ABSTRACT

Stillage or bottom slops is a highly polluting effluent derived from fermentation ethanol distillation. It is produced in Brazilian conventional sugarcane and mandioca distilleries at a rate 12 to 13 times the alcohol volumetric output.

With the implementation of the Brazilian Gasohol Program, stillage annual production will reach 60 million cubic meters by 1983.

This paper discusses the economics of in-natura stillage recovery through its application as a sugarcane fertilizer. This process can be carried out by a mobile equipment or through a furrow system.

The fleet of mobile equipment required to transport and distribute stillage on the crop field was calculated for different daily stillage production rates. Investment and application cost figures are also presented.

The replacement of conventional NPK fertilizer in sugarcane and/or mandioca cultivation by in-natura stillage can in certain cases represent a measurable benefit allowing acceptable rates of return on investment.

The problems and opportunities of concentrating stillage to improve the economics of this recovery alternative are also assessed.

A review of the Brazilian experience on the benefits and potential hazards of this stillage recovery alternative to sugarcane crops is presented.
INTRODUCTION

The residue of distilled fermented mashes known as stillage, vinasse, slop, bottom slop or still residue, is the largest volume outflow of a distillery. The composition of this residue varies as a function of the fermentation process used, the raw material employed and the distillate produced.

Due to its organic and mineral contents, stillage has extremely high water pollution potential, e.g., two liters of stillage on the average, have the same water pollution potential as an individual's daily domestic sewage production.

In the past, almost all stillage produced at alcohol distilleries in Brazil was discharged into rivers and lakes because it was considered to be a useless waste. Little concern was expressed over its water pollution potential or the possibility of recycling many of its valuable components.

Absolute alcohol in Brazil is produced primarily from fermentation of sugarcane molasses (also known as blackstrap molasses) in distilleries adjacent to sugar mills (by-product or molasses distillery). It can also be produced directly from sugarcane juice, in the so-called independent distillery.

The Brazilian Gasohol Program considers mandioca as an alternative potential raw material for fuel alcohol production. The process is similar to that which uses cane particularly in the fermentation and distillation steps (Trindade and Yang).

The different types of stillage produced in Brazil are named according to the raw material utilized.

The quantitative and qualitative characteristics of stillage generated in the various processes of ethyl alcohol production vary depending on the raw material and operational variable.

The historic and projected alcohol/stillage production in Brazil by type of distillery, up to 1983, is shown in Fig. 1 (1 to 8). The composition of the various types of Brazilian in-natura stillages is presented in Table 1 (8 to 13).

To a certain extent, in-natura stillage in Brazil has been recycled through its direct application in the field as a fertilizer. However, the actual volume for this purpose remains undocumented.

Like any conventional fertilizer, stillage alters the soil's original properties, as well as the productivity and characteristics of the crops grown on it. The industrial recovery of the end-products of such crops is also affected.

As a product derived from fermentation, stillage has peculiar fertilizing characteristics that will be discussed later in this paper. In principle, stillage could be used to fertilize many different crops. However, for reasons of economics and location, its sole use nowadays in Brazil has been as a fertilizer of sugarcane.
Experimental evidence of the beneficial effects derived from application of in-natura stillage as fertilizer for sugarcane in Brazil has justified its being considered as a raw material of commercial value, not only reducing the use of conventional fertilizers but under certain conditions, also eliminating the problem of pollution by stillage (Centro de Tecnologia Promos).
Organic matter is the main fraction of the total solids present in the different types of stillage presented in Table 1. It is therefore to be expected that its application to the soil corresponds basically to organic fertilization with all the major effects generally observed when organic matter is added to the soil. All these effects are generally common to any type of organic matter, regardless of its origin, and have been observed to a lesser or greater degree when stillage is applied to the soil (Gloria and Mattiazzo, 1976; Gloria, 1981).

**TABLE 1. Typical composition of in-natura Brazilian stillages (grams per liter)**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Type of Stillage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Molasses</td>
</tr>
<tr>
<td>Total solids</td>
<td>81.5</td>
</tr>
<tr>
<td>Volatile solids</td>
<td>60.0</td>
</tr>
<tr>
<td>Fixed solids</td>
<td>21.5</td>
</tr>
<tr>
<td>Carbon (C) (a)</td>
<td>18.2</td>
</tr>
<tr>
<td>Reducing substances</td>
<td>9.5</td>
</tr>
<tr>
<td>Crude protein (b)</td>
<td>7.5</td>
</tr>
<tr>
<td>Potassium (K₂O)</td>
<td>7.8</td>
</tr>
<tr>
<td>Sulfur (SO₄²⁻)</td>
<td>6.4</td>
</tr>
<tr>
<td>Calcium (CaO)</td>
<td>3.6</td>
</tr>
<tr>
<td>Chlorine (Nace)</td>
<td>3.0</td>
</tr>
<tr>
<td>Nitrogen (N)</td>
<td>1.2</td>
</tr>
<tr>
<td>Magnesium (MgO)</td>
<td>1.0</td>
</tr>
<tr>
<td>Phosphorus (P₂O₅)</td>
<td>0.2</td>
</tr>
<tr>
<td>BOD</td>
<td>25.0</td>
</tr>
<tr>
<td>COD</td>
<td>65.0</td>
</tr>
<tr>
<td>Acidity (c)</td>
<td>4.5</td>
</tr>
</tbody>
</table>

(a) Carbon content = Organic solids content / 3.3
(b) Crude protein content = Nitrogen content x 6.25
(c) Expressed in pH units.
The effects on the soil caused by the organic water will be significant only if the stillage is applied at high rates.

These effects are not pronounced for the volumes presently applied — 30 to 50 m³/ha for cane molasses stillage and up to 200 m³/ha for cane juice stillage — since the organic matter concentration in these stillages is low in comparison with other organic fertilizers.

Stillage contains potassium, sulfate and calcium in relatively high concentrations, in addition to organic matter. When stillage is applied as fertilizer, the concentration of these ions in the soil will increase. All the important sugarcane nutrients, especially potassium (Catan et al.9 Instituto de Açúcar e do Álcool22).

Stillage application therefore corresponds to fertilization with potassium, calcium and sulfate which, in appropriate quantities, has no negative effect on the soil. If large amounts are applied, however, they may overload the soil with salts. The ideal quantity of stillage to be applied to the soil as fertilizer is therefore a function of its composition and the type of soil.

The experience accumulated in Brazil has demonstrated that application on some types of soil of up to 50 m³ of cane molasses stillage per hectare does not cause soil salinization. These volumes correspond to conventional fertilization with potassium, calcium and sulfur as practiced in other countries at levels often higher than conventional fertilizers (Jackman28 and Brieger7). It is evident that indiscriminate application of stillage on highly fertile soils or on those with saline characteristics would result in their salinization.

The information presently available about the use of cane juice stillage as fertilizer is incomplete to allow conclusions about its effects on the soil.

**TABLE 2. Receptivity to stillage by type of soil (Sugarcane areas in Brazil)**

<table>
<thead>
<tr>
<th>Receptivity to Stillage</th>
<th>Type of Soil</th>
<th>Main Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good</td>
<td>Lateritic</td>
<td>Low to average fertility requiring mineral Fertilizer</td>
</tr>
<tr>
<td></td>
<td>Podzolic</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tertiary (tabuleiro)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tableland</td>
<td></td>
</tr>
<tr>
<td>Limited</td>
<td>Alluvial</td>
<td>High fertility</td>
</tr>
<tr>
<td>Limited-Low</td>
<td>Structured purple</td>
<td>Saline soils, with high content of Ca, Mg, Na and K</td>
</tr>
<tr>
<td></td>
<td>Hydromorphic</td>
<td></td>
</tr>
</tbody>
</table>

(22 Instituto de Açúcar e do Álcool)
However, preliminary results show that the application of 80 to 120 m³ of such stillage per hectare has no damaging effect to the soil.

The different types of soils dedicated to sugarcane growing in Brazil and their stillage receptivity is presented in Table 2 (15). A substantial fraction of the sugar cane cultivation areas in Brazil have soils with characteristics which permit the use of in-natura stillage as fertilizer.

The experience acquired in the application of stillage as fertilizer in Brazil can be summed up in the following general conclusions:

(i) The use of stillage to fertilize sugarcane increases the crop sugar yield (pol/ha or real sucrose/ha) (COPERSUCAR13, Stupiello et al137, Magro and Gloria30, Rosseto et al34).

(ii) Sugar yield remains practically unaltered through the fourth cutting when the ratoon cane is fertilized with in-natura stillage. This evidence is particularly fortunate since the harvest period, which is concurrent to field fertilization, also coincides with distillery operations and, therefore, with stillage availability. (Agujaro3).

(iii) Optimal stillage application rates are a function of soil fertility, among other parameters, but appear to fall into the 30 to 50 m³/ha range for cane-molasses stillage and 80 to 200 m³/ha for cane-juice stillage. Rates substantially higher than these have undesirable effects on the crop while only slightly increasing yield (Gloria21, Gloria and Magro20).

(iv) Among the major undesirable effects of stillage fertilization is its ability to increase ash content in cane. This increase is close to that obtained through application of equivalent mineral fertilizers and, for the suggested application rates, does not jeopardize sugar quality or industrial yield, (COPERSUCAR13, Stupiello et al37, Magro and Gloria30, Rosseto et al34, Gloria21, Silva et al36, Rodella and Ferrari32). Increased ash content, which corresponds to increased potassium concentration, can benefit the fermentation yield when cane is used exclusively for alcohol production.

(v) Stillage application retards cane maturation, noticeably during the first two months of plant growth (23, 27,30).

(vi) Additional investigation is required for evaluation of other possible deleterious effects of stillage fertilization, such as increased cane fiber and starch content (21, 28, 31).

(vii) The effects of using mandioca stillage to fertilize mandioca crops are not fully known. The lack of experimental information restricts assessment of this possibility to inferences based on the composition of the mandioca stillage and that plant's requirement. Conclusive results will only be attained through field tests based on the stillage generated at mandioca distilleries that have only recently started operations in Brazil (32 to 34).
There are also two basic methods of applying stillage to the soil: distribution through a furrow system or by mobile equipment such as tank-trucks.

(i) Furrow System

This is the most widely-used method in Brazil and, therefore, the most studied. It involves intermediate storage tanks, known as collection boxes, pumps, pipes and a network of channels throughout the area where stillage is applied. The land must be prepared by hand to adapt the system to the land topography slopes, so stillage distribution is uniform and erosion caused by excessively fast flows is prevented.

However, this method is handicapped by the need to dilute the stillage, the impossibility of accurately controlling the rate of distribution and the interference of rainfall patterns on the total yield of the operation. The difficulty of accurately controlling the rate of application (m\(^3\)/hectare) may create problems for the sugarcane and subsequently have a negative impact on sugar yield. Moreover, the iron pipes that carry the stillage from the distillery to the collection boxes have a useful life of one to two years (Stupiello et al\(^{37}\)). The corrosiveness of stillage is worsened by its high temperature (90°C).

(ii) Mobile Equipment

Mobile systems have been used generally to provide for better control of the stillage application rate. However, these systems differ among themselves in terms of areas irrigated per unit of time, soil compaction, operational speed, flexibility, mechanical strength and durability (STAB\(^{36}\)).

The use of tank-trucks and/or tractor-drawn tanks to transport and spread the stillage is still undergoing tests. Thus, there appears to be no consensus at the Brazilian distilleries about the best system. All are based on gravity spraying or pressurized tank spraying.

When tank-trucks are used, stillage is usually carried and applied by the same vehicle. The capacity of the tanks, types of compressors and arrangement of the spray heads are the characteristics that vary the most, depending on the manufacturer and user.

The tractor-drawn pressurized tanks (SVD) operate in conjunction with tank-trucks that carry the stillage from the distillery to the field, where it is sprayed by the SDV. This is known as the Stillage Distribution Vehicle System (SDV) and is more advantageous in almost all cases than the pressurized tank-trucks, inasmuch as the SDV system always require less vehicles than the tank-truck systems.

Many of the stillage’s effects on the soil and on the crop can be traced to the type of system and equipment utilized to spread it on the field (36). Table 3 summarizes the advantages and disadvantages of the various stillage application systems (8).
<table>
<thead>
<tr>
<th>System</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tank truck:</td>
<td>3 to 4 times faster than TTFL</td>
<td>Large investment and fuel consumption</td>
</tr>
<tr>
<td>Motor Pump of Pressure driven (MPTT-PTT)</td>
<td>Uniform application over entire area</td>
<td>Inapplicable on rainy days or on hilly land</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Soil is compacted by vehicle although less than TTFL</td>
</tr>
<tr>
<td>Stillage Distribution Vehicle (SVD Unit)</td>
<td>Less soil compaction</td>
<td>High initial capital outlay</td>
</tr>
<tr>
<td></td>
<td>Greater mobility on terrain</td>
<td>Fleet of tank-trucks required for transport</td>
</tr>
<tr>
<td></td>
<td>May be used on rainy days</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Speeds comparable with those of the MPTT or PTT</td>
<td></td>
</tr>
<tr>
<td>Furrow System</td>
<td>Low initial capital outlay</td>
<td>High investment in labor to prepare terrain</td>
</tr>
<tr>
<td></td>
<td>Stillage dilution will allow adequate disposal of other distillery waste waters</td>
<td>Soil erosion caused by fast flows</td>
</tr>
<tr>
<td></td>
<td>Ideal for hilly land</td>
<td>Inaccurate control of the amount applied</td>
</tr>
<tr>
<td></td>
<td></td>
<td>High cost for maintenance of pipework and pumps</td>
</tr>
</tbody>
</table>

*Note: TTFL = Tank-truck with free fall of stillage.*
METHODOLOGY

Application Rates

The right amount of stillage to be applied to the soil as fertilizer will depend on its source, the type of soil and crop.

With regard to sugarcane cultivation, calculation of stillage application rates expressed in cubic meters per hectare (m$^3$/ha) may be based, for example, on the content of this element in the stillage. The same method of calculation may be used for mandioca, wherein the predominant factor is the quantity of potassium required by the plant, i.e., nearly 300 kg/ha.

In calculating the application rates shown in Table 4, the standard composition of the various types of stillage was used (Table 1). These application rates were taken as a basis for sizing the application systems. The application rates for cane-juice and mandioca stillages are conservative owing to the present lack of more detailed experimental evidence of its effectiveness as a fertilizer.

<table>
<thead>
<tr>
<th>Type of Stillage</th>
<th>Application Rate (m$^3$/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Molasses</td>
<td>50</td>
</tr>
<tr>
<td>Cane-juice</td>
<td>200</td>
</tr>
<tr>
<td>Mandioca</td>
<td>300</td>
</tr>
</tbody>
</table>

Selection of Type and Size of Application Systems

Whether or not to adopt the furrow method of stillage application will depend on the topography of the cane or mandioca fields, plus the distillery-to-field distance. The choice of the system will therefore depend on an individual case-to-case analysis.

However, for the SDV system, a methodology was developed for sizing the fleet of vehicles according to the following parameters: daily stillage production, type of stillage and distance from distillery to field.

The stillage application model adopted in this paper (Fig. 2) has set distillery-to-land pilot distances of 5, 10, 20 and 30 km (Centro de Tecnologia Promon$^1$). It also determines that daily stillage output must be applied within 20 hours, since stillage is a perishable product.
Crop area – Daily stillage production/stillage application

FIGURE 2. Stillage application as fertilizer-system concept adopted.

The tank-trucks carry the stillage over this distance to spread it over cropland. When the SDV system is used, the stillage is trucked to the cropland and transferred to the stillage distribution vehicle (SDV) for spreading over the crop.

The area of distribution is determined by daily stillage output and the rate of application. In the model, this area was assumed as available in all instances. Table 5 illustrates that in all cases the area required for application will always be much smaller than that planted in sugarcane for alcohol and/or sugar production (Trindade and Yang40, Centro de Tecnologia Promon10, Yang and Luchi43, Almedial). The number of trucks and tractors are also a function of several other individual characteristics: tank capacity, loading time, velocity of transporting vehicle (full and empty) and distribution velocity. The values of these parameters adopted in the model are presented in Table 6, including others required for the economic evaluation of this recovery alternative (Stupiello et al38, Balbo4, Brieger8, Velho42).

Based on the size of the application system it was possible to assess the costs of such utilization using the methodology shown in Fig. 3 (Centro de Tecnologia Promon10). Technical assets, i.e., investment in vehicles and equipment required by the SDV system, were estimated for each type of stillage, over the range of capacities assessed (380 to 4500 m3 of stillage/24 h) and 5 to 30 km distillery-to-field distances.
<table>
<thead>
<tr>
<th>BW PRODUCTS</th>
<th>( \text{M} )</th>
<th>( \text{C} )</th>
<th>( \text{D} )</th>
<th>( \text{E} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>1650</td>
<td>300</td>
<td>12000</td>
<td>3.3</td>
</tr>
<tr>
<td>21</td>
<td>1500</td>
<td>200</td>
<td>720</td>
<td>3.3</td>
</tr>
<tr>
<td>0.6</td>
<td></td>
<td></td>
<td>320</td>
<td></td>
</tr>
<tr>
<td>area (%)</td>
<td>area (ha)</td>
<td>area (ha)</td>
<td>area (ha)</td>
<td>area (ha)</td>
</tr>
<tr>
<td>application</td>
<td>application</td>
<td>application</td>
<td>application</td>
<td>application</td>
</tr>
<tr>
<td>dry material</td>
<td>Total Yield</td>
<td>Crop</td>
<td>Stillage</td>
<td>Application</td>
</tr>
</tbody>
</table>

**TABLE 6:** Relation between crop area for absolute alcohol production and area for application of in-water stillage as fertilizer.
In the economic and financial analysis 80% of the funds necessary for project implementation were considered as obtainable from subsidized financing sources. Working capital was taken as provided from own funds. The subsidized money are subjected to the following conditions:

- Duration: 24 semesters, including 6 semesters of grace;
- Annual Interest Rate: 17% including monetary correction;
- Annual Inflation: 40%

**TABLE 6. Characteristics of stillage application systems**

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Unit</th>
<th>SDV Unit</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Truck</td>
<td>Tractor +</td>
<td>Tank</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tank capacity</td>
<td>m³</td>
<td>16</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>Application velocity</td>
<td>km/h</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transport velocity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>o empty</td>
<td>km/h</td>
<td>45</td>
<td></td>
<td></td>
</tr>
<tr>
<td>o loaded</td>
<td>km/h</td>
<td>20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loading time</td>
<td>min</td>
<td>6</td>
<td>6.6</td>
<td></td>
</tr>
<tr>
<td>Average fuels consumption (b)</td>
<td>liter/km</td>
<td>0.25</td>
<td>4.3 (a)</td>
<td></td>
</tr>
<tr>
<td>Economic useful life</td>
<td>year</td>
<td>4</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Initial investment</td>
<td>10³ Cr$ (c)</td>
<td>680</td>
<td>790</td>
<td></td>
</tr>
</tbody>
</table>

Notes:
- a Width of application strip: about 10 meters
- b Diesel oil
- c August 1978 cruzeiros (Cr$ 20.00/US$)

SDV – Stillage Distribution Vehicle

A 15-year operating period was considered, during which trucks were replaced every four years and SDV tractors every five years. So a typical implementation schedule resulted.

The operating costs of stillage fertilizer application were the sum of:

(i) variable costs: included only the costs of fuel used in the vehicles and calculated on the average mileage for both transporting and spreading the stillage;

(ii) fixed costs: manpower, vehicle and equipment maintenance and insurance, calculated on an annual basis;
(iii) depreciation: annual amortization of loans and depreciation (20% per year) of equipment and vehicles.

The application costs were determined so as to ensure a return on the entrepreneur's invested capital of 15% per year. In-natura stillage was taken as available at zero-cost.

FIGURE 3. Economic analysis of systems for stillage application as fertilizer – adopted methodology –

FIGURE 4. In-natura stillage application as fertilizer – Economy of scale of SDV system –

Note: SDV = Stillage Distribution Vehicle
RESULTS

Investments

The investments in vehicles and equipment for agronomic in-natura stillage utilization systems are given in Fig. 4 as economy-of-scale curves covering the range of capacities under assessment. Financing costs and charges are not included.

An analysis of Fig. 4 will show that investments in SDV systems for applying cane-juice or mandioca stillages are always lower than those required for spreading cane-molasses stillage. Therefore, the lower the application rate, the higher the investment in vehicles required to handle a given volume of stillage.

Application Costs

The tank-truck and SDV fleets required for application of molasses stillage as fertilizer, at distilleries of various capacities and at different distillery-to-field distances are shown in Fig. 5. The diagram indicates that:

(i) The number of SDVs required to handle the same daily plant output on in-natura stillage is an increasing, non-linear function of the distance;

(ii) When plant capacity varies but plant-to-field distance remains constant, the same conclusions as in (i) apply;

(iii) The number of SDV (tractor/tank) varies only with the daily stillage output. The number of trucks to transport the stillage to the SDVs varies according to the distance;

(iv) The ratio between the number of tank-trucks and the number of SDVs is not dependent on the daily plant output and varies according to the distance (Table 7).

<table>
<thead>
<tr>
<th>TABLE 7. Molasses stillage application by SDV system-TT/SDV ratio as a function of distillery-to-land plot distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance (km)</td>
</tr>
<tr>
<td>----------------</td>
</tr>
<tr>
<td>5</td>
</tr>
<tr>
<td>10</td>
</tr>
<tr>
<td>20</td>
</tr>
<tr>
<td>30</td>
</tr>
</tbody>
</table>

Notes: TT = Tank truck (Part of SDV unit)
SDV = Stillage distribution vehicle
The combination of the desired capital recovery rate, distillery-to-field distance and distribution system capacity formed the parameters for establishing the values represented in this paper in discrete graphic form, for molasses stillage.

Fig. 5 also indicates the costs of applying in-natura stillage through the SDV system. The costs presented are limited to a 15% annual capital recovery rate under a subsidized financing scheme.
The transportation and application costs for the various types of stillage, production capacities and distillery-to-field distances served as the bases for determining the economic stillage transportation and application radius, which was then ascertained by comparing the costs calculated for transporting and applying stillage to the costs associated with conventional NPK fertilization.

The economic radius is thus defined as the distillery-to-field distance—in kilometers—for which the Cr$/hectare cost of transporting and applying stillage is equal to the Cr$/hectare cost of transporting and applying the conventional fertilizer taken as a reference.

The reference costs (for conventional fertilizer) were determined assuming the same financing scheme and capital recovery rate (CRR) adopted for calculating the stillage fertilization cost and using the Uniform Annual Series of End-of-Year-Payments (UASEP) Method over the 15-year period analyzed (Grant and Irresom15).

Results of this comparative analysis are depicted in Fig. 6 where the ranges of values cover the subsidized financing and own capital schemes and

**Bases:** Boundaries defined for following conditions:

- Subsidized financing and own capital schemes
- Capital recovery rates: 5 - 15% per year.
- Values in August 1978 Cr$ (Cr$20/US$)

**FIGURE 6.** In-natura stillage application as fertilizer — Economic radius—
CRR's of 5 to 15% per year. Inspection of this figure permits the following conclusions:

(i) The economic radii are a function of the type of stillage and are practically independent of the distillery's daily stillage output.

(ii) The minimum cane-juice stillage volume, produced daily, which allows the economical application by SDV system is 750 m$^3$.

(iii) The economic radius for mandioca stillage is bigger than that for cane-juice stillage because the annual operating period of the application system (330 days) is longer and the application cost of the equivalent conventional fertilizer is higher. The operating period of sugarcane based distilleries is 200 days per year.

DISCUSSION

In utilizing in-natura stillage as fertilizer the fuel required for its transportation represents the main component of the application costs (30 to 35% of the total cost Centro de Tecnologia Promon). Thus, reduction of this cost item will enhance the profitability of this stillage recovery alternative. For this reason there have been some discussion whether concentrating stillage before its application would represent a substantial reduction in the total cost of the operation.

Concentrated stillage has two advantages over in-natura stillage with respect to its application as fertilizer: greater stability and reduction of the volume to be transported. The second advantage could, in principle, help reduce the costs involved in transporting the product from distillery to field.

In comparison with in-natura stillage, the major disadvantages of using the concentrated products as fertilizer are:

(i) It requires a much more accurate control of the application rate;

(ii) Irrigation effect attributed to the water content of in-natura stillage will not occur;

(iii) Pumping difficulties due to its greater viscosity, particularly when the product is cold; thus concentrated stillage cannot be distributed over the field by the furrow system;

(iv) Incorporation into the soil could be difficult in certain types of soil;

(v) Product must be processed prior to application, which requires high capital outlay.

Assuming stillage concentration by multiple effect evaporation and land distribution with SDV system, the concentrated stillage total application cost was assessed.
Bases: * Curves I, II and III refer to application costs for the stillage distribution vehicle - SDV system
* Distillery-to-field distance = 5 km
* Subsidized financing scheme
* Capital recovery rate = 5% per year.
* Values in August 1978 Cr$ (Cr$ 20/US$)
* Concentrated stillage with 60% total solids

<table>
<thead>
<tr>
<th>Curve</th>
<th>Type of concentrated stillage</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Mandioca</td>
</tr>
<tr>
<td>II</td>
<td>Cane-Juice</td>
</tr>
<tr>
<td>III</td>
<td>Cane-Molasses</td>
</tr>
</tbody>
</table>

![Concentrated stillage application cost](image)

**FIGURE 7.** Concentrated stillage application cost

Comparison of concentrated stillage application costs according to the same criteria adopted for in-natura stillage shows these costs to be higher than those for conventional fertilizers even at distillery-to-field distances under 5 kilometers. This is because the high cost of concentrating the stillage add to the final cost. Within the economic prism of the subsidized financing schemes considered, Fig. 7 illustrates this fact and indicates the cost of applying concentrated stillage at a distance of 5 kilometers from the distillery. The application cost of conventional fertilizer is also indicated.

Yet other benefits arising from the application of concentrated stillage as fertilizer might render this use economically feasible. Reclamation of unproductive soils in areas suitable for sugarcane cultivation could be one of the benefits, and revenue from improved agricultural yields could offset the high cost of concentrated stillage application.
Speculation suggests that one way of lowering stillage application costs to a minimum would be reducing the volume to be applied by concentration to intermediary level between in-natura and 60% total solids concentrated forms.

Bases: * 1500 m$^3$ of in-natura stillage per 24 hours  
* Type of stillage: Cane-molasses  
* August 1978 Cr$\$/ (Cr$\$/20/US$)

NOTES: (a) Concentration through multiple-effect evaporation  
(b) Stillage transportation by tank-truck over distillery-to-field distance of 30 kms and application by SDV (stillage distribution vehicle)

**FIGURE 8.** Cost of concentrating, transporting and applying stillage as fertilizer at different concentrations

This is not the case, however, for a simple reason. The application cost comprises three different cost factors: concentration, transportation and application. The first cost factor is high, even for intermediary concentrations. The third cost factor is directly proportional to the increase in the stillage total solids concentration, an effect due exclusively to the low application rates required for efficacious distribution of concentrated stillage. The increase in the application cost therefore more than offsets the reduction in the transportation cost. Fig. 8 illustrates this observation for molasses stillage at reference capacity (Centro de Tecnologia Promon$^{10}$).

**CONCLUSION**

Based on recent experimental evidence accumulated in the Brazilian sugar cane agroindustry it is possible to conclude that in-natura stillage can be used as a sugarcane fertilizer. Through this practice increased cane productivity,
in terms of tons of cane per hectare, is obtained without jeopardizing alcohol industrial yield (liter of alcohol/ton cane). In certain cases, this practice can negatively affect industrial sugar yields due to abnormal ash content levels in the cane juice.

The SDV system seems to be the most suitable equipment for stillage land distribution due mainly to its capability of operating under harsh environmental conditions, such as rain and terrain roughness; greater field mobility; better controlled application capability; and lower soil compacting rate.

The effects of applying stillage to the soil may be regarded as resulting from mineral-organic fertilization combined with irrigation. The borders of each of these effects are thus difficult to define, suggesting that stillage is actually a fertilizer with unconventional characteristics.

In comparison with other processing alternatives the use of in-natura stillage as fertilizer presents one of the lowest cost/benefit ratios. The measurable benefit can in certain cases be attributed to the replacement of conventional NPK fertilizer sugarcane crops by in-natura stillage.

Moreover, this stillage recovery alternative requires low investment for its implementation. This investment is one order of magnitude lower than those for industrial stillage processing, as for example stillage evaporation, incineration and others.

In case no credit is given to the fertilizer value of stillage, there will be a negative impact on the alcohol selling price of the order of 5%. This figure refers to the application of molasses stillage at 30 km from a 30 m³ absolute alcohol/day distillery.

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ECONOMIA DE LA UTILIZACION DE IN-NATURA "STILLAGE" COMO FERTILIZANTE

J. R. Castello Branco, P. A. Lacaz y C. Costa Ribeiro

RESUMEN

"Stillage o bottom slops" es altamente un contaminador efluente derivado de destilacion de ethanol fermentado. Es un producto corriente en destilerias Brasilienas de caña de azucar y mandioce a una medida de produccion de 12 a 13 veces mas de alcohol volumetrico.

Con la implantacion del Programa Brasileño Gasohol el "Stillage" anual de produccion llegara a una circa de 60 milones de metros cubicos en 1983.

Este tratado discute la economia de recobre de in-natura "stillage" en su aplicacion como fertilizante de caña de azucar. Este proce-
dimiento puede llevarse a cabo por equipo mobible o por el sistema de sucro.

La “esciadra” de equipo mobible requerida para transportar y distribuir el “stillage” al campo de cosecha se calculó para valuaciones diferentes de producción de “stillage” diario. Se presentan también cifras de costo de inversión y aplicación.

El reemplazar el fertilizante corriente NPK en el cultivo de caña dulce y/o mandioca por in-natura “stillage” puede en ciertos casos representar un beneficio calculable permitiendo valores aceptables de remite de inversión.

También se valuan los problemas y oportunidades en concentrar “stillage” para mejorar la economía de este recobro alternativo.

Se presentan también la experiencia Brazilena sobre los beneficios y posible que haces de este recobro de “stillage” alternativo a cosechas de caña dulce.