



Feasibility of Bioethanol production from selected Livestock manure

O.A. Akinyele^{1*} and A.I. Bamgboye²

¹Department of Agricultural and Bio-Environmental Engineering, Federal College of Agriculture, Ibadan, Nigeria

²Department of Agricultural and Environmental Engineering, University of Ibadan, Ibadan, Nigeria
seunakinyele.aa@gmail.com

Available online at: www.isca.in, www.isca.me

Received 9th June 2025, revised 3rd August 2025, accepted 14th September 2025

Abstract

The study aimed to determine the bioethanol potential of three selected livestock manure. The manure was hydrolysed by dilute H₂SO₄ (250, 350 and 450 ml) at 100 °C for 30 mins. Maximum reducing sugar (glucose) was obtained from hydrolysis of 20 kg poultry manure by 450 ml H₂SO₄ at 100 °C for 30 mins. Ethanol was produced from 10, 15 and 20 kg each of cow, pig and poultry manure through biochemical conversion process. Ethanol of 4.0, 6.25 and 10.0 l/kg; 4.5, 6.75 and 10.5 l/kg; and 4.0, 6.5 and 10.25 l/kg were produced from 10, 15 and 20 kg each from cow, pig and poultry manure, respectively. The amount of ethanol produced increases with the quantity of manure applied in all the three samples, which also increases with the concentration of acid used for hydrolysis at 24 hours fermentation time. The hydrolysis process enhanced the quantity of ethanol obtained, as the temperature was high enough to break cellulosic material in the manure. The ethanol was obtained at a cooling temperature of 70-75 °C, while at 90.1 °C, the distilled liquid turns to steam which may actually lead to reduction in the quantity of ethanol produced. The study shows that the livestock manure has a good reducing sugar potential to produce ethanol. Hence, the bioethanol production substantially reduced the pollution strength of the livestock manure.

Keywords: Bioethanol, livestock manure, feasibility, unit operations, distillation.

Introduction

Ethanol, C₂H₅OH, is a chemically pure compound that is colourless, flammable, and contains oxygen. It can be utilised as a transport fuel in four distinct variations: anhydrous ethanol (100% pure ethanol), hydrous ethanol (95% ethanol and 5% water), anhydrous ethanol-gasoline blends (10 - 20% ethanol combined with gasoline), and as a feedstock for ethyl t-butyl ether (ETBE)¹. Several advantages of bioethanol compared to traditional fuels include its derivation from renewable resources, specifically crops rather than finite resources, and the ability of these crops, such as grains, sugar beetroot, and maize, to grow effectively. By utilising bioethanol, these emissions can be minimised when fuel crops sequester the carbon dioxide (CO₂) they release during their growth².

Blending bioethanol with petrol will effectively mitigate the significant reliance on nations that produce oil¹. Bioethanol exhibits biodegradability and lower toxicity compared to fossil fuels. Ethanol possesses a significantly higher latent heat of vaporisation (855 MJ/kg) compared to petrol (293 kJ/kg). Ethanol possesses a superior octane rating of 99, in comparison to petrol which typically ranges from 80 to 100². Consequently, the utilisation of ethanol prevents pre-ignition from happening. Ethanol has higher combustion efficiency, resulting in significantly reduced hydrocarbon emissions in comparison to petrol³. Ethanol exhibits a significantly reduced propensity to ignite and undergo explosive combustion in the event of fuel spill. The bioethanol's application in antiquated engines can effectively decrease the carbon monoxide they emit from

vehicles, therefore enhancing the air quality. The use of biofuels has significant viability in mitigating emissions of greenhouse gas⁴. Precisely, they highlight the promising prospects of producing bioethanol from agricultural by-products, such as crop and animal wastes.

Animal manure is a biomass resource that is seldom used to its full potential. It contains a significant quantity of organic carbon that is typically squandered in current manure discarding methods². Research has demonstrated that fibre constitutes the primary constituent of manure, comprising roughly 36%, 40% and 50% of poultry, swine and dairy wastes, respectively. Over 56% of the solid content of dairy manure consists of particles that are larger than 1.68 mm. Manure serves as both a carbon source and a supplier of various nutrients for fungi, for example, *T. reesei* and *Aspergillus phoenicis*, which are capable of producing cellulase. In addition, the hemicellulose constituent present in the manure fibre can be easily transformed into sugar by means of acid hydrolysis. Among the many treatments for manure cellulose hydrolysis, concentrated acid decrystallisation has been found to be the most effectual method⁵. In addition, different from other sources of lignocellulosic feedstocks, animal manure is highly concentrated in or around farms, making it cost-effective to gather and transport. Prior research has demonstrated that pentose and glucose may be effectively extracted from raw dairy manure, with pentose sugars being recovered at approximately 96% and glucose sugars at levels ranging from 40% to 52%. This extraction process involves dilute acid pre-treatment followed by enzyme hydrolysis, as described in experiments conducted by many researchers⁶⁻⁸.

Several researches and reviews on bioethanol production from sugar, starch and lignocellulosic feed stocks have been published, which include: Comparative analysis of bioethanol production from agricultural wastes using *Saccharomyces cerevisiae*, *Aspergillus niger*, and their co-culture⁹; Bioethanol production from agricultural waste: A review¹⁰; Simultaneous production of biofuel from agricultural wastes and bioremediation of the waste substrates: A review¹¹; Bioethanol production from agricultural residues as lignocellulosic biomass feedstock's waste valorization approach: A comprehensive review¹²; Ethanol Production from Livestock Manure: A Review¹; A Review on First and Second Generation Bioethanol Production: Recent Progress¹³; Bioethanol Production from Lignocellulosic Feed stocks Based on Enzymatic Hydrolysis: Current Status and Recent Developments¹⁴; Bioethanol Production: Feedstock and Current Technologies¹⁵; Bioethanol Production from Fermentable Sugar Juice¹⁶; Bioethanol Production from Poultry manure at Bonga Poultry Farm in Ethiopia²; Production of Bioethanol from Sweet Sorghum: A Review¹⁷; Bioethanol from agricultural waste residues¹⁸, A review of the production of ethanol from softwood¹⁹, etc.

This research was conducted to examine the bioethanol production potential of livestock manure, while providing environment-friendly alternative and reduction of wastes in the environment. Therefore, the objectives of the research were: to determine the quantity of reducing sugar produced from the acid hydrolysis of livestock manure at different acid concentrations and at different temperatures, and to determine the quantity of ethanol produced from the fermentation of reducing sugar by distillation method.

Methodology

Materials: The materials used for the experiment include: livestock manure (cow, pig and poultry), potassium hydroxide (KOH), sulphuric acid (H_2SO_4), yeast (*Saccharomyces cerevisiae*), high performance liquid chromatography (HPLC), filter medium, plastic bucket, developed ethanol plant (consisting of mixer, sieve, alkaline treater, dryer, burr mill, hydrolyser, fermenter and distiller).

Feedstock collection and preparation: Livestock manures were collected from the Research Farm of the Institute of Agricultural Research and Training, Ibadan, Nigeria. The solid manures were transported in polythene bags and later separated of debris, stones, bedding materials and any other unwanted particles that could disturb the flow of operation during the experiment. Before treatment, the manure samples were liquified at 4°C for 24 hours and the characterisation of the manure was carried out by titration method.

Methods: The bioethanol plant consisting of eight-unit operations (mixing, sieving, alkaline treatment, drying, milling, hydrolysis, fermentation and distillation) was developed with indigenous materials using ASTM standards²⁰. Ethanol was

produced from the livestock manure through biochemical conversion process. The three main feed stocks used are cow, pig and poultry manure of 10, 15 and 20 kg sample each. The experimental work was designed to determine the ethanol content of the three livestock manure. In order to produce sugars from the manure, it was pre-treated with acid and the hemicellulose/cellulose portion was broken down (hydrolyzed) by dilute acid into sugar content that was then fermented into ethanol. The experimental procedures for the production of bioethanol from the livestock manure were described according to the following unit operations.

Mixing process: The three manure samples (cow, pig and poultry) of 10, 15 and 20 kg each were mixed thoroughly with 15, 20 and 25 litres of water each to form slurry, with the aid of a mixer. The designed and fabricated mixers are shown in Figure-1. After the homogenous mixture was achieved, the tap was opened to allow the mixed manure passed out and discharged into the sieving unit. The mixing operation was effective in achieving homogenous and thorough mixture of the feedstocks.

Sieving process: The mixed manure samples were then sieved for solid/liquid separation with the aid of a sieve. The designed and fabricated sieves are shown in Figure-2. As the sieving chamber automatically moves front and back to sieve and separate the content (already in slurry manure), the solid fractions are retained on the sieve, while the liquid content moves down and discharged through the outlet into a container and was disposed-off properly. The sieving operation was effective in achieving thorough separation of solid and liquid particles for efficient process.

Alkaline treatment process: The solid fractions (sieved manure samples) were treated with 50, 100 and 150 g of potassium hydroxide (KOH), respectively, with the aid of an alkaline treater. The designed and fabricated alkaline treaters are shown in Figure-3. The process enhanced the breaking up of integrated structure of the cellulosic material, even though there was still insufficient access due to the damaged structure for the acid to affect the cellulose molecules. The alkaline treatment was effective to improve the acid hydrolysis to glucose.

Drying process: The KOH treated manures were subjected to drying using a charcoal-fired dryer to reduce the bulkiness of the feedstock and to degrade the organic matter at a high temperature of 93.5°C, thereby opening up more cellulose. The designed and fabricated dryers are shown in Figure-4.

Milling process: The dried manures were ground (milled), with the aid of a burr mill, to reduce the particle size of the feedstock and as well creating a larger surface area for reaction. The designed and fabricated burr mill are shown in Figure-5. The dried feedstock was milled into a powdery form using a burr mill. The milling operation aided the substrate to become significantly more susceptible to acid interaction.

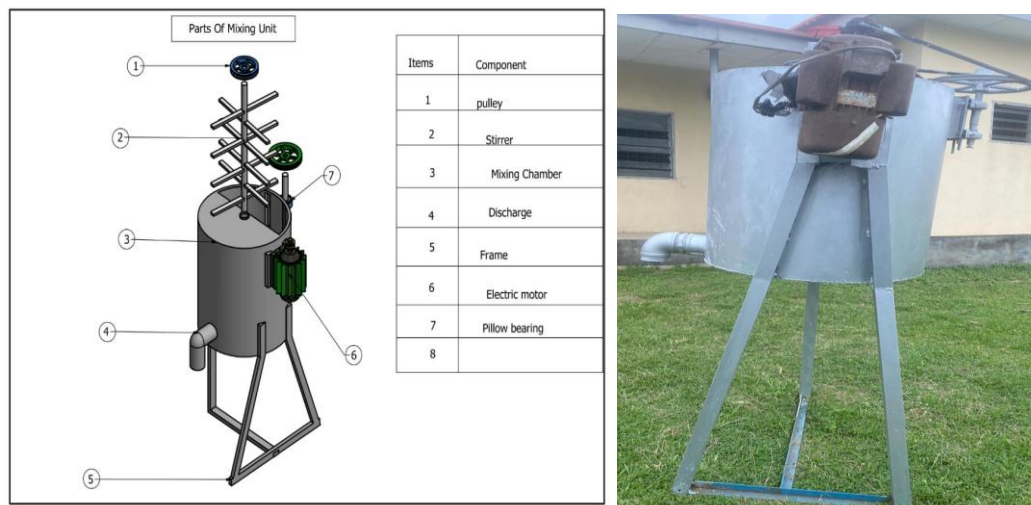


Figure-1: Designed and Fabricated Mixers.

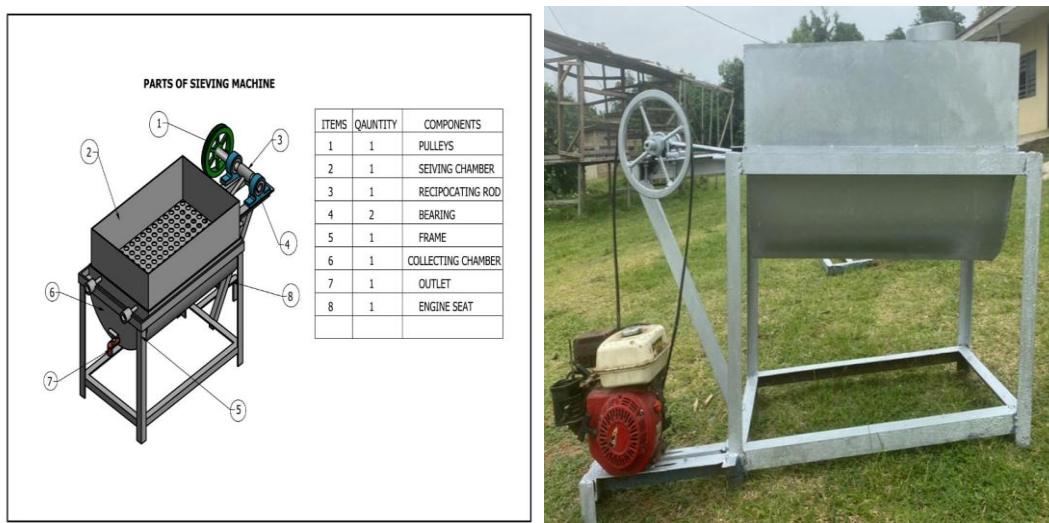


Figure-2: Designed and Fabricated Sieves.



Figure-3: Designed and Fabricated Alkaline Treaters.

Hydrolysis process: The milled manure samples were hydrolysed with 250, 350 and 450 ml of dilute sulphuric acid (H₂SO₄), respectively, in the tank to aid the process, while the solutions were heated for 30 mins each. The designed and fabricated hydrolysers are shown in Figure-6. After hydrolysis, the solution was allowed to cool and then filtered into a container using a filtering medium. The liquid fraction (filtrate) was kept for further process while the solid fraction was disposed. The hydrolysis process decomposes the cellulose component of the manure into simple sugar (glucose).

Fermentation process: The hydrolysed (sugar) solution was fermented, with the aid of a fermenter, using 100, 150 and 200 g of the yeast (*Saccharomyces Cerevisiae*) thawed in 100 ml of warm water each to enhance yeast growth. The designed and fabricated fermenters are shown in Figure-7. The yeast was afterward added to three fermented solutions and incubated for 24 hours in a fermentation tank (to be kept warm) for effective

fermentation. The fermentation process aided the production of bioethanol by breaking down of sugar in the absence of oxygen.

Distillation process: The fermented sugar solution was finally distilled in a distillation tank to produce bioethanol, heated with gas burner to form steamed solution and cooled through the cooling pipe and inside a cooling box (condenser) before being discharged. The designed and fabricated distillers are shown in Figure-8. The distilled solution (bioethanol) was collected through the discharge outlet on the cooling box into a container. The solution was distilled at a cooling temperature of 70-75°C. The distillation process facilitated the separation of liquids from non-volatile solids with the aid of intense heat to produce ethanol.

The overall process of bioethanol production from the livestock manure is shown in Figure-9, while the developed bioethanol plant is shown in Figure-10.

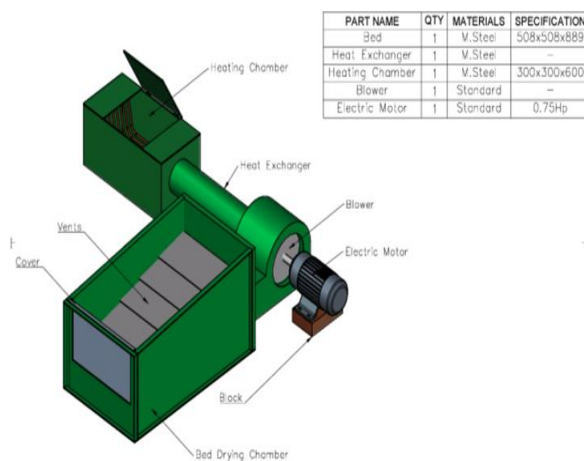


Figure-4: Designed and Fabricated Dryers.

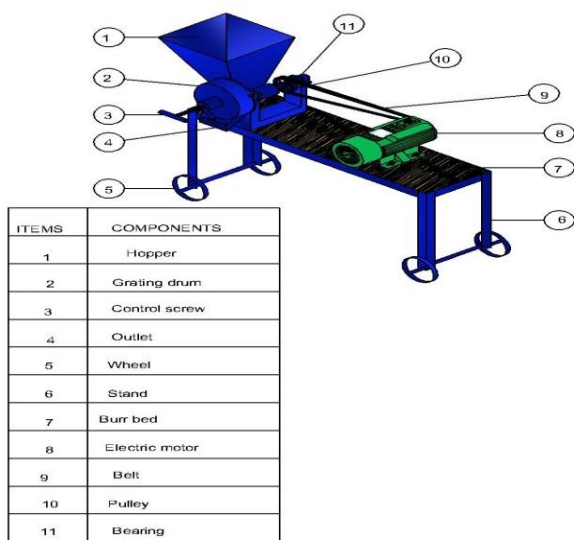


Figure-5: Designed and Fabricated Burr Mills.



Figure-6: Designed and Fabricated Hydrolysers.



Figure-7: Designed and Fabricated Fermenter.

Results and Discussion

Reducing sugar concentration with acid concentration: The experimental results showed that the samples (cow, pig and poultry manure) have good reducing sugar potential. The results also showed that the amount of total reducing sugar in the samples increases with increase in acid concentration used for hydrolysis and temperature of hydrolysis. The results are given in Table-1. It can also be seen that the reducing sugar (glucose) is detected from breaking down of cellulosic material in the samples on hydrolysis using 250, 350 and 450 ml H₂SO₄ with 10, 15 and 20 kg manure samples, respectively. This indicates

that the concentration of the acid used for hydrolysis of the samples is able to break cellulosic materials in the samples completely. The livestock manure has a good reducing sugar potential with respective acid concentration^{2,18}. In general, the results from high performance liquid chromatography (HPLC) indicate the presence of reducing sugar (glucose) in the samples and the amount of sugar depends on the concentration of acid used for hydrolyzing the samples. As shown in Table-1, the total amount of sugar increases with increase in concentration of acid used for hydrolysis with 250, 350, 450 ml H₂SO₄ for 10, 15 and 20 kg manure samples each.

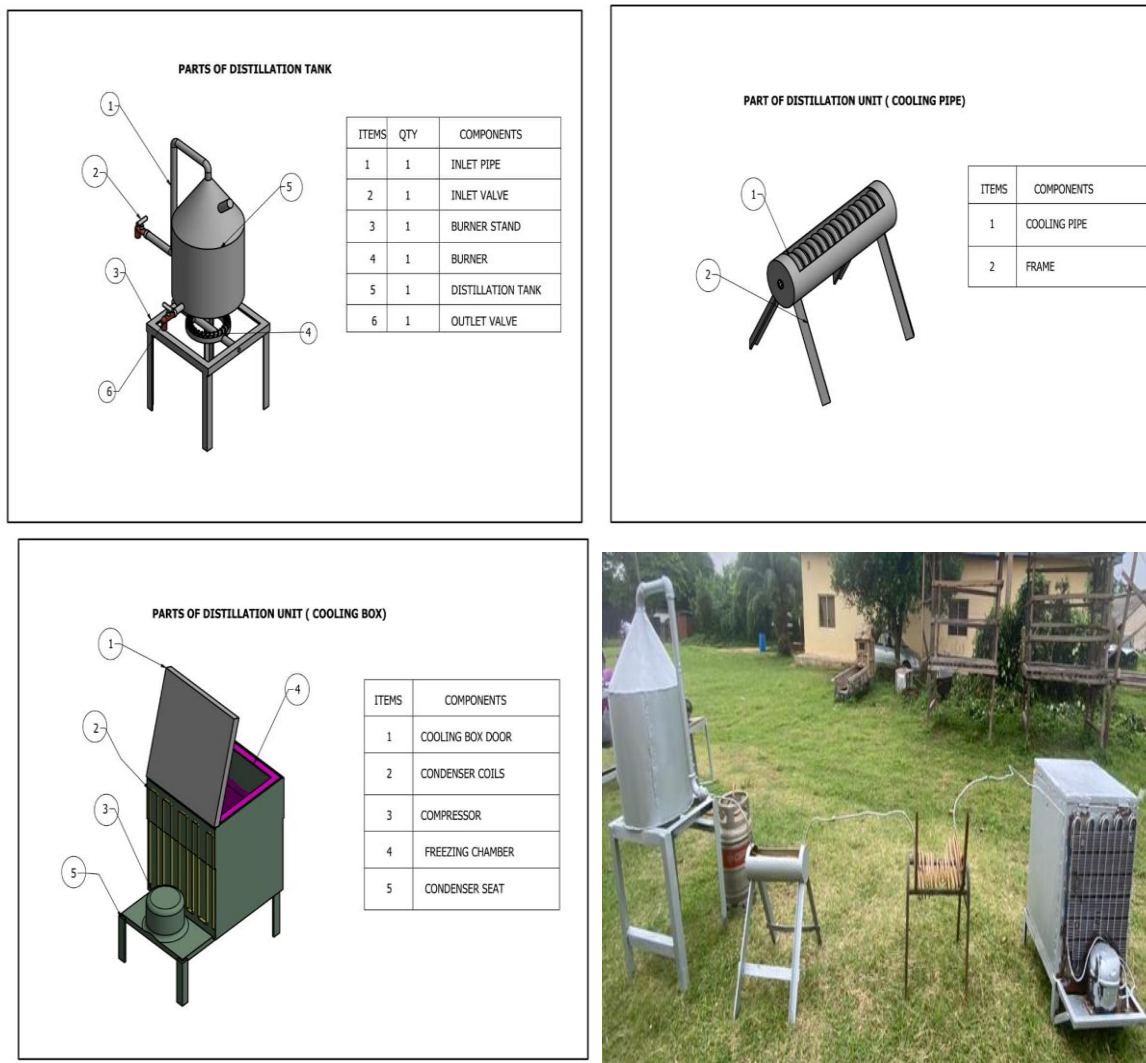


Figure-8: Designed and Fabricated Distillers.

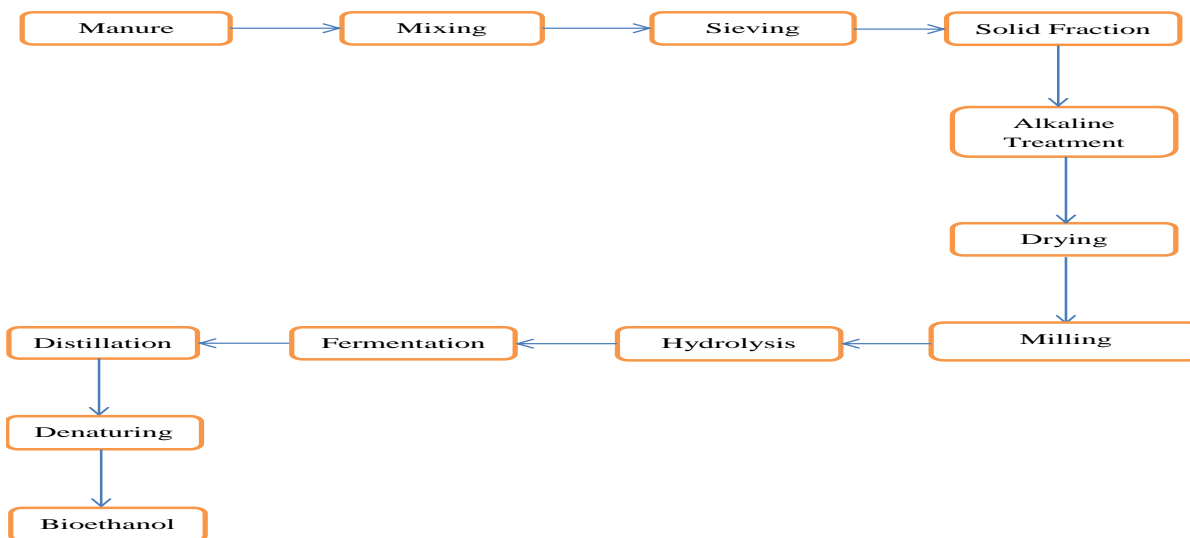


Figure-9: Process flow diagram of bioethanol production from livestock manure.



Figure-10: Developed-synchronised bioethanol plant.

Table-1: Reducing sugar (glucose) concentration in the samples at 250, 350 and 450 ml H₂SO₄.

Feedstock	Quantity of manure applied (kg)	Glucose concentration (%) at 250 ml H ₂ SO ₄	Glucose concentration (%) at 350 ml H ₂ SO ₄	Glucose concentration (%) at 450 ml H ₂ SO ₄
Cow	10	37.30	38.40	39.50
Cow	15	44.72	45.82	46.92
Cow	20	50.15	51.25	52.35
Pig	10	38.25	39.35	40.45
Pig	15	46.35	47.45	48.55
Pig	20	51.14	52.24	53.34
Poultry	10	37.95	38.05	39.15
Poultry	15	45.85	46.95	47.05
Poultry	20	50.75	51.85	52.95

Ethanol concentration as a function of acid concentration and fermentation time: The results in Table-2 shows that ethanol of 4.0, 6.25 and 10.0 l/kg; 4.5, 6.75 and 10.5 l/kg; and 4.0, 6.5 and 10.25 l/kg were produced respectively, from 10, 15 and 20 kg each of cow, pig and poultry manure. It was observed that the ethanol concentration increases with the quantity of manure loaded in all the three samples²⁰. The amount of ethanol obtained from the samples increases with the concentration of acid used for hydrolysis. The hydrolysis process at 78.5°C enhanced the quantity of ethanol obtained, because the temperature is high enough to break cellulosic material in the manure. The quantity of ethanol increases with fermentation time of 24 hours for the three samples²⁰. Generally, with 10, 15 and 20 kg of manure loaded in the three samples, the maximum

volume of ethanol (4.5, 6.75 and 10.5 litres/kg) was obtained from pig manure at 250, 350 and 450 ml acid hydrolysate with 24 hours fermentation. It was established that using 250, 350 and 450 ml of H₂SO₄, better rate of hydrolysis was achieved, as well as cellulose conversion without seriously affecting the pH of the solution. The pH range of 3.0-4.0 was obtained in all three samples and the samples fermented well with the minimum fermentation time of 24 hours, which consistently shows that the rate of fermentation aids the production of ethanol. The ethanol was obtained at a cooling temperature of 70-75°C, while at 90.1°C, the distilled liquid turns to steam which may actually lead to reduction in the quantity of ethanol produced. Hence, distillation temperature should be maintained at 70-75°C²⁰.

In general, the livestock manure has a good reducing sugar potential to produce ethanol^{2,18}. The pre-treatment and acid hydrolysis process to convert the cellulose into reducing sugars showed positive results and were very effective in the bioethanol production from manure, thereby reducing the odour of the wastes significantly. Livestock manure has been found to be a good raw material for bioethanol production. The results showed that ethanol production from cow, pig and poultry manure is feasible, considering the quantity of manure loaded, increasing the quantity of manure will increase the quantity of ethanol produced.

Table-2: Quantity of ethanol produced from the livestock manure at different acid concentration.

Feedstock	Concentration of H ₂ SO ₄ (ml)	Quantity of manure applied (kg)	Amount of ethanol produced (l/kg)
Cow	250	10	4.0
Cow	350	15	6.25
Cow	450	20	10.0
Pig	250	10	4.5
Pig	350	15	6.75
Pig	450	20	10.5
Poultry	250	10	4.0
Poultry	350	15	6.5
Poultry	450	20	10.25

Conclusion

The following conclusions were made from the study: i. Ethanol was produced from cow, pig and poultry manure through biochemical conversion process, using developed bioethanol plant which consist of eight-unit operations. ii. The experimental results showed that the samples (cow, pig and poultry manure) have good reducing sugar potential. iii. The amount of total reducing sugar in the samples increases with increase in acid concentration used for hydrolysis and temperature of hydrolysis. iv. The quantity of ethanol produced increases with the amount of manure applied at different acid concentration. v. The ethanol produced was a clear fuel with a distinct odour and it was obtained at a cooling temperature of 70-75°C. vi. The bioethanol production substantially reduced the pollution strength of the livestock manure from environmental standpoint. vii. The production of bioethanol from the livestock manure (cow, pig and poultry) is feasible, without depending on the edible ethanol sources. viii. Hence, the ethanol produced can be blended with petrol, which may be used to power small engines.

Acknowledgement

The authors acknowledge the technical supports from Federal College of Agriculture, Ibadan and University of Ibadan, Ibadan.

References

1. Akinyele, O.A. and Bamgboye, A.I. (2021). Ethanol production from livestock manure: A review. *Research Journal of Chemical Sciences*, 11(2), 7-19.
2. Woldesenbet, A.G., Shiferaw, G. and Chandravanshi, B.S. (2013). Bioethanol production from poultry manure at Bonga poultry farm in Ethiopia. *African Journal of Environmental Science and Technology*, 7(6), 435-440. DOI: 10.5897/AJEST2013.1443.
3. Sajid, K., Rehan, M. and Nizami, A-S. (2025). Optimizing bioethanol production by comparative environmental and economic assessments of multiple agricultural feedstocks. *Processes*, 13, 1027. <https://doi.org/10.3390/pr13041027>
4. Scott, F., Quintero, J., Morales, M., Conejeros, R., Cardona, C. and Aroca, G. (2013). Process design and sustainability in the production of bioethanol from lignocellulosic materials. *Bio. Technol.*, 16(3), 1-7
5. Chen, S., Wen, Z., Liao, W., Liu, C., Kincaid, R.L. and Harrison, J.H. (2005). Studies into using manure in a bio-refinery concept. *Applied Biochemistry and Biotechnology*, 121-124, 999-1015.
6. Liao, W., Liu, Y., Liu, C. and Chen, S. (2004). Optimising dilute acid hydrolysis of hemicellulose in a nitrogen-rich cellulosic material - dairy manure. *Bioresource Technology*, 94(1), 33-41.
7. Wen, Z., Liao, W. and Chen, S. (2004). Hydrolysis of animal manure lignocellulosics for reducing sugar production. *Bioresource Technology*, 91(1), 31-39.
8. Davison, B., Evans, B., Finkelstein, M., McMillan, J., Liao, W. and Wen, Z. (2005). Effects of hemicellulose and lignin on enzymatic hydrolysis of cellulose from dairy manure, in: 26th symposium on biotechnology for fuels and chemicals. *Humana Press*, 1017-1030.
9. Rajput, C. and Shrivastav, P. (2025). Comparative analysis of bioethanol production from agricultural wastes using *Saccharomyces cerevisiae*, *Aspergillus niger*, and their co-culture. *International Journal of Advanced Biochemistry Research*, 9(1), 105-109.
10. Hamdi, G.M., Abbas, M.N., and Ali, S.A.K. (2024). Bioethanol production from agricultural waste: A review. *Journal of Engineering and Sustainable Development*, 28(2).
11. Ahamefule, C.S., Osilo, C., Ahamefule, B.C., Madueke, S.N. and Moneke, A.N. (2024). Simultaneous production of biofuel from agricultural wastes and bioremediation of the

- waste substrates: A review. *Current Research in Microbial Sciences*, 7, 100305
12. Jayakumar, M., Gindaba, G.T., Gebeyehu, K.B., Periyasamy, S., Jabesa, A., Baskar, G., John, B.I. and Pugazhendhi, A. (2023). Bioethanol production from agricultural residues as lignocellulosic biomass feedstock's waste valorization approach: A comprehensive review. *Science of The Total Environment*, 879, 163158
 13. Muktham, R., Bhargava, S.K., Bankupalli, S. and Ball, A.S. (2016). A review on first and second-generation bioethanol production - recent progress. *Journal of Sustainable Bioenergy Systems*, 6, 72-92.
 14. El-Naggar, N.E., Deraz, S., Khalil, A. (2014). Bioethanol production from lignocellulosic feedstocks based on enzymatic hydrolysis: Current status and recent developments. *Biotechnology*, 13(1), 1-21.
 15. Vohra, M., Manwar, J., Manmode, R., Padgilwar, S. and Patil, S. (2014). Bioethanol production: Feedstock and current technologies. *Journal of Environmental Chemical Engineering*, 2, 573-584. <http://dx.doi.org/10.1016/j.jece.2013.10.013>
 16. Zabed, H., Faruq, G., Sahu, J.N., Azirun, M.S., Hashim, R. and Boyce, A.N. (2014). Bioethanol production from fermentable sugar juice. *The Scientific World Journal*, Article ID 957102, 11 pages. <http://dx.doi.org/10.1155/2014/957102>.
 17. Almodares, A. and Hadi, M.R. (2009). Production of bioethanol from sweet sorghum: A review. *African Journal of Agricultural Research*, 4, 772-780.
 18. Champagne, P. (2007). Bioethanol from agricultural waste residues. *Environmental Progress*, 27(1), 51-57. DOI 10.1002/ep.
 19. Galbe, M. and Zacchi, G. (2002). A review of the production of ethanol from softwood. *Applied Microbiology and Biotechnology*, 59, 618-628.
 20. Akinyele, O.A. (2024). Energy-cost and environmental impact analyses of bioethanol production from selected livestock manure. A Ph.D. Thesis in the Department of Agricultural and Environmental Engineering, University of Ibadan, Ibadan, Nigeria.