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Eco-friendly Treatment of Poultry Waste by Anaerobic Co-digestion with Vegetable Waste

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Abstract

India is agro-based country and produces huge quantities of organic waste per day. Poultry industry is a growing industrial sector in India. Poultry generates huge quantity of wastes every day. The disposal of these wastes by unscientific treatment methods causes serious environmental pollution. Vegetable markets generate huge quantity of vegetable waste due to poor and inappropriate collection, transportation and handling practices. Vegetable waste being highly biodegradable serve as source of nuisance in market. The present work was undertaken to study anaerobic digestion of poultry waste alone and in combination with vegetable waste with the objectives of treating the waste to generate biogas and to decrease its environmental pollution potential. The anaerobic digestion and co-digestion experiments were carried out at laboratory scale using 1 litre capacity digesters at ambient temperature conditions. The results indicated that anaerobic co-digestion of these wastes produces sufficient energy generation in the form of biogas and also reduces its environmental pollution potential.

***Key words*:** Poultry wastes, Vegetable waste, Environmental pollution, Co-digestion, Biogas

India has the world's largest population of 1.458 billion which accounts for 17.78% of world's population [1]. India has achieved rapid and remarkable economic and industrial development in the past two decades, received status as emerging global economic powerhouse and is the world's fifth largest economy in 2024. India is the third largest energy consumer in the world after China and the United States in 2024. The world's 85% energy comes from non-renewable supplies like coal, oil, natural gas and nuclear energy. Coal, Oil, Natural gas and nuclear energy has estimated present reserves in India as 361.41 billion tonnes, 653.02 million tonnes, 1149.46 billion cubic meters, and 80000 tonnes respectively and has expected exhaustion period as 200, 30, 100 and 85 years respectively [2]. Besides their limited reserves, the extensive use of non-renewable energy resources has caused environmental, social and economic problems globally [3]. A huge amount of agro-industrial wastes are produced every year.

Poultry industry is a one of the fastest growing agriculture-based industry in the world. The global poultry meat production has increased by 807.8% between 1970 and 2020. Poultry primarily produces chicken and supplies safe meat and eggs at inexpensive rates to meet the increasing demand of growing population. Chicken meat and eggs provides high-quality protein, and important vitamins and minerals also. The United States of America is the world's largest poultry meat producer, with 20 percent of global output, followed by China and Brazil. China is the world's largest egg producer, with 38 percent of global production, followed by the United States and India. Asia is the largest egg-producing region, with more than 64 percent of global output. India ranks 2nd in egg production and 5th in meat production in the world [4]. Egg production in the country has increased from 78.48 billion in 2014-15 to 142.77 billion numbers in 2023-24. Egg production in the country is growing rapidly. Meat production in the country has increased from 6.69 million tonnes in 2014-15 to 10.25 million tonnes in 2023-24.

Poultry industry waste includes a mixture of faecal and urinary excreta, bedding material, waste feed, dead birds, broken eggs, feathers removed from poultry houses and water flushing systems [5]. Poultry manure has a higher fraction of biodegradable organic matter than other livestock wastes [6]. The litter and manure component of poultry waste is used as organic manure as it is nutritionally very rich. Traditionally these wastes are land spread on soil as amendments. However, over-application of this nutrient rich waste as a manure to soil results in eutrophication of water bodies [7], the spread of pathogens [8], the production of phytotoxic substances, high levels of NO_3 in drinking water [9], air pollution and emission of greenhouse gases [10].

The present effective methods of poultry waste management include composting, direct combustion with combined heat and power and anaerobic digestion. Composting is the aerobic degradation of biodegradable organic waste. The advantages of composting include relatively fast biodegradation process, composted material is odorless and fine textured with a low moisture content, easy to handle, pathogen free and can be used as an organic fertilizer. The disadvantages of composting include loss of nitrogen and other, equipment cost and labour, odour and available land [11-12]. The second alternative disposal route is direct combustion of poultry litter

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to generate heat and power. However, the operational parameters like combustion temperature, air mixture and moisture content should be optimal for the efficient running of a combustion facility. The resulting ash fusion cause problems with the use of conventional grate combustion system. Anaerobic digestion, of poultry manure is a third viable disposal option. Anaerobic digestion, also called bio-methanation process where consortia of microorganisms generate biogas from degradation of biodegradable organic material in anaerobic conditions [13]. Biogas is mainly composed of methane; a source of renewable energy can be converted into electricity and effluent from digester can be used as soil conditioner [14-15]. The generation of biogas from poultry manure alone is generally very problematic due to the toxicity of ammonia [16-18]. Operating parameters of anaerobic digestion like excessive levels of ammonia and/or high pH or temperature levels that are likely to inhibit the methanogenesis process are to be seriously considered. The ammonia toxicity can be managed during the process either by dilution of raw material or co-digestion with other available organic substrates. Co-digestion of poultry waste is advantageous over dilution method since alternative agricultural wastes are very easily available.

Anaerobic co-digestion is the simultaneous digestion of two or more substrates [19]. The advantages of co-digestion include better nutrient balance in substrate and in turn higher biogas yields, dilution of toxic substances, synergistic effects on microorganisms, economic benefits, etc. [20].

Vegetable waste represents a major share of agricultural wastes [21]. It is produced in during harvesting, poor and inadequate transportation, storage facilities and marketing practices of vegetables. They are perishable and voluminous. Disposal of vegetable wastes in unscientific manner cause an adverse impact on the environment and human health [22]. India is agro-based country and produces huge quantities of these organic waste. The present work was undertaken to study anaerobic digestion and co-digestion of poultry waste with vegetable waste with the objectives of treating the waste to generate biogas and to decrease its environmental pollution potential.

MATERIALS AND METHODS

Experimental setup

Poultry waste (PW) was collected from Poultry located at Karandi, 10 km away from Satara city. They were kept in refrigerator at 4 °C until used. Vegetable wastes (VW) for the present studies were collected from the local vegetable market. Vegetable waste used for co-digestion comprised equal mixture of potato (*Solanum tuberosum* L.), onion (*Allium cepa* L.), cabbage (*Brassica oleraceae* L. var. capitata), cauliflower (*Brassica oleraceae* L. var. botrytis), tomato (*Lycopersicon esculentum* Mill.) and brinjal (*Solanum melongena* L.). The wastes were shredded and ground in a kitchen blender to make paste. Inoculum was obtained from an active mesophilic digester of cattle dung based anaerobic digester. Anaerobic co-digestion studies were carried out in 1 liter capacity reactor-plastic carboys. The reactors were provided with suitable arrangements for feeding, gas collection and draining of residues. The reactors were mixed manually by means of shaking and swirling once in a day to break the scum.

Physico-chemical analysis of substrates and digester effluents

The physico-chemical analysis of substrates and effluent were determined according to standard methods [23-25]. Different parameters and its analytical methods are given the (Table 1).

Anaerobic co-digestion of poultry waste with vegetable waste

The anaerobic co-digestion of poultry waste with vegetable waste was carried out at ambient temperature conditions. Acclimatization of inoculums in each reactor was done before initiation of every experiment. Poultry waste was mixed with vegetable waste in various proportions as 1:0, 0.75: 0.25, 0.5:0.5, 0.25:0.75 and 0:1. The reactors were fed with these combinations separately at 20 days HRT, pH 7.0 of the substrate and ambient temperature conditions. The reactors were mixed manually by shaking and swirling. The experiment was run in triplicates. Water displacement method was used for measurement of biogas yield [23]. Biogas production from all the digesters was monitored daily. Combustibility was tested by burning the biogas. Quantitative analysis of biogas was carried on Michro 9100 Gas chromatograph by using Thermal conductivity detector (TCD) and nitrogen as carrier gas.

Pollution abatement study

The reduction in pollution potential of poultry and vegetable waste after co-digestion was studied with reference to % reduction of organic content in terms of TS and VS.

RESULTS AND DISCUSSION

The waste and results of its physico-chemical analysis is represented as per (Fig 1, Table 1) respectively. The poultry waste was found to be rich in nitrogen, alkaline in nature and rich in organic matter content. The vegetable waste was found to be slightly neutral in nature, rich in organic matter content and high moisture content.

Fig 1 Substrate used for co-digestion experiment

Table 1 Physico-chemical analysis of wastes

S. No.	Parameter	Name of analytical method	Unit	Poultry waste	Mixed vegetable waste
1.	pH	Potentiometric	-	8.20	6.80
2.	Moisture	Gravimetric	%	15.63	89.00
3.	Total solids	Gravimetric	%	84.37	4.43
4.	Volatile solids	Gravimetric	%	28.78	3.83
5.	Total organic carbon	Walkley and Black	%	16.70	2.23
6.	Total nitrogen	Kjeldahl distillation	%	2.43	0.15
7.	BOD	Azide modification	mg/L	54800	97150
8.	COD	Dichromate reflux and Titrimetric	mg/L	215000	174000

The co-digestion of poultry waste (PW) and vegetable waste (VW) was carried out at 20 days HRT and substrate pH 7.0. The ambient temperature throughout the experiment period was 30-35ºC.

The daily biogas yields in volume (ml) from the co-digestion of poultry waste (PW) and VW are represented in (Fig 4). Total biogas yield for 0:1,0.25:0.75,0.5:0.5,0.75:0.25 and 1:0 (PW:VW) combinations in 20 days HRT was found to be 2950 ± 150 ml, 3008 ± 192 ml, 4622 ± 222 ml, 7106 ± 206 ml and 4494 ± 194 ml respectively. The average daily biogas volume for 0:1,0.25:0.75,0.5:0.5,0.75:0.25 and 1:0 (PW:VW) combinations was found to be 147.5 ± 7.5 ml, 150.4 ± 9.6 ml, 231.1 ± 11.1 ml, 355.5 ± 10.30 ml and 224.7 ± 9.7 ml respectively. The maximum biogas volume was obtained with the 0.75:0.25 (PW: VW) combination. The highest biogas volume (viz. 483 ml) was produced on 7th day of experiment.

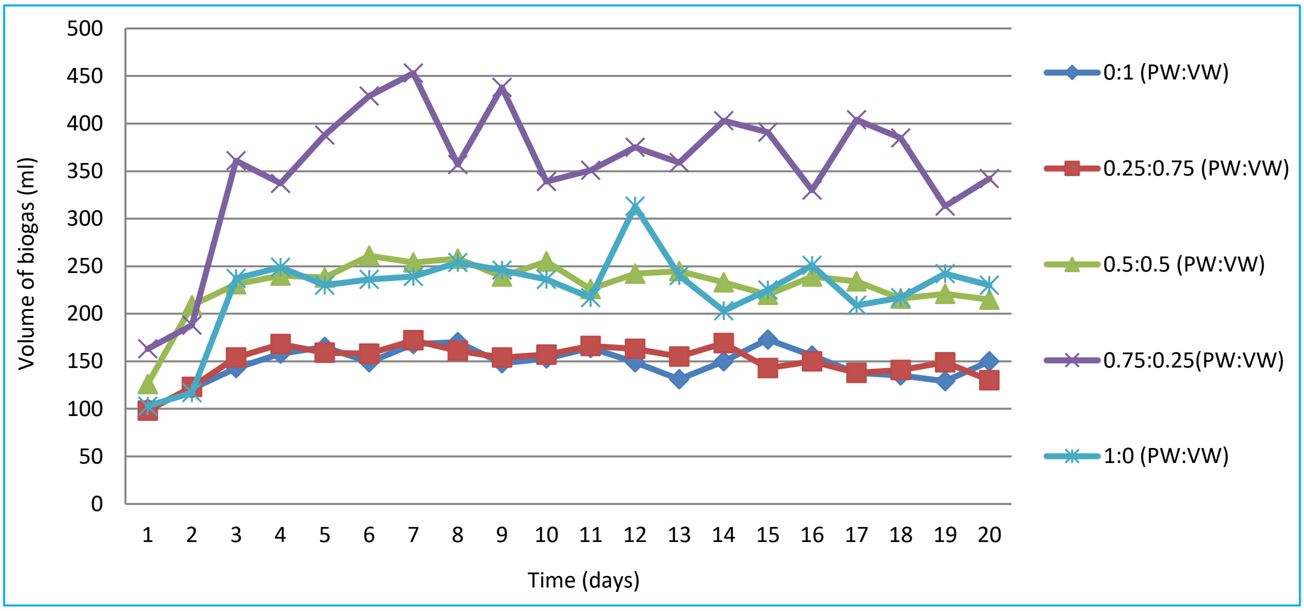

Fig 4 Co-digestion of poultry waste (PW) and vegetable waste (VW) for biogas generation

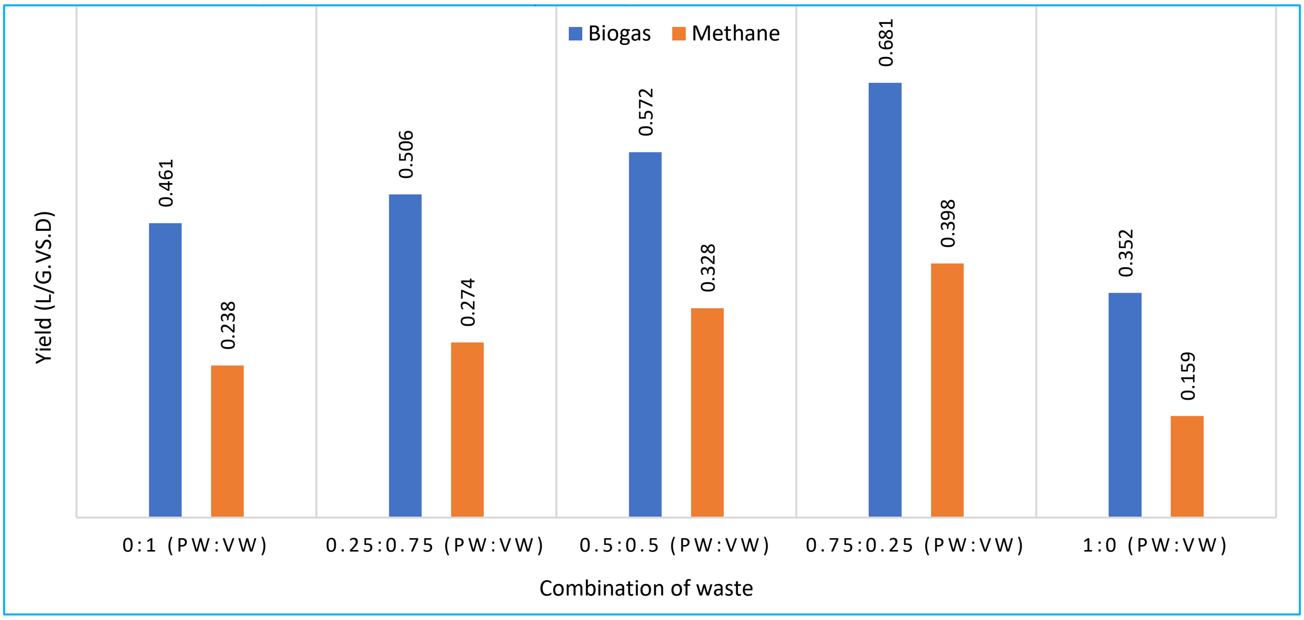

Fig 5 Average biogas yield from mixture of poultry waste (PW) and vegetable waste (VW)

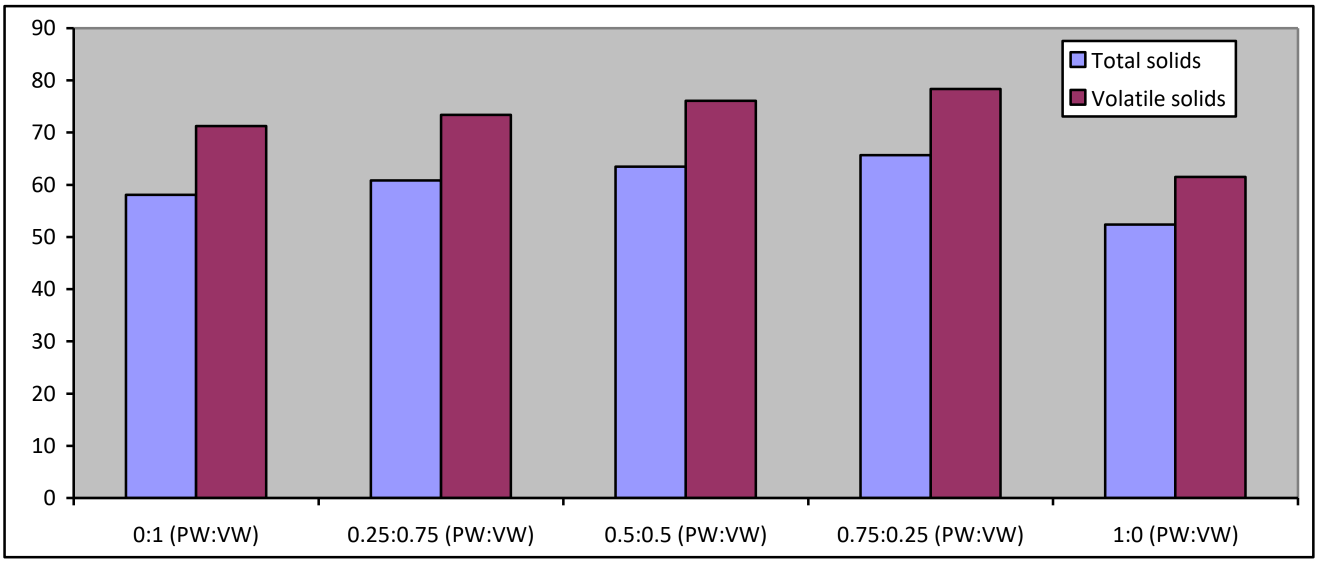

Fig 6 Reduction in total and volatile solid content during co-digestion studies

The average daily biogas yield in terms of L/g.VS degraded during co-digestion of PW and VW in 20 days experiment is represented in (Fig 5). The maximum biogas yield (viz. 0.681 L/g.VS.d) was obtained with the 0.75:0.25 (PW: VW) combination and minimum biogas yield (viz.0.352 L/g.VS.d) was obtained with 1:0 (PW: VW) combination. Thus, during the co-digestion of PW and VW, the highest biogas yield was obtained with the 0.75:0.25 (PW: VW) combination and lowest biogas yield was obtained with the 1:0 (PW: VW) combinations. The methane content in biogas collected from digester fed with 0.75:0.25 (PW: VW) was found to be 58.46±0.91%. The reduction in total solids (TS) and volatile solids (VS) values for digester fed with 0.75:0.25 (PW: VW) were found to be 65.70 ± 2.7% and 78.35 ± 3.07% respectively.

The results are comparable with those of previous researchers on anaerobic digestion of PW only [26-27] and co-digestion of PW with other organic wastes like wheat straw [28]; cow dung, poultry waste and water hyacinth [29]; Swine manure and chicken manure [30]; fresh water hyacinth, dry water hyacinth, poultry litter, cow manure and primary sludge [31]. High biogas yield from poultry manure is associated with its high nitrogen content and high bio-digestibility [32]. Due to these positive properties of poultry manure, the manure has been used to enhance digestion of and biogas production from various low-nitrogenous organic materials [33-35]. The results align with previous studies on both mono- and co-digestion of poultry waste, confirming its effectiveness in enhancing biogas production. This is largely due to the high nitrogen content and biodegradability of poultry manure, which make it a valuable co-substrate for low-nitrogen organic materials.

CONCLUSION

The disposal of poultry wastes by unscientific manner causes serious environmental pollution. The present study carried out at laboratory scale using 1 litre capacity digesters reveals that treatment of this waste by anaerobic co-digestion with vegetable waste generates considerable biogas yield and also decrease its environmental pollution potential as compared to individual substrates. Thus, it is evident that anaerobic digestion is an eco-friendly and technology wise simple method of energy generation and waste disposal. Anaerobic digestion is advantageous over other treatment methods used for disposal. With the further scale up studies of co-digestion with vegetable waste can serve as potential source for energy which can be used to meet the energy needs of nation and subsequently there will be ecofriendly treatment of these waste meeting sustainable development goals of nation.

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