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Investigations On Enhancement Of Biogas Production From Fruit And Vegetable Leftovers

C. Gopinathan[1*], T. Deepa Kumari[2], Aparna Menon Ambalakode[3]
[1] *(Associate Professor, Bioprocess Laboratory, Department Of Biotechnology, University Of Calicut, India)*
[2] *(M. Sc Student, Bioprocess Laboratory, Department Of Biotechnology, University Of Calicut, India)*
[3] *(Research Scholar, Bioprocess Laboratory, Department Of Biotechnology, University Of Calicut, India)*

Abstract:
1st Advance Estimates of National Horticulture Database by National Horticulture Board revealed that the year 2023-2024 witnessed total production of fruits and vegetables in India to be 11.21 and 209.39 million metric tonnes respectively. 774 tonnes of grapes were annually produced in India, which could generate ₹ 602.88 crores from exports alone during 2011-12. Later, by 2015 the figures rose to 1234.9 million metric tonnes (Ghosh et al., 2017; Malwe et al., 2022). It is unfortunate that about 30 % of the total produce are gone to waste owing to improper handling, spoilage, unscientific storing and processing. Freshly expressed grape juice is composed of sugars, organic acids, phenolic and nitrogenous compounds, minerals and pectic substances. The leftover grape pomace contributes to 20-25 % of total weight of grapes, with its major constituents being phenolic acids, flavonoids, procyanidins, resveratrol, anthocyanins, essential fatty acids, non-digestible fiber and minerals. The grape seed contain 13-19 % oil, 11 % protein, 60-70 % non- digestible fiber, tocopherols and beta-carotene. Of the total yield of 9.17 g per 100 g, pineapple peels contained around 5.11 % protein, 5.31 % lipid, 4.39 % ash, 14.80 % crude fiber and 55.52 % carbohydrate. Rotten grapes, vegetable wastes, pineapple peels and leftover pomace from cultivation sites which are otherwise discarded can be subjected to bio-processing for synthesis of value-added products like biogas and biofertilizers. This study focusses on enhancement of bio-methanation and hence generation of biogas from fruit and vegetable leftovers, upon supplementation with agricultural grade N.P.K fertilizer, ferric chloride, cow's urine, fish and poultry feather hydrolysate, powdered prawn peel, steam pretreatment of raw material and activation of inoculum using plastic bags with priority given to make the whole process cost-effective.

Keywords: *Anaerobic digestion, Biogas, Cost efficiency, Renewable energy, Grape pomace, Vegetable leftovers, Pineapple peel, Fish and poultry feather hydrolysate, cow urine.*

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I. Introduction:

Electricity is the most common form of energy the modern-day world relies heavily on. Generation of energy for various applications, derived from non-renewable resources like fossil fuel and nuclear energy can leave a lasting immense impact on global greenhouse gas emission and the waste management could be a major risk factor which if handled carelessly can lead to deadly consequences. Once depleted, these resources require longer time for its regeneration and replenishment if at all possible. Since people are becoming more aware of the relevance of sustainable development, more efforts are directed into utilizing renewable resources like wind, geothermal, solar, biomass, hydro power as major sources of energy generators. Also, on comparison with fossil fuel, biogas is a cleaner option which imposes less burden on environmental health, yet capable of meeting a significant proportion of the world energy demands. However, with an increasing demand in order to avoid an energy crisis on transition to generation from renewable resources, it is essential that the generation procedure be made more efficient and economical.

India being a major producer of fruits and vegetables, has immense scope of generation of economically viable products as the by-products of processing industries and could be a major source of revenue generation. The waste products from the processing units if left heedlessly could pose as a breeding ground for insects, disease causing parasites and may attract scavengers which may be nuisance to the society and the decomposed products from the leftover could produce foul-smelling substances which may also pollute water bodies.

Controlled anaerobic digestion of these by-products has the potential to generate many economically viable end products like enzymes, acid and alcohol to name a few. This study focuses on enhancement in the efficiency of biogas production by carefully varying production parameters as well as with the addition of products that could increase the biogas production. Attention was given to the type of raw material used, pre-treatment of the raw material, supplementation with biogas production enhancers like agricultural grade N.P.K fertilizer, ferric chloride, cow urine, fish hydrolysates, solar irradiation and use of plastic sheets for the activation of starter inoculum. The end-product slurry obtained after microbial digestion can also be used as an excellent biofertilizer which will also help condition soil.

Biogas, which is a renewable source of energy, is an admixture of different gases which are generated as a result of breakdown of organic wastes under anaerobic condition. Agricultural wastes, manure, municipal waste, plant materials, sewage, green waste or food waste can be used as potential raw materials for the production of biogas. Methane is the major component of biogas consisting of 40-75 %, followed by carbon dioxide (25-55 %), hydrogen sulfide (50-5000 ppm), trace amounts of other constituents like ammonia, nitrogen, oxygen and hydrogen along with water (0-10 %). Previous studies have shown that methane biogas from cow manure would be sufficient to produce 100 billion kilowatt hours enough to power millions of homes across the globe and that it could play a significant role in cutting down greenhouse gas emissions by around 99 million metric tons. The rural population of India which are engaged in animal husbandry and cattle rearing has easier availability of raw materials which allow them to directly or indirectly benefit from biogas technology.

Invention of newer and efficient technology in crop production strategies have resulted in improved yields, however its poor handling and processing has resulted in a significant proportion of the yield been wasted. According to the United Nations Environment Programme Food waste index report of 2024, about 1.05 billion tonnes of food from household, food service and retail sectors were wasted globally in the year 2022 (https://wedocs.unep.org/20.500.11822/45230), with the losses and waste of horticultural commodities being the highest among all types of foods, reaching up to 60%. The loss of food commodities is inclusive of additional losses incurred indirectly from wasting of critical resources such as land, water, fertilizers, chemicals, energy, and labor. These waste products if let to decompose in landfills could cause immense environmental problems and emit harmful greenhouse gases (Sagar et al., 2018). In addition to household garbage, fruit and vegetable processing units are other major contributors to generation of waste (Sagar et al., 2018). A common feature of various forms of food wastes includes high COD, richness in protein, carbohydrate, and lipid biomolecules with noticeable pH variation. Joshi et al. reported that wastes from vegetables industries including carrot, peas, and tomatoes have a high BOD and are a rich source of several nutrients like vitamins, minerals, fibers, etc. So, a detailed study of waste characteristics is essential for deciding its application and determination of economic feasibility of the process.

The horticultural waste is a rich source of potentially valuable bioactive compounds. This study focusses on utilizing less exploited horticultural leftovers like rotten grapes discarded from fruit markets and fields, vegetable wastes. We have also taken care to include slow degrading proteinaceous sources like fish and poultry waste. We have effectively channelized mainly the carbon and nitrogen elements of the rotten grapes and poultry wastes/ fish wastes for enhancing the biogas yield by optimum usage of inoculum and its activation and also making the process technologically and economically viable although more efforts are required to scale up the technology which will substantially decreases our present dependences on fossil fuel.

II. Materials And Methods:

Determination of biogas production with rotten grapes wastes as substrates

Materials required

1. Fresh Cow Dung
2. Rotten grape juices and pomace
3. Tap water
4. 1 Liter Conical flask
5. Measuring cylinder
6. Rubber stopper 1 and 2 holder
7. Rubber tubing of 5 mm diameter
8. Measuring cylinder
9. Wooden stand for gas collection.

Methods

a) 100 g fresh cow dung was mixed with 100 mL rotten grape juices and the final volume was made up to 700 mL and it was mixed well. The slurry was poured to 1-liter conical flask and closed with rubber stopper connected with rubber tubing to an inverted conical flask filled with water which bears two-hole rubber stopper and the outlet tubing of the inverted conical flask was placed in glass beaker with 100 mL of water. Fermentation gases produced were collected in the beaker by downward displacement of water and the daily displaced volume of water was measured using measuring cylinder which is equal to the daily biogas produced from particular set up.

b) 100 g fresh cow dung was mixed with 100 g rotten grape pomace and the final volume was made up to 700 mL and it was mixed well. The slurry was poured to 1-liter conical flask and closed with rubber stopper connected with rubber tubing to an inverted conical flask filled with water which bears two-hole rubber stopper and the outlet tubing of the inverted conical flask was placed in glass beaker with 100 mL of water. Fermentation gases produced were collected in the beaker by downward displacement of water and the daily displaced volume of water was measured using measuring cylinder which is equal to the daily biogas produced from particular set.

Determination of biogas production from rotten grape wastes (juices and pomace) along with N.P.K fertilizer supplementation

Materials required
1. Fresh Cow Dung
2. N.P.K fertilizer
3. Rotten grape juices and pomace
4. Tap water
5. 1 Liter Conical flask
6. Measuring cylinder
7. Rubber stopper 1 and 2 holder
8. Rubber tubing of 5 mm diameter
9. Wooden stand for gas collection.

Methods
a) 100 g fresh cow dung was mixed with 100 mL rotten grape juices and 1% NPK and the final volume was made up to 700 mL. 100 g fresh cow dung was mixed with 100 g of grape pomace, 1% NPK and the final volume was made up to 700 mL. The slurry was poured to 1-liter conical flask and closed with rubber stopper connected with rubber tubing to an inverted conical flask filled with water which bears two-hole rubber stopper and the outlet tubing of the inverted conical flask was placed in glass beaker in 100 mL of water. Fermentation gases produced were collected in the beaker by downward displacement of water and the daily displaced volume of water was measured using measuring cylinder which is equal to the daily biogas produced from particular set up.
b) 100 g fresh cow dung mixed was with 100 mL rotten grape juices and 1% NPK and the final volume was made up to 700 mL. 100 g fresh cow dung mixed was with 100 g of grape pomace and 1% NPK and the final volume was made to 700 mL. The slurry was poured to 1-liter conical flask and closed with rubber cork connected with rubber tubing to an inverted conical flask fill with water which bears two-hole rubber stopper and the outlet tubing of the inverted conical flask was placed in glass beaker in 100 mL of water. Fermentation gases produced were collected in the beaker by downward displacement of water and the daily displaced volume of water was measured using measuring cylinder which is equal to the daily biogas produced from particular set up.

Determination of biogas production from untreated, physically pre-treated and supplemented N.P.K (agricultural grade) fertilizer **and pineapple peel wastes**

Materials required
1. Fresh Cow Dung
2. Pineapple peel wastes
3. N.P.K fertilizer
4. Tap water
5. 1 Liter Conical flask
6. Measuring cylinder
7. Rubber stopper 1 and 2 holder
8. Rubber tubing of 5 mm diameter
9. Wooden stand for gas collection.

Methods
a) 100 g fresh cow dung was mixed with 100 g raw pineapple peel waste and the final volume was made up to 700 mL. The slurry was poured to 1-Liter conical flask and closed with rubber stopper connected with rubber tubing to an inverted conical flask fill with water which bears two-hole rubber stopper and the outlet tubing of the inverted conical flask was placed in glass beaker in 100 mL of water. Fermentation gases produced were collected in the beaker by downward displacement of water and the daily displaced volume of water was measured using measuring cylinder which is equal to the daily biogas produced from particular set up.
b) 100 g fresh cow dung was mixed with 100 g pineapple peel wastes (steamed at 15 psi for 15 min). The slurry was poured to 1-Liter conical flask and closed with rubber stopper connected with rubber tubing to an inverted conical flask fill with water which bears two-hole rubber stopper and the outlet tubing of the inverted conical flask was placed in glass beaker in 100 mL of water. Fermentation gases produced were collected in the beaker by

downward displacement of water and the daily displaced volume of water was measured using measuring cylinder which is equal to the daily biogas produced from particular set up.

c) 100 g fresh cow dung was mixed with 100 g pineapple peel wastes (steamed at 15 psi for 15 min) along with 1% N.P.K fertilizer. The slurry was poured to 1-Liter conical flask and closed with rubber stopper connected with rubber tubing to an inverted conical flask fill with water which bears two-hole rubber stopper and the outlet tubing of the inverted conical flask was placed in glass beaker in 100 mL of water. Fermentation gases produced were collected in the beaker by downward displacement of water and the daily displaced volume of water was measured using measuring cylinder which is equal to the daily biogas produced from particular set up.

Determination of biogas production from untreated, physically pre-treated and supplemented (N.P.K fertilizer) agricultural grade with mixed vegetables wastes

Materials required

1. Fresh Cow Dung
2. Vegetable wastes
3. N.P.K fertilizer
4. Tap water
5. 1 Liter Conical flask
6. Measuring cylinder
7. Rubber stopper 1 and 2 holder
8. Rubber tubing of 5 mm diameter
9. Wooden stand for gas collection.

Methods

a) 100 g fresh cow dung was mixed with 100 g vegetables wastes and the final volume was made up to 700 mL tap water and it was mixed well. The slurry was poured to 1-liter conical flask and closed with rubber stopper connected with rubber tubing to an inverted conical flask fill with water which bears two-hole rubber stopper and the outlet tubing of the inverted conical flask was placed in glass beaker in 100 mL of water. Fermentation gases produced were collected in the beaker by downward displacement of water and the daily displaced volume of water was measured using measuring cylinder which is equal to the daily biogas produced from particular set up.

b) 100 g fresh cow dung was mixed with 100 g vegetables wastes and 1% N.P.K fertilizer and the final volume made up to 700 mL tap water and mixed well. The slurry was poured to 1-liter conical flask and closed with rubber stopper connected with rubber tubing to an inverted conical flask fill with water which bears two-hole rubber stopper and the outlet tubing of the inverted conical flask was placed in glass beaker in 100 mL of water. Fermentation gases produced were collected in the beaker by downward displacement of water and the daily displaced volume of water was measured using measuring cylinder which is equal to the daily biogas produced from particular set up.

c) 100 g fresh cow dung was mixed with 100 g physically pre-treated (Steamed at 15 psi for 15 min) and the final volume made up to 700 mL with tap water. The slurry was poured to 1-liter conical flask and closed with rubber stopper connected with rubber tubing to an inverted conical flask fill with water which bears two-hole rubber stopper and the outlet tubing of the inverted conical flask was placed in glass beaker in 100 mL of water. Fermentation gases produced were collected in the beaker by downward displacement of water and the daily displaced volume of water was measured using measuring cylinder which is equal to the daily biogas produced from particular set up.

d) 100 g fresh cow dung was mixed with 100 g physically pre-treated mixed vegetable wastes (Steamed at 15 psi for 15 min) and supplemented 1% NPK and the final volume made up to 700 mL with tap water. The slurry was poured to 1-liter conical flask and closed with rubber stopper connected with rubber tubing to an inverted conical flask fill with water which bears two-hole rubber stopper and the outlet tubing of the inverted conical flask was placed in glass beaker in 100 mL of water. Fermentation gases produced were collected in the beaker by downward displacement of water and the daily displaced volume of water was measured using measuring cylinder which is equal to the daily biogas produced from particular set up.

Determination of biogas production from physically pre-treated vegetable waste along with varying concentration of N.P.K fertilizer **(agricultural grade)**

Materials required

1. Fresh Cow Dung
2. Vegetable wastes
3. N.P.K fertilizer
4. Tap water

5. 1 Liter Conical flask
6 Measuring cylinder
7. Rubber stopper 1 and 2 holder
8 Rubber tubing of 5 mm diameter
9 Wooden stand for gas collection.

Methods

a) 100 g fresh cow dung was mixed with 100 g physically pre-treated (steamed at 15 psi for 15 min) vegetables wastes and 5% N.P.K fertilizer was added and the final volume was made up to 700 mL tap water and it was mixed well. The slurry was poured to 1-liter conical flask and closed with rubber stopper connected with rubber tubing to an inverted conical flask fill with water which bears two-hole rubber stopper and the outlet tubing of the inverted conical flask was placed in glass beaker in 100 mL of water. Fermentation gases produced were collected in the beaker by downward displacement of water and the daily displaced volume of water was measured using measuring cylinder which is equal to the daily biogas produced from particular set up.

b) 100 g fresh cow dung was mixed with 100 g physically pre-treated (Steamed at 15 psi for 15 min) vegetables wastes and 10% NPK and the final volume was made up to 700 mL tap water and it was mixed well. The slurry was poured to 1-liter conical flask and closed with rubber stopper connected with rubber tubing to an inverted conical flask fill with water which bears two-hole rubber stopper and the outlet tubing of the inverted conical flask was placed in glass beaker in 100 mL of water. Fermentation gases produced were collected in the beaker by downward displacement of water and the daily displaced volume of water was measured using measuring cylinder which is equal to the daily biogas produced from particular set up.

Determination of biogas production from rotten grape wastes with activated inoculum

Materials required

1. Fresh Cow Dung
2. Rotten grape juices
3. Polythene bag
4. Tap water
5. 1 Liter Conical flask
6. Measuring cylinder
7. Rubber stopper 1 and 2 holder
8. Rubber tubing of 5 mm diameter
9. Wooden stand for gas collection.

Methods

a) 100 g fresh cow dung was mixed with 100 mL tap water was mixed well in 1-liter conical flask and seal with aluminium foil and was kept in sunlight for 9 h. After 9 h 100 mL rotten grape juices were mixed with the activated inoculum and the final volume was made up to 700 mL and it was mixed well. The slurry was poured to 1-liter conical flask and closed with rubber stopper connected with rubber tubing to an inverted conical flask fill with water which bears two-hole rubber stopper and the outlet tubing of the inverted conical flask was placed in glass beaker in 100 mL of water. Fermentation gases produced were collected in the beaker by downward displacement of water and the daily displaced volume of water was measured using measuring cylinder which is equal to the daily biogas produced from particular set.

b) 100 g fresh cow dung mixed with 100 mL tap water was mixed well in 1-litre polythene bag and seal by binding with rope and was kept in sunlight for 9 h. After 9 h 100 mL rotten grape juices were mixed with the activated inoculum and the final volume was made up to 700 mL and it was mixed well. The slurry was poured to 1-liter conical flask and closed with rubber stopper connected with rubber tubing to an inverted conical flask fill with water which bears two-hole rubber stopper and the outlet tubing of the inverted conical flask was placed in glass beaker in 100 mL of water. Fermentation gases produced were collected in the beaker by downward displacement of water and the daily displaced volume of water was measured using measuring cylinder which is equal to the daily biogas produced from particular set up.

Determination of biogas production from rotten grapes wastes along with urea (agricultural grade) and $FeCl_3$ supplementation

Materials required

1. Fresh Cow Dung
2. Rotten grape juices
3 Urea
4. $FeCl_3$

5. Tap water
6. 1 Liter Conical flask
7 Measuring cylinder
7. Rubber stopper 1 and 2 holder
8. Rubber tubing of 5 mm diameter
9. Wooden stand for gas collection.

Methods

a) 100 g fresh cow dung was mixed with 100 mL rotten grape juices and 1% Urea was added and the final volume was made up to 700 mL and it was mixed well. The slurry was poured to 1-liter conical flask and closed with rubber stopper connected with rubber tubing to an inverted conical flask fill with water which bears two-hole rubber stopper and the outlet tubing of the inverted conical flask was placed in glass beaker in 100 mL of water fermentation gases produced were collected in the beaker by downward displacement of water and the daily displaced volume of water was measured using measuring cylinder which is equal to the daily biogas produced from particular set up.

b) 100 g fresh cow dung was mixed with 100 mL rotten grape juices and 1% Urea and 25 ppm $FeCl_3$ was added and the final volume was made up to 700 mL and it was mixed well. The slurry was poured to 1-liter conical flask and closed with rubber stopper connected with rubber tubing to an inverted conical flask fill with water which bears two-hole rubber stopper and the outlet tubing of the inverted conical flask was placed in glass beaker in 100 mL of water. Fermentation gases produced were collected in the beaker by downward displacement of water and the daily displaced volume of water was measured using measuring cylinder which is equal to the daily biogas produced from particular set up.

Determination of biogas production from rotten grape wastes along with N.P.K fertilizer (agricultural grade) and $FeCl_3$ supplementation

Materials required

1. Fresh Cow Dung
2. Rotten grape juices
3. N.P.K fertilizer
4. $FeCl_3$
5. Tap water
6. 1 Liter Conical flask
7. Measuring cylinder
8. Rubber stopper 1 and 2 holder
9. Rubber tubing of 5 mm diameter
10. Wooden stand for gas collection.

Methods

a) 100 g fresh cow dung was mixed with 100 mL rotten grape juices and 1% N.P.K fertilizer and the final volume was made up to 700 mL and it was mixed well. The slurry was poured to 1-liter conical flask and closed with rubber stopper connected with rubber tubing to an inverted conical flask fill with water which bears two-hole rubber stopper and the outlet tubing of the inverted conical flask was placed in glass beaker in 100 mL of water. Fermentation gases produced were collected in the beaker by downward displacement of water and the daily displaced volume of water was measured using measuring cylinder which is equal to the daily biogas produced from particular set up.

b) 100 g fresh cow dung was mixed with 100 mL rotten grape juices 1% N.P.K fertilizer and 25 ppm $FeCl_3$ and the final volume was made up to 700 mL and it was mixed well. The slurry was poured to 1-liter conical flask and closed with rubber stopper connected with rubber tubing to an inverted conical flask fill with water which bears two-hole rubber stopper and the outlet tubing of the inverted conical flask was placed in glass beaker in 100 mL of water. Fermentation gases produced were collected in the beaker by downward displacement of water and the daily displaced volume of water was measured using measuring cylinder which is equal to the daily biogas produced from particular set up.

Determination of biogas production from rotten grape wastes along with cow urine as supplement

Materials required

1. Fresh Cow Dung
2. Rotten grape juices
3 Cow Urine
4. Tap water

5. 1 Liter Conical flask
6 Measuring cylinder
6. Rubber stopper 1 and 2 holder
7. Rubber tubing of 5 mm diameter
8. Wooden stand for gas collection.

Methods

a) 100 g fresh cow dung was mixed with 90 mL rotten grape juices and 10 mL of cow urine and the final volume was made up to 700 mL and it was mixed well. The slurry was poured to 1-liter conical flask and closed with rubber stopper connected with rubber tubing to an inverted conical flask fill with water which bears two-hole rubber stopper and the outlet tubing of the inverted conical flask was placed in glass beaker in 100 mL of water. Fermentation gases produced were collected in the beaker by downward displacement of water and the daily displaced volume of water was measured using measuring cylinder which is equal to the daily biogas produced from particular set up.

Determination of biogas production from rotten grape wastes along with fish amino acids, chicken feather hydrolysates and prawn peel powder hydrolysates as substrates

Materials required

1. Fresh Cow Dung
2. Rotten grape juices
3. Rotten fish
4. Jaggery
5. Chicken feather
6. Prawn peel powder
7. Sodium sulphite
8. Tap water
9. 1 Liter Conical flask
10. 100 mL Measuring cylinder
11. Rubber stopper 1 and 2 holder
12. Rubber tubing of 5 mm diameters
13. Wooden stand for gas collection.

Methods

a) Equal volume of Jaggery and Rotten fish (500 g) each were taken and then layer by layer they were stuffed in a beaker and then the beaker was covered with aluminium foil with a pinhole pinch on top of that foil for air inlet and was kept for 1 month, the extract was filtered and use.

100 g fresh cow dung was mixed with 50 mL rotten grape juices and 50 mL fish amino acids hydrolysates and the final volume was made up to 700 mL and it was mixed well. The slurry was poured to 1-liter conical flask and closed with rubber stopper connected with rubber tubing to an inverted conical flask fill with water which bears two-hole rubber stopper and the outlet tubing of the inverted conical flask was placed in glass beaker in 100 mL of water. Fermentation gases produced were collected in the beaker by downward displacement of water and the daily displaced volume of water was measured using measuring cylinder which is equal to the daily biogas produced from particular set up.

b) Poultry feather was collected from the nearby poultry butcher house. It was first washed with soap in running tap water then it was dried. The dried feather was then stripped from its midrib and 10 g was weighed. This weighed quantity was then steamed in 15 Psi for 15 min to remove the wax coating and then it was ground in a grinder to make paste. 100 mL of 0.5 M sodium sulphite (pH 8.0) was added to the feather powder and was kept for 4 days in room temperature. After 4 days, the feather extract was taken and its pH adjusted to 7.0 and was used for biogas production. 100 g fresh cow dung was mixed with 90 mL rotten grape juice, 10 mL poultry feather hydrolysates and the final volume was made up to 700 mL and it was mixed well. The slurry was poured to 1-liter conical flask and closed with rubber stopper connected with rubber tubing to an inverted conical flask fill with water which bears two-hole rubber stopper and the outlet tubing of the inverted conical flask was placed in glass beaker in 100 mL of water. Fermentation gases produced were collected in the beaker by downward displacement of water and the daily displaced volume of water was measured using measuring cylinder which is equal to the daily biogas produced from particular set up.

c) Prawn peels were collected from nearby fish market. It was washed, dried the dried peel was ground to a powdery form and then it was used for biogas production. 100 g fresh cow dung was mixed with 100 mL rotten grape juices. To the mixture, 2 % prawn peel powder was added and the final volume was made up to 700 mL and mixed well. The slurry was poured to 1-liter conical flask and closed with rubber stopper connected with rubber tubing to an inverted conical flask fill with water and which bears two-hole rubber stopper and the outlet tubing of the inverted conical flask was placed in glass beaker in 100 mL of water. Fermentation gases produced were collected in a beaker by downward displacement of water and the daily displaced volume was checked using a measuring cylinder which equaled the daily biogas produced from the particular set up.

III. Results And Discussion:

Lack of unscientific post-harvest handling has led to increase in the proportion of valuable produce being left as waste. This creates a huge impact on the national economy. Having identified presence of important components in often discarded fruit and vegetable leftovers, this study has demonstrated the potential of these by-products to be used for the generation of renewable sources of energy and soil conditioners.

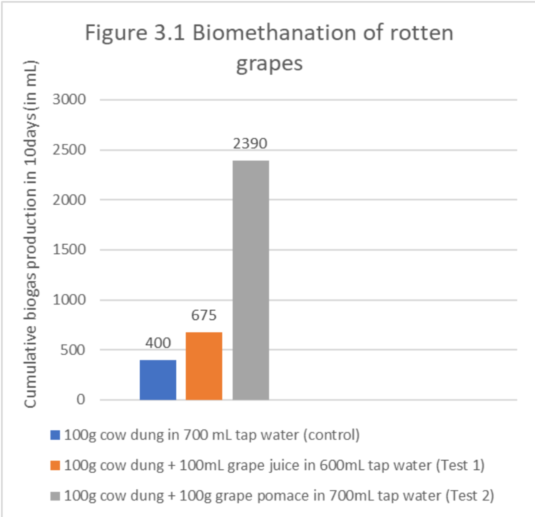


Figure 3.1 shows the bio methanation data of rotten grape juice and pomace compared to control (inoculum/Cow dung). 100 mL grape juice produced 675 mL biogas, while 100 mL grape pomace produced 2390 mL biogas in 10 days. The solid content of the pomace is responsible for high yield of gas this opens up new opportunity related to Bio processing use for production of biofuels like Biogas which can considerably reduce our present dependence on fossil fuels.

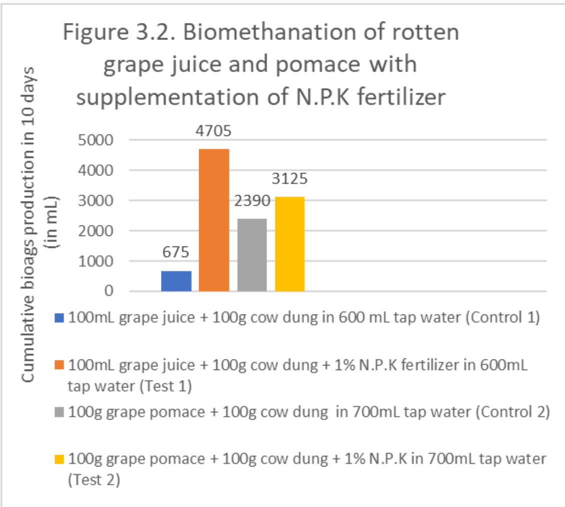


Figure 3.2 shows the Bio-methanation data of rotten grape juice and pomace with supplementation of agricultural grade N.P.K fertilizer. Since grape juice and pomace do not have much of nitrogen, phosphorus and potash we have supplemented with N.P.K fertilizer which is very cheap additive that can also be used even on large scale biogas plant. This figure shows the enhancement of biogas production upon addition of N.P.K fertilizer to grape juice, with the cumulative biogas production of 4705 mL as compared to unsupplemented sample which only yielded 675 mL. Similarly, the pomace supplemented with N.P.K fertilizer produced 3125 mL and 4705 mL which were higher than in unsupplemented ones. This proves that supplementation of grape juice with nitrogen, phosphorus and potash could enhance biogas production.

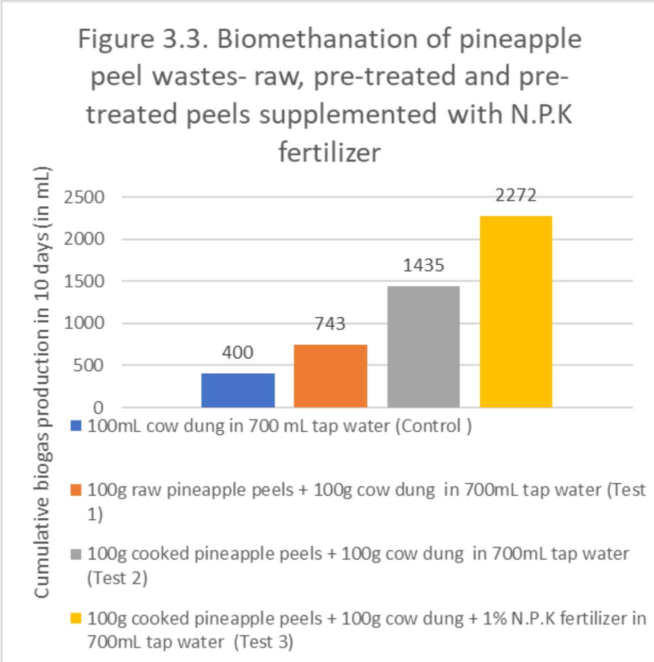


Figure 3.3 shows the Bio-methanation data of pineapple peel wastes. India produces 14.6 million tonnes of fruits making it the fifth largest producer of pineapple with an annual output of about 1.2 million tonnes. As a part of pineapple fruit processing, peels get accumulated in huge quantities. Pineapple peel total yield was per 9.17g / 100 g. Difficulty in digesting pineapple peels arise from its bio chemical composition containing 5.11% crude protein, 5.31% lipids, 4.39 % ash, 14.80 % crude fiber and 55.52% carbohydrate. Since the pineapple peel is difficult to digest, we have subjected the peels to pre-treatment with steam under pressure Fig 3.3 shows biogas production from pre-treated and N.P.K fertilizer supplemented samples. There was considerable increase in biogas production after pre-treatment compared to control. A substantial increase in production was observed with further supplementation with N.P.K fertilizer. This could substantially improve performance to cater greater biofuel demands.

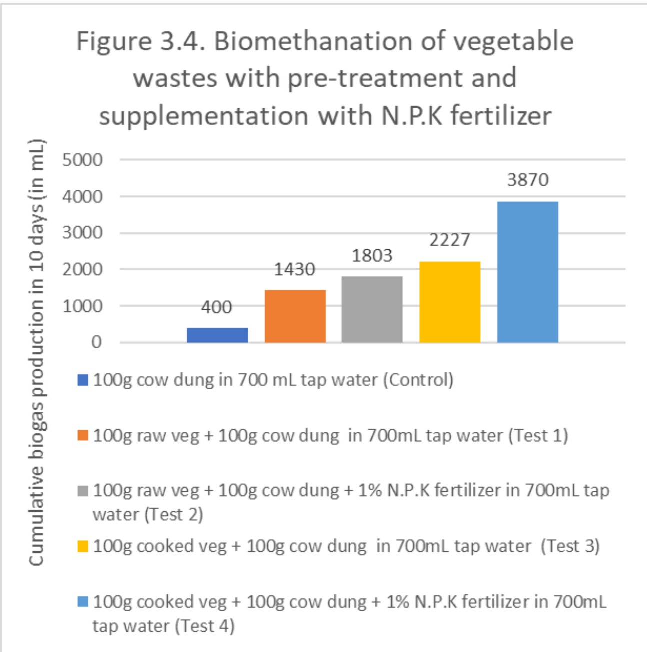


Figure 3.4 shows the Bio-methanation data of vegetables wastes. India is one of the leading producers of vegetables and fruits, where almost 30% of the produce goes wasted due to physical damages and lack of proper storage facilities. Fig 3.4 clearly shows biogas yield by 1430 mL without any addition, 1803 mL with supplementing N.P.K fertilizer, 2227 mL when it was pre-treated with steam and 3870 mL when it was pre-treated with steam along with N.P.K fertilizer supplementation.

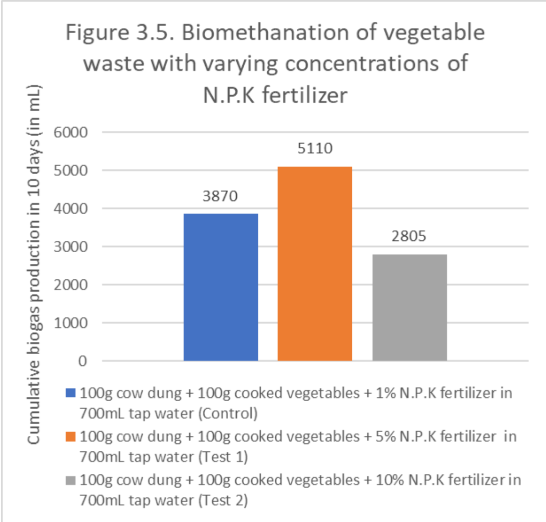
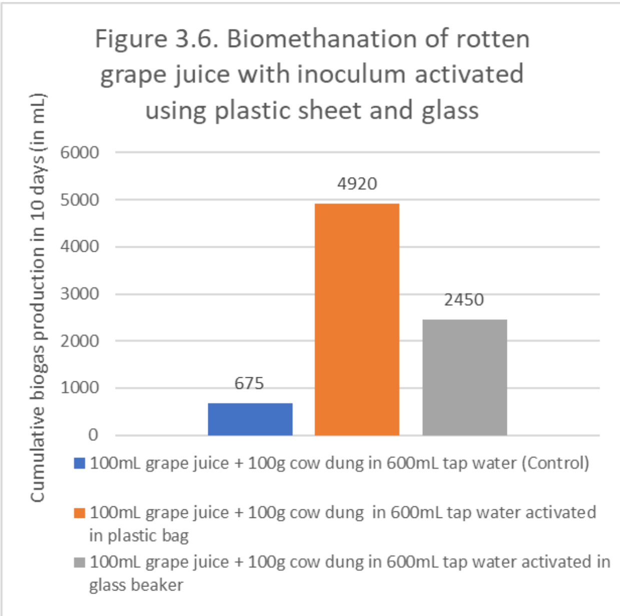


Figure 3.5 shows that the biogas production from vegetable wastes supplemented with varying levels of N.P.K fertilizer. Some minerals like phosphorus would inhibit the bio methanation beyond a critical unit. In addition, there is an optimum C:N ratio needed for biogas production like 25:1 to 30:1. In this context the N.P.K fertilizer was mixed with vegetables for maximum biogas yield. The concentration was varied from 1% to 10% and it was found that 1% supplementation resulted in 3870 mL biogas production, while 5% produced 5110 mL and 10% produced 2805 mL, which proves that N.P.K fertilizer concentration above 5% is inhibitory to Bio-methanation process.



(Figure 3.6) In anaerobic digestion process biogas is produced in 4 stages -Hydrolysis, Acidogenesis, Acetogenesis and Methanogenesis. A group of bacteria are involved in initiating the process of methanogenesis in the reactor. Initially the bioreactor is seeded with inoculum. Though it is common to use cow dung or pig dung or horse manure is widely used, in Europe they preferentially use pig and horse manure. In India cow dung and cattle dung are preferred, which contain all 4 groups of bacteria responsible for successful Bio-methanation process. The growth stage and age of inoculum is very critical in enhancing biogas production, preferably inoculum from mid log phase. In addition, since Methanogenic bacteria is a thermophile activating the microbial consortia using sunlight has found to be beneficial in improving volume of gas production. With pre-treated inoculum, the bio-methanation of rotten grapes juice, which were also subjected to activation using plastic bags resulted in higher levels of biogas production, compared to the glass beaker-based set up. Since both are very cheap methods of activation and enhancement of biogas production, it will be economically feasible to replicate even in large scale operations. Fig 3.6 shows that the bio-methanation yield was grater in both plastic sheet as well as glass beaker set up.

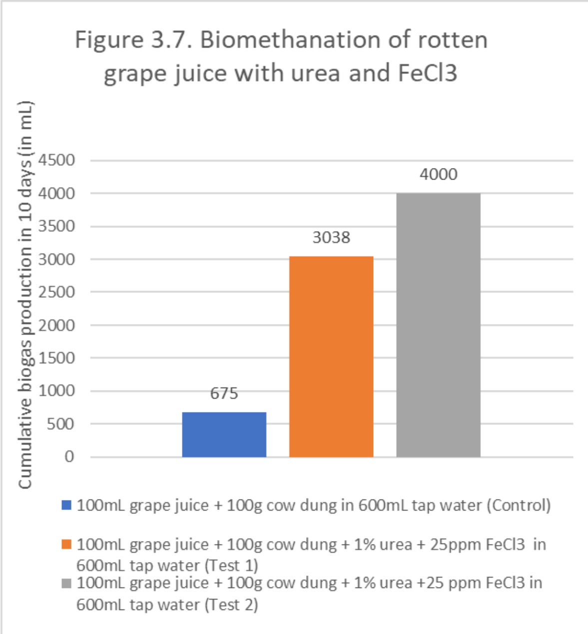


Figure 3.7 shows the Bio-methanation of rotten grapes supplemented with Urea for efficient Bio-methanation. For efficient gas production to happen the optimum ratio of Carbon and Nitrogen has to be in range of 25:1 to 30:1. Biochemical composition of Grape juice makes it clear that it is a substrate deficient in Nitrogen. Supplementation of Urea has considerable impact on increasing biogas production with cumulative biogas production from 675 mL to 3038 mL. Alternatively, gas production was further enhanced by the ferric ions which acts as cofactor, while converting acetate into methane. Both Urea and Ferric chloride enhanced the biogas production and they could be used as cheap supplements during upscaling of the process making the whole set up cost-efficient.

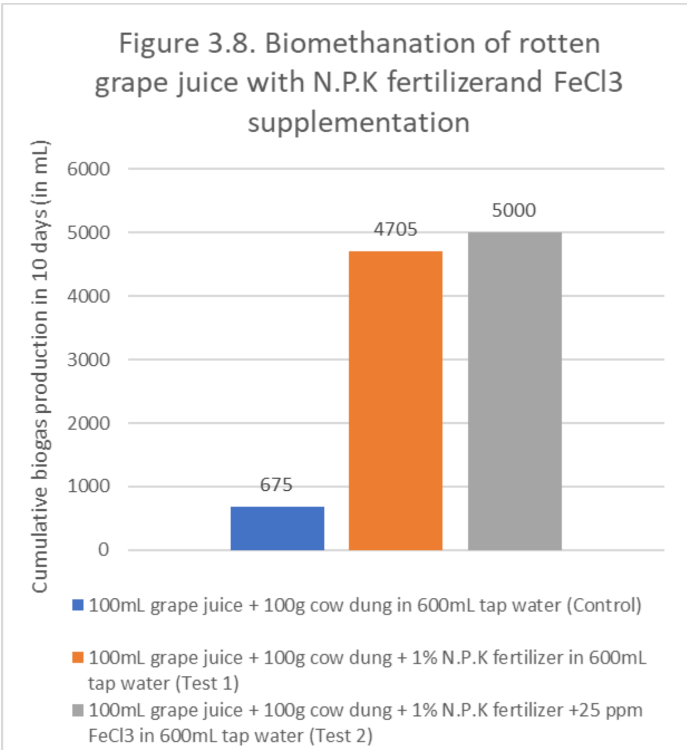


Figure 3.8 shows bio-methanation levels on supplemen tation with N.P.K fertilizer and $FeCl_3$ combination. With N.P.K fertilizer supplementation alone, 4705 mL gas was produced and additional supplementation of $FeCl_3$ could increase production to 5000 mL. This proves that supplementation of media with nitrogen potash and phosphorus, optimum concentration of substrates and $FeCl_3$ could improve biogas production from rotten grape juice.

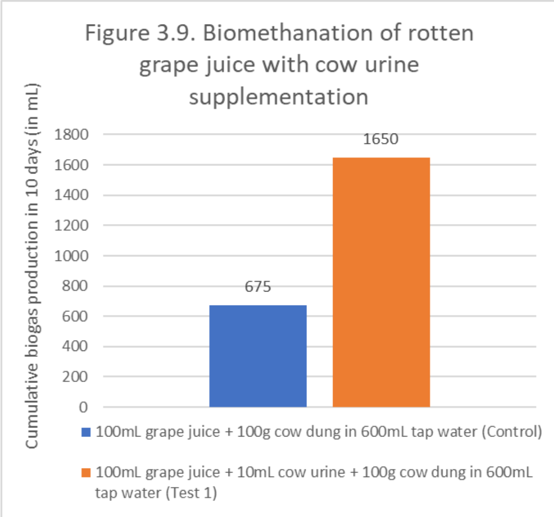
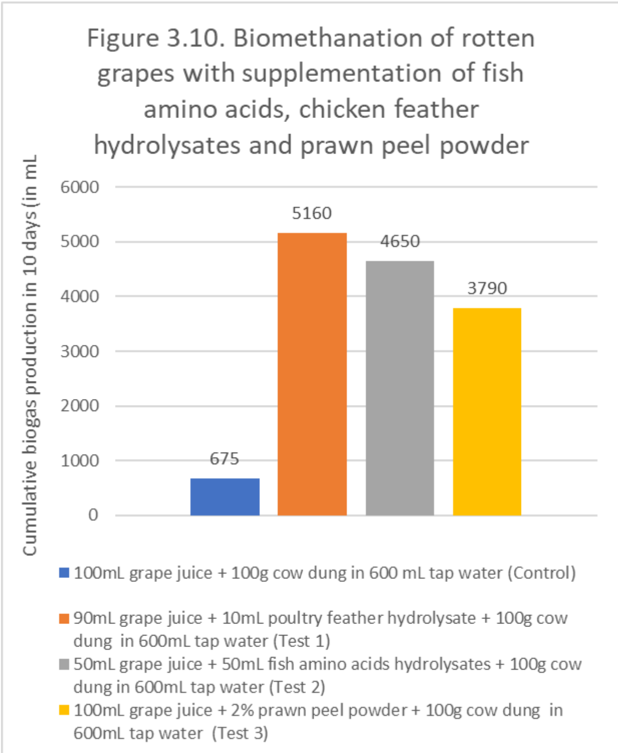


Figure 3.9 shows the Bio-methanation of rotten grapes juice with cow urine. Supplementation with cow urine has shown great potential on implementation in national level since, India is the largest cattle population in the world.



(Figure 3.10) Supplementation with poultry feather extract also considerably increases gas production, it is a slowly degrading material, keratin protein which is present in feather contains interlinked SH cross linkage this make it so hard to degrade. It was hydrolyzed into amino acid mixture using Na_2S0_3 which is yet another cheap material. Globally, the poultry meat consumption is increasing every year giving excellent opportunity to tap this easily available resource for use in enhancing biogas production. Fish basically being protein can be used to enhance biogas production from carbohydrate rich sources. Out of the total daily catch, almost 30% goes as waste. The channelization of this amino acids to anaerobic digestors is a cheaper method for enhancing biogas production. Results shows that supplementation with fish hydrolysate, gas production was enhanced to 4650 mL compared to control which yielded of 675 mL (Fig 3.10). Supplementation with powdered prawn peel have shown considerable enhancement in yield. Composed of about 30% protein and 70% chitin, this particular peel is wasted and it form piles in prawn processing units. This could pollute the environment. Effective utilization of prawn peel assumes considerable importance because it is easily available in India, with the country being blessed with a coastline of 7500 km.

IV. Conclusions:

Biogas can be produced in a cost-effective way by using rotten/damaged grapes pineapple peel waste and vegetables wastes from vegetables markets and cultivating area and also from food processing industries. Supplementation of agricultural grade N.P.K fertilizer could enhance biogas production. Through bio-methanation process pineapple peel wastes can be used to produce biogas. Those supplemented with N.P.K fertilizer and pre-treated with steam under pressure, the quantity of biogas produced has increased. Biogas could also be produced in cost effective way by using vegetables wastes from market and yield could be enhanced by steam pre-treatment and supplementation with up to 5% agricultural grade N.P.K fertilizer 5 % was found to be optimum level for enhancing the biogas production from vegetables wastes. Activation of inoculum using solar radiation increased biogas production as well as reduced start up time. However, activation using plastic sheet was found to be more effective. Supplementation with ferric chloride greatly enhanced biogas production from grape juice. Addition of urea also helped to increase production from rotten grape juice. Supplementation with cow urine also enhanced biogas production from rotten grape juice which assumes great potential considering the cattle population of this country. Crude nitrogenous supplements like fish hydrolysates and poultry feather hydrolysates have also been found to enhances biogas production.

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