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# Digestate from anaerobic reactor as a potential fertilizer

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**Abstract:** Biogas is one of the most promising sources of renewable energy in today's world. Liquid and the solid digestates are the byproducts of anaerobic digestion of various kinds of wastes to produce biogas. Disposal of liquid digestate is one of the major issues faced by the existing biogas plant facilities worldwide. In this study, liquid digestate from anaerobic digestion of food waste is examined for its potential as an organic fertilizer for food crops. Coconut peat is used as a matrix to hold the digestate and also to grow plants in a soil-less culture. Three plants from the family- Solanaceae were chosen viz. tomato (*Solanum lycopersicum),* green chilli *(Capsicum annum)* and eggplant or brinjal (*Solanum melogena).* The plants were grown in trays as control (coconut peat and water) and slurry (coconut peat and digestate). Digestate sets showed an increase in growth parameters as compared to control by a factor of 60.8% in tomato, 48.6% in chilli and 97% in brinjal for plant height, 86% in tomato, 82.4% in chilli and 63.8% in brinjal for leaf length, and 66.3% in tomato, 87.3% in chilli for number of leaves. The final yield for chilli plants was 2.5 fruits/plant in 70 days while for brinjal it was 2 fruits/plant after 74 days of growth.

**Keywords:** digestate, anaerobic digestion, soil-less culture, coconut peat, organic fertilizer

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**1 Introduction:** During the anaerobic digestion of food waste, the complex components of food like the sugars, fats and proteins are broken down into simpler products by anaerobic bacteria and methanogens thereby producing methane and carbon dioxide as the end products. Methane is directly supplied via gas pipelines for use as a kitchen fuel and also to produce electricity. The by-product of this process is the digestate, which could be either solid or liquid and has a high nutrient content and also rich in organic matter. These properties make the digestate suitable for using it as plant nutrients and a fertilizer **[1].** Potential benefits of liquid digestates regarding nitrogen availability and crop yields were reported in comparison to the use of untreated animal manures **[2]**. Now, this might seem a fancy alternative but the real problem arises with the issue of transportation of the liquid digestate.

The digestate is almost 80-90% water which makes its direct use as a fertilizer as well as its transportation from the source to the field all the more difficult. The potential for nutrient leaching is higher on sandy soils with poor water retention capacity **[3]**. Thus, the better approach would be to find suitable substrates that can hold the liquid digestate along with the nutrients and also be able to provide slow release of these nutrients to the plants.

Coco peat or the coir dust is the byproduct of the industries that use coconut husk. When the long fibers are removed from coconut husk, the remaining product is a large amount of pith tissue along with mixed length fibers. This is washed, heat treated and sieved to produce coco peat products of varying granularities. Coco peat has a very high water and nutrient retention capacity. It was shown that incorporation of waste coir dust into the sandy soils was beneficial in terms of their physical conditions, moisture and nutrient retention capacity **[4]**. These properties make it a potential substrate for plant growth. Coir dust also has a potential to be a substitute to peat for the formulation of substrates for ornamental plants grown in containers **[5]**.

The anaerobic digester at our institute facility is a horizontal plug flow reactor used for production of biogas via degradation of food waste from the mess and cafeteria kitchens. It produces $30m^3$ of methane per day. The amount of liquid digestate produced is 200L per day. It is rich in inorganic nutrients and yet its proper disposal has become a serious concern. In our study, we have used coco peat as the substrate to hold liquid digestate and thereby the nutrients and moisture. This mixture has been analyzed for its potential as a fertilizer as a soil less culture for plants. The major objective of this work is to solve the problem of digestate disposal as well as to utilize the good amount of nutrients present in it, by growing vegetable crops, which would otherwise be washed off and wasted.

**2 Digestate characterization** Liquid digestate was collected at regular intervals from the anaerobic digester in the campus which is a Horizontal plug flow reactor. The collected samples were stored at $4^oC$ for the subsequent analysis. The following parameters were calculated based on standard protocols:

Total Nitrogen: The liquid sample was subjected to Kjeldahl's digestion **[6]** to determine the percentage of total nitrogen present. The method employs decomposition of Nitrogen in the organic sample by a concentrated acid solution followed by color reaction and titration. This method allows the determination of nitrogen in organic as well inorganic samples.

Orthophosphate Phophorous: Vanadomolybdophosphoric acid method **[7]** being one of the commonly used methods. Orthophosphate in the sample reacts with molybdate in an acid medium to produce a yellow colored complex whose intensity is measured at 430 nm.

Total Potassium: The amount of potassium present in the sample was determined using flame photometry **[8]**.

Chemical Oxygen demand: Chemical oxygen demand is a measure of the total organics present in the sample. Colorimetric method was used **[9]** by digestion of the sample at high temperature under acidic conditions and a strong oxidizing agent ($K_2Cr_2O_7$).

Total and Volatile Solids: The samples were dried at 105 $^oC$ for 15 hours for Total Solids and at 550 $^oC$ for 2 hours for Volatile Solids **[8]**.

**3 Plant Growth experiments** Sixteen plastic trays (30 cm x 40 cm) were washed and air dried. Coconut peat was purchased from the green triangle garden center, Bardez, Goa. The trays were filled with equal amount of coconut peat (2 kg each). The trays were marked as control or as slurry depending upon the liquid used to wet the coconut peat. The volume of liquid used was kept constant based on the nitrogen requirement calculation by the plants (180 kg/ha N is taken as the reference for calculation). For the control trays, 1.4 L water was added and for the slurry trays, 1.4 L of slurry was added. The peat and the liquid were mixed thoroughly to form a uniform mixture. The plantlets of different vegetable crops viz. tomato, chilli and brinjal were purchased from ICAR (Indian council for Agricultural Research), Goa. These plantlets were taken out and washed off the compost in which they were received so as to free the roots. They were then planted onto the respective trays. After the experimental setup was complete, plant height, maximum leaf size, and number of leaves was monitored over a period of one month at an interval of 3-4 days.

After one month of growth in the trays, the plants had grown up to a certain height and good amount of branching. Control plants had ceased to grow by then and thus weren't transferred to field. They were then transferred to three plots (1m×1m×0.2m) made near the anaerobic reactor. Each plot was filled with the mixture of coconut peat and digestate in the same proportions as the earlier experiments up to a depth of 0.17 m. Each plant type i.e. tomato, brinjal and chilli was planted in a separate plot and allowed to grow for another one month with regular watering.

Experimental setup**:** Table 1: Number of plants in each tray

| **Plants** | **Control (2kg peat and 1.5L water)** | | | **Slurry (2kg peat and 1.5 L slurry)** | | |
|---|---|---|---|---|---|---|
| | Tray 1 | Tray 2 | Tray 3 | Tray 1 | Tray 2 | Tray 3 |
| **Tomato** | 3 | 3 | 3 | 3 | 3 | 3 |
| **Chilli** | 3 | 3 | 3 | 3 | 3 | 3 |
| **Brinjal** | 3 | 2 | - | 2 | 3 | - |

The experiments were done in triplicates (for chilli and tomato) and in duplicate (for brinjal) in order to minimize errors. Plant height, maximum average leaf size and number of leaves were monitored regularly until the plants were transferred to the field.

Yield: Final yield was measured in terms of average number of fruits per plant.

## 4 Results and Discussion:

**4.1 Digestate:** Following the methods as discussed above, the characteristics of digestate used in the experiment is as follows: 10.81 % total solids, 7.07 % volatile solids, VS/TS ratio as 0.65, chemical oxygen demand (COD) of 8181 mg/L, 778 mg/L of Ammonia nitrogen, 2101 mg/L total kjeldahl nitrogen (TKN), 1122 mg/L of phosphorous and 148 ppm potassium. For the plant growth experiments, the amount of digestate required was calculated based on the nitrogen requirements of the plants. It was reported that a rate of 200 kg/ha of N application was sufficient to maximize fruit yield [10]. The influence of levels of N and K on the growth and production of chilies was studied and it was found that application of 180 kg nitrogen and 50 kg potassium $ha^{-1}$ gave the best results [11]. It was shown that that fruit yield of eggplant increased when nitrogen application rate was increased up to187.5 kg N/ha [12]. Based on these results, **180 kg/ha** was decided to be the rate of application of Nitrogen.

Calculation:

Average N requirement by the three plants: 180 kg/ha = 18 $g/m^2$
Area of the trays being used: 0.135 $m^2$
Concentration of nitrogen in the slurry = 1.75 g/L
Total N requirement = 18 $g/m^2$*0.135 $m^2$ = 2.4 g
Vol. of slurry required = 2.4 g/1.74$gL^{-1}$ =1.4 L

Also, the amount of coconut peat used was 2 kg to suit the depth. Hence, the mixture of coconut peat: slurry was formed in the ratio 1.4: 1 and this proportion was used for the further experiments. In case of control, same volume of tap water was used in the same proportion.

**4.2 Tray Experiments:** Trays were filled with the mixture (control and digestate) up to one third of the depth of the trays. Plantlets were planted, monitored and watered regularly.



**Figure 1**: (above) Growth status of the plants on 30th day of growth. From top left, pictures (1-3) control tomato plants, (4-6) tomato plants with digestate, (7-9) chilli control, (10-12) chilli with digestate, (13, 14) brinjal control, (15, 16) brinjal with digestate.

**4.3 Growth Parameters:** For all the tables given below; IC, IIC and IIIC represent the control plants in tray I, II and III respectively. Similarly the ID, IID and IIID represent the plants with digestate in tray I, II and III respectively. Also, 'a', 'b' and 'c' represent the plants in each tray.

1) Plant Height:
Plant height was measured from the level of coco peat up to the tip of the plant. Now for the values obtained for the different plants for each plant type, average height was calculated for each day as given in the table. From these values, rate of increase in plant height was calculated by subtracting plant height on last day with that on the first day and dividing it by number of days.

Table1: Plant height measurements.

| | **Average height on the given days of growth (in cm)** | | | | | | **Rate of increase in plant height** |
|---|---|---|---|---|---|---|---|
| **Tomato** | **2nd** | **5th** | **9th** | **14th** | **19th** | **26th** | |
| 1.Control | 30.56±3.46 | 31.84±3.34 | 33.31±3.9 | 33.65±4.11 | 34.31±4.1 | 34.75±4.1 | 0.161 |
| 2.Digestate | 26.05±2.58 | 27.07±2.81 | 29.2±2.97 | 30.6±2.82 | 32.75±3.15 | 36.75±4.24 | 0.411 |
| **Chilli** | | | | | | | |
| 1.Control | 20.33±1.52 | 21.11±1.71 | 22.9±2.23 | 23.81±2.72 | 24.75±3 | 25.5±3.2 | 0.19 |
| 2.Digestate | 15±1.8 | 15.22±2 | 17.44±2.32 | 18.52±2.84 | 21.78±4.18 | 24.55±5.07 | 0.37 |
| **Brinjal** | | | | | | | |
| 1.Control | 10.6±0.9 | 11.1±1.08 | 11.6±0.97 | 11.6±0.96 | 11.8±0.83 | 11.9±1.02 | 0.05 |
| 2.Digestate | 11.1±0.74 | 11.66±0.77 | 12.4±1.02 | 12.54±1.2 | 13.4±1.55 | 14.4±2.16 | 0.127 |

Note: ± indicates standard deviation. It was observed that the rate of increase in plant height was higher in the digestate than the control plants by a factor of 60.8% in tomato, 48.6% in chilli and 97% in brinjal. The highest difference between control and digestate was found in the brinjal plants.

2) Maximum average leaf length:
Three big leaves were selected out of all the leaves for each plant, their length was measured and the average of the three was taken. Now for the values obtained for the different plants for each plant type, average leaf length was calculated for each day as given in the table. From these values, rate of increase in leaf length was calculated using the same concept as described above.

Table 2: Leaf length measurements.

| | **Maximum average leaf length on the given days of growth (in cm)** | | | | | | **Rate of increase in leaf length** |
|---|---|---|---|---|---|---|---|
| **Tomato** | **2nd** | **5th** | **9th** | **14th** | **19th** | **26th** | |
| 1.Control | 4.1±0.46 | 4.14±0.5 | 4.25±0.52 | 4.26±0.53 | 4.26±0.53 | 4.26±0.6 | 0.0065 |
| 2.Digestate | 3.69±0.33 | 3.89±0.4 | 4.05±0.5 | 4.19±0.57 | 4.54±0.63 | 4.87±0.58 | 0.046 |
| **Chilli** | | | | | | | |
| 1.Control | 7.56±1.09 | 7.8±1.06 | 8.04±1 | 8.24±1.18 | 8.11±1.2 | 8.23±1.17 | 0.026 |
| 2.Digestate | 5.84±0.46 | 6.18±0.42 | 7.11±0.54 | 7.83±0.71 | 8.76±1.13 | 9.17±1.12 | 0.13 |
| **Brinjal** | | | | | | | |
| 1.Control | 8.49±0.74 | 8.65±0.62 | 8.93±0.57 | 9.29±0.59 | 9.51±0.65 | 9.71±0.57 | 0.047 |
| 2.Digestate | 8±0.76 | 8.2±0.73 | 8.7±0.76 | 9.2±1.31 | 10.33±1.88 | 11.31±1.49 | 0.13 |

Note: ± indicates standard deviation. It was observed that the rate of increase in leaf length was higher in the digestate than the control plants by a factor of 86 % in tomato, 82.4 % in chilli and 63.8 % in brinjal. The highest difference between control and digestate was found in the tomato plants.

3) <u>Number of leaves per plant:</u>
Number of leaves was counted after every 3-4 days for every plant. The values obtained for the different plants for each plant type, average number of leaves were calculated for each day as given in the table. From these values, rate of increase in number of leaves was calculated.

Table 3: Number of leaves per plant.

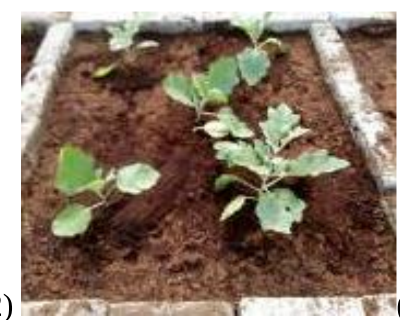
| | **Average number of leaves on the given days of growth (in cm)** | | | | | **Rate of increase in leaf number** |
|---|---|---|---|---|---|---|
| **Tomato** | **2$^{nd}$** | **5$^{th}$** | **9$^{th}$** | **14$^{th}$** | **19$^{th}$** | |
| 1.Control | 22.44±5.72 | 23.11±4.85 | 26.22±6.83 | 23.89±7.77 | 23.89±5.48 | 0.076 |
| 2.Digestate | 16±3.87 | 24.55±6.32 | 28.89±2.6 | 37.22±8.74 | 52.78±12 | 2.26 |
| **Chilli** | | | | | | |
| 1.Control | 12.67±2.69 | 13.33±3.31 | 13.75±3.32 | 13.5±3.42 | 14.75±4.33 | 0.11 |
| 2.Digestate | 11.78±2.55 | 13±2.72 | 15.33±3.8 | 19.78±4.79 | 28.4±3.78 | 0.875 |
| **Brinjal** | | | | | | |
| 1.Control | 4.6±0.54 | 4.4±0.54 | 4.4±0.54 | 4.2±0.44 | 4±0.54 | -0.01 |
| 2.Digestate | 4.2±0.44 | 4.4±0.54 | 4.6±0.89 | 5.4±1.34 | 7.2±0.44 | 0.063 |

<u>Note:</u> ± indicates standard deviation. It was observed that the rate of increase in leaf number was higher in the digestate than the control plants by a factor of 66.3 % in tomato, 87.3 % in chilli. The negative value in case of brinjal control plants is because of the shedding of leaves because of which the value on the last day is lower than that on the first day.

**4.4 Plot Experiments:** Coconut peat provides a good support as a plant growth medium but lacks enough nutrients. As a result after a period of time the growth of plants declined and eventually led to death of the control set of plants. Whereas, the digestate set of plants showed a considerable increase in the growth parameters chosen for the study. Thus, to study the effect further on till the fruiting stage, plants from the digestate set were transferred on to the field. Three plots of an area 1m$^2$ each were made and filled up to a depth of 17cm with the mixture of coconut peat and digestate in the same proportion as tray experiments. These were propagated for another month so as to identify the yield in terms of number of fruits per plant.


(1)


(2)


(3)


(4)


(5)


(6)

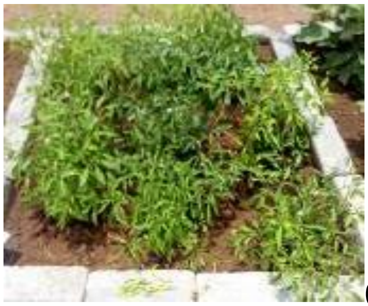
 (7)  (8)  (9)

Figure (2): From top left (1-3) chilli, tomato and brinjal plants respectively in digestate and coco peat mixture transferred to field after one month of growth in trays. (4-6) chilli, tomato and brinjal plants respectively, 15 days after transferring to the field. Tomato plants started dying while chilli and brinjal started nearing fruits. (7-9) Chilli, tomato and brinjal respectively, after one month of plot experiments.

Tomato plants started wilting and eventually died when grown in plot. The reasons were unknown but there could be a possibility that direct exposure to sunlight as opposed to that in a greenhouse. In one of the plants that bore tomato fruit, the fruit was seen to have a round black bottom which is also known as the bottom rot disease and the reasons are both irregular watering and calcium deficiency. Since this problem was not encountered by the other two plant types, the investigation is yet to be done. Chilli and brinjal plants, on the other hand, bore fruits and the yield was noted in terms of number of fruits per plant.

<u>Yield:</u> For a growth period of two months

1) Chillies- Total: 23, Number of plants = 9 ; Yield= 2.5 chillies/ plant in 70 days
2) Brinjal- Total : 10, Number of plants = 5 ; Yield= 2 brinjals/ plant in 74 days

 (1)  (2)

 (3)  (4)

Figure 3: (1-2) Ripe brinjal borne by two months old plant and yield after two and a half months respectively. (3-4) Ripe chilli on a one and a half month old plant and yield after two months respectively.

**5 Conclusion:** The above data only represents preliminary studies to investigate the possibility of employing a soil-less culture for vegetable crops. In coastal areas like Goa which usually lack fertile soil, this study has a huge potential application. Coconut peat is easily available in such places and thus using the mixture of liquid digestate with coco peat can solve the problem of both digestate disposal and lack of fertile soil. The approach is unique in terms of the combination of the two components which have been reported in their respective roles in plant growth but not together. The results obtained were satisfactory for brinjal and chilli but an unknown problem was encountered with the tomato crops. Thus, to assess the scope of fertilizer potential of liquid digestate from biogas plant, its effect needs to be tested on a variety of food crops.

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