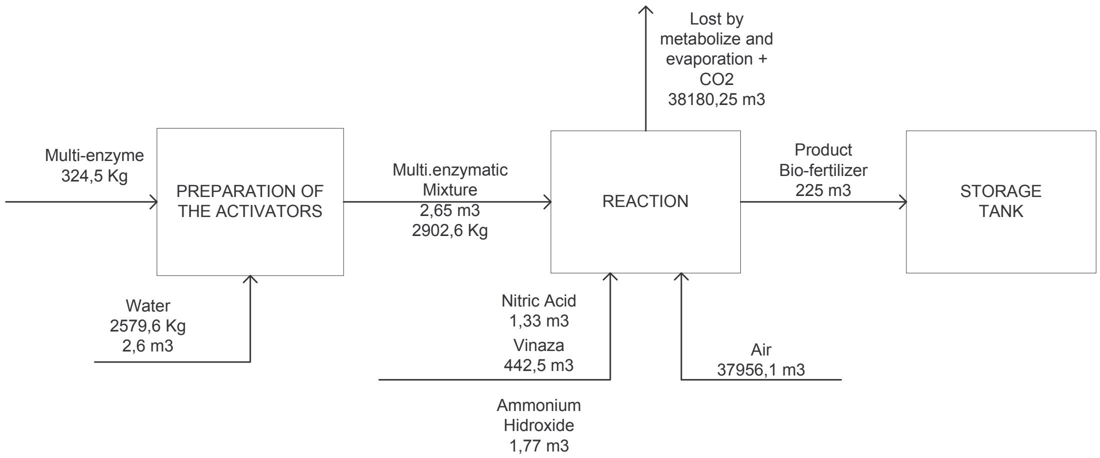

Figure 5: Block diagram of the process of production of bio-fertilizer

Each one of these parts fulfills an essential function that will be described following:

- Section of preparation of the activators: This includes the hopper of multi-enzyme storage T-103 and the tank of preparation of the multi-enzymatic mixture T-104; the function that is fulfilled in this section is to activate the enzymes that will act in the catalytic-enzymatic phase of the biological reaction. The route of the currents is described following:

The solid multi-enzyme necessary to nourish a reactor, is fed by gravimetry to the T-103 tank, later feeds service water on 40˚C to the T-104 until reaching the indicated minimum level in this tank. Next the agitator of the T-104 ignites and the multi-enzyme content of the T-103 tank is added to the T-104 maintaining ignited the agitator; is left the mixture during a time of 30 minutes in rest to allow the activation of enzymes, being of this form ready to be transported to the process of reaction. To allow the passage of the multi-enzymatic mixture to the reactor, the valve of passage of the mixture to the reactor is opened and the B-103 pump ignites

- Section of reaction: It is conformed by three bio-reactors R-101A/B/C; here it is where is carried out the transformation of the organic matter in humic substances with flows of the currents described next:

After opens the valve of passage of the first reactor, is made pass directly of the tower of beer the flow of vinaza until reaching 75% of the capacity of the tank (considered time of filling 23,6 hours), once reached this time, the valve of passage of reactor R-101A is closed and the valve of passage of vinaza to reactor R-101B is opened simultaneously to guarantee the continuous filling of the raw material, of the same form is made with the R-101C.

During the filling of reactor R-101B, to the time in that the valve of passage of vinaza of the R-101A is closed, is opened the valve that allows the nitric acid passage and is ignited the B-101 pump controlling the volume of entrance with the flow and the considered time of filling (1,6 hours). During the filling, the system of agitation of the reactor ignites and once finished the filling of the acid; it is left more in constant agitation by 6 hours. After passed this time, the valve of ammonium hydroxide passage is opened and the B-102 pump ignites remaining active the agitation. Just as in the case of nitric acid, the volume of feeding of the hydroxides is controlled by the caudal and the anticipated time of filling. Finished the filling of the hydroxide, it is left in constant agitation by six hours.

Once culminated first stage of the reaction, it is come to the adjustment from pH; this is made in parallel to the indicated procedure in the previous section. Here, it will add the amounts of base that are necessary to elevate pH to a value of 5. Once obtained this and with the preparation of the mixture activated, opens the valve of passage of the multi-enzymatic mixture and the B-103 pump ignites to take step to the multi-enzyme prepared in the T-104 to the reactor, where they will remain by a period of 30 days under the conditions of agitation and ventilation during the evolutionary process.

Finished the 30 days period of reaction, is stopped the supply of air and the agitation, and is pumped the product to the storage tank, where it will be available for sell and distribution

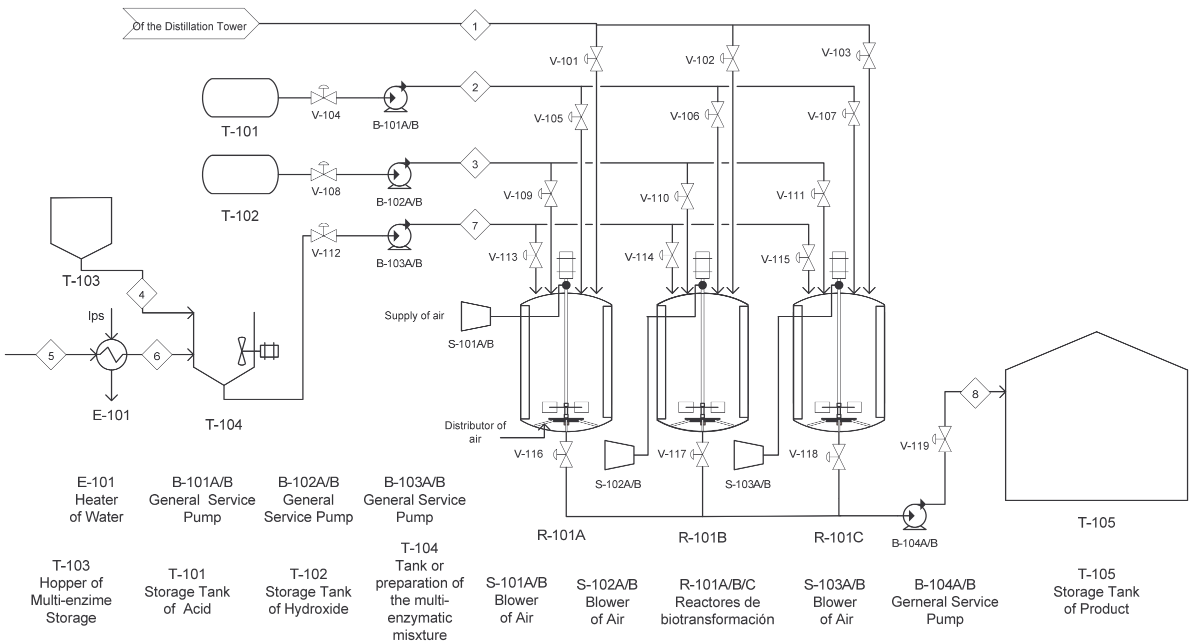

Figure 6: Flow chart of the process

Once the equipment are identified, it is necessary to make their sizing, using for this the heuristics shown by Turton et. al., 1998, filling also the specifications sheets of each one of these equipment. At the final, was settled down the required philosophy of control as well as the required services, which are shown in table 9

Table 9: Required services for charge

Service	Quantity (Kg)
Vapor	7,992
Water	23,976

CONCLUSIONS

- The use of vinaza like raw material for the obtaining of a bio-fertilizer that allows the partial substitution of those that are use at the moment, is feasible.
- The plant designed will have an annual capacity of 6.750 m^3 of bio-fertilizer, with a time of residence of vinaza in the process of around 30 days.
- All services and other required raw materials are available in the national market; this increases the feasibility of the installation of process.
- It is recommended to make an economic feasibility study of this process.

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