

**DEVELOPMENT OF CO₂ HARVESTER FROM THE
PHOTOCATALYTIC DECOMPOSITION OF
AGRICULTURAL WASTES**

ROCHELLE S. JANDOC

An Undergraduate Thesis Submitted to the Faculty of the Department of Agricultural and
Biosystems Engineering, College of Engineering, Central Luzon State University,
Science City of Munoz, Nueva Ecija, Philippines
in Partial Fulfillment of the Requirements
for the Degree of

**BACHELOR OF SCIENCE IN AGRICULTURAL AND BIOSYSTEMS ENGINEERING
(AB Machinery and Power Engineering)**

JUNE 2023

TABLE OF CONTENTS

	PAGE
LIST OF TABLES	ix
LIST OF FIGURES	x
LIST OF APPENDICES	xii
LIST OF APPENDIX TABLES	xiii
LIST OF APPENDIX FIGURES	xiv
LIST OF EQUATIONS	xv
INTRODUCTION	
Background of the Study	1
Statement of the Problem	2
Significance of the Study	3
Objectives of the Study	4
Scope and Limitation of the Study	4
Time and Place of the Study	5
REVIEW OF RELATED LITERATURE	
Agricultural Waste	6
Rice Straw	7
Corn Silage	8
Chicken Manure	9
Effect of Lignin on the Rate of Decomposition	10
Photocatalysis	12
Photocatalysis Studies	13
Carbon Dioxide Emissions	15
Direct CO ₂ Capture	18
Qualitative measurements of CO ₂ adsorption by FTIR	19
Carbon Dioxide Concentration Determination by Precipitation Method	20
Effect of CO ₂ in the Crop	21
Effect of UV Light Irradiation Power	22

Fermentation Time	23
METHODOLOGY	
Conceptualization of the Study	24
Design Concept of CO ₂ Harvester	26
Principles of Operation	27
Major Components of the CO ₂ Harvester	27
Performance Evaluation of the System	28
Parameters for the CO ₂ harvester	28
Amount of Agricultural Waste	28
Temperature	29
Pressure	29
Determination of the Volume of CO ₂ Produced	29
Determination of CO ₂ Produced	30
Determination of Flowrate	30
Cost of Operation	31
Statistical Analysis	31
RESULT & DISCUSSION	
The CO ₂ Harvester	32
Description of the System	33
Components of the System	33
Performance Evaluation of the System	34
Pressure Reading and Actual CO ₂ Volume Relationship	35
Total CO ₂ Produced	36
Volume of CO ₂ Produced	37
Effect of Temperature in a Daily CO ₂ Production	39
Daily CO ₂ Concentration	42
Flowrate of CO ₂ Production	44
SUMMARY	46
CONCLUSION	47

RECOMMENDATION	48
LITERATURE CITED	49

LIST OF TABLES

TABLE		PAGE
1	Composition of rice straw and rice husk	8
2	Materials and specific purposes of CO ₂ harvester	28
3	Specification of the system	33
4	Daily CO ₂ produced	36
5	Daily volume of CO ₂ produced	38
6	Temperature and actual volume production in UV light application	40
7	Temperature and actual volume production in sunlight application	41
8	Daily CO ₂ concentration	43
9	Flowrate of CO ₂ production	44

LIST OF FIGURES

FIGURE		PAGE
1	Structure of lignin	11
2	Chemical reactions	13
3	The conceptual framework of the study	25
4	Design of the CO ₂ harvester	26
5	The developed CO ₂ harvester	32
6	Preparation of agricultural wastes	35
7	Relation between pressure reading and actual volume production	35
8	Daily CO ₂ production	37
9	Daily volume of CO ₂ produced	39
10	Relation between temperature and actual volume production in UV light application	41
11	Relation between temperature and actual volume production in sunlight application	42
12	Daily CO ₂ concentration	43
13	Flowrate of CO ₂ production	45

LIST OF APPENDICES

APPENDICES	PAGE
Appendix Table	59
Appendix Figure	61

LIST OF APPENDIX TABLES

APPENDIX TABLES		PAGE
1	Data collection for pressure	59
2	Data collection for temperature	59
3	Bill of materials used in the development of the system	59

LIST OF APPENDIX FIGURES

APPENDIX FIGURES		PAGE
1	Preparation of agricultural wastes	61
2	Separation of corncob from unnecessary materials	61
3	Weighing of corncob	62
4	Moving the collected chicken manure in CRRDC	62
5	Cleaning of storage tank	63
6	Connecting of gas meter into the tire interior	63
7	Installation of UV light	64
8	1000L IBC tank	64
9	UV light	65
10	Pressure Gauge	65
11	Gas meter	66
12	Installed thermometer	66
13	Scheduler device	67
14	Tire interior	67
15	Applying sealant to seal any leakage	68
16	Collecting of data during daytime	68
17	Collecting of data at night time	69

LIST OF EQUATIONS

EQUATION		PAGE
1	Amount of CO ₂ produced	29
2	CO ₂ concentration	30
3	Flowrate	30

ABSTRACT

JANDOC, ROCHELLE S., Department of Agricultural and Biosystems Engineering, College of Engineering, Central Luzon State University, Science City of Muñoz Nueva Ecija, Philippines, **June 2023, DEVELOPMENT OF CO₂ HARVESTER FROM THE PHOTOCATALYTIC DECOMPOSITION OF AGRICULTURAL WASTES.**

Adviser: ENGR. ROLDAN T. QUITOS, M.Sc.

Agricultural wastes are often found in different places where farming activities take place. These wastes are generated primarily by farming activities which is not limited during the production but also includes other activities related to farming and food chain. This agricultural wastes decomposed in a natural way and produced an amount of CO₂ which led directly into the atmosphere. Carbon dioxide is required by plants for photosynthesis and can be of great help to boost the growth when applied directly into plants. However, despite the abundance of it in the atmosphere, collecting and storing carbon dioxide is a major problem. Thus, this study aimed to develop a CO₂ harvester and storage system that can be used to harvest and store CO₂. The developed system is composed of a 1000L IBC tank with a UV light installed inside and a tire interior having a size of 20.8 × 38. The performance of the system showed that a 1000L IBC tank which contains a mixture of an agricultural waste such as rice straw, corn cob, chicken manure and titanium dioxide (TiO₂) for photocatalytic decomposition can produce a total volume of 42.2 L within 7 days. Moreover, it showed the comparison between the application of UV Light which applies for continuous exposure of sunlight during the night for 12 hours wherein it produces a total volume of 0.6 L and natural sunlight during the day wherein it produces a total volume of 41.6 L for another 12 hours. Among the two, daylight shows an

excellent result in the production of CO₂ where it produces a larger volume of CO₂ than the application UV light or artificial sunlight during the night.

Keywords: agricultural waste; carbon dioxide; harvester & storage; titanium dioxide

LITERATURE CITED

- Abebe, A., Pathak, H., Singh, S.D., Bhatia, A., Harit, R.C., & Kumar, V. (2016). Agriculture, Ecosystems & Environment, Growth, yield and quality of maize with elevated atmospheric carbon dioxide and temperature in north–west India, Volume 218 (0167-8809), Pages 66-72, <https://doi.org/10.1016/j.agee.2015.11.014>.
- Agamuthu, P. (2009, November). Challenges and opportunities in agro-waste management: An Asian perspective. In Inaugural meeting of first regional 3R forum in Asia (pp. 11-12).
- Aminuzzaman, M., Kei, L. M., & Liang, W. H. (2017, April). Green synthesis of copper oxide (CuO) nanoparticles using banana peel extract and their photocatalytic activities. In AIP Conference Proceedings (Vol. 1828, No. 1, p. 020016). AIP Publishing LLC.
- Anjum, M., Al-Talhi, H. A., Mohamed, S. A., Kumar, R., & Barakat, M. A. (2018). Visible light photocatalytic disintegration of waste activated sludge for enhancing biogas production. *Journal of environmental management*, 216, 120-127.
- Ayyildiz, M., Erdal, G. (2021) The relationship between carbon dioxide emission and crop and livestock production indexes: a dynamic common correlated effects approach. *Environ Sci Pollut Res* 28, 597–610, <https://doi.org/10.1007/s11356-020-10409-8>.
- Benedix, R., Dehn, F., Quaas, J., & Orgass, M. (2000). Application of titanium dioxide photocatalysis to create self-cleaning building materials. *Lacer*, 5, 157-168.
- Boerjan, W., Ralph, J., & Baucher, M. (2003, February). Lignin Biosynthesis. *Annual review of plant biology*. 54. 519-46. [10.1146/annurev.arplant.54.031902.134938](https://doi.org/10.1146/annurev.arplant.54.031902.134938).

- Byrne, C., Subramanian, G., & Pillai, S. C. (2018). Recent advances in photocatalysis for environmental applications. *Journal of Environmental Chemical Engineering*, 6(3), 3531-3555.
- CureBasilAcock, Jennifer D. *Agricultural and Forest Meteorology*. Volume 38, Issues 1–3, October 1986, Pages 127-145 [https://doi.org/10.1016/0168-1923\(86\)90054-7](https://doi.org/10.1016/0168-1923(86)90054-7).
- Dessai, D. D., Gonsalves, G. B., Luis, M. R., & Samantha, M. (2017). Dark detector system for paper waste detection. *International Journal for Scientific Research & Development* 5(1), 873–875.
- Diaz, L. F., Golucke, C. G., Savage, G. M., & Eggerth, L. L. (2020). *Composting and recycling municipal solid waste*. CRC Press.
- Dibble, L. A., & Raupp, G. B. (1992). Fluidized-bed photocatalytic oxidation of trichloroethylene in contaminated air streams. *Environmental Science & Technology*, 26(3), 492-495.
- D'Oliveira, J. C., Al-Sayyed, G., & Pichat, P. (1990). Photodegradation of 2-and 3-chlorophenol in titanium dioxide aqueous suspensions. *Environmental science & technology*, 24(7), 990-996.
- Elfving, J., Bajamundi, C., & Kauppinen, J. (2017). Characterization and performance of direct air capture sorbent. *Energy Procedia*, 6087-6089.
- Ferrara, G., Lanzini, A., Leone, P., Ho, M. T., & Wiley, D. E. (2017). Exergetic and exergoeconomic analysis of post-combustion CO₂ capture using MEA-solvent chemical absorption. *Energy*, 130, 113-128.

- Fujishima, A., & Honda, K. (1972). Electrochemical photolysis of water at a semiconductor electrode. *nature*, 238(5358), 37-38.
- García-Marco, S., Ravella, S. R., Chadwick, D., Vallejo, A., Gregory, A. S., & Cárdenas, L. M. (2014). Ranking factors affecting emissions of GHG from incubated agricultural soils. *European journal of soil science*, 65(4), 573-583.
- Gentzis, T. (2000). Subsurface sequestration of carbon dioxide — an overview from an Alberta (Canada) perspective, *International Journal of Coal Geology*, Volume 43, Issues 1–4, Pages 287-305, ISSN 0166-5162, [https://doi.org/10.1016/S0166-5162\(99\)00064-6](https://doi.org/10.1016/S0166-5162(99)00064-6).
- Herrmann, J. M., & Guillard, C. (2000). Photocatalytic degradation of pesticides in agricultural used waters. *Comptes Rendus de l'Académie des Sciences-Series IIC-Chemistry*, 3(6), 417-422.
- Hobbs, P. R., Sayre, K., & Gupta, R. (2008). The role of conservation agriculture in sustainable agriculture. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 363(1491), 543-555.
- Huang, D. D., Cao, G. J., Geng, Y. H., Wang, L. C., Chen, X. W., & Liang, A. Z. (2019). Impact of agricultural waste return on soil greenhouse gas emissions. *Applied Ecology and Environmental Research*, 17(1), 1321-1335.
- Janusz, G., Pawlik, A., Sulej, J., Świdarska-Burek, U., Jarosz-Wilkołazka, A., & Paszczyński, A. (2017). Lignin degradation: microorganisms, enzymes involved, genomes analysis and evolution. *FEMS microbiology reviews*, 41(6), 941-962.

- Jo, W. K., & Kim, J. T. (2009). Application of visible-light photocatalysis with nitrogen-doped or unmodified titanium dioxide for control of indoor-level volatile organic compounds. *Journal of Hazardous Materials*, 164(1), 360-366.
- Kargbo, F. R., Xing, J., & Zhang, Y. (2009). Pretreatment for energy use of rice straw: A review. *African Journal of Agricultural Research*, 4(11), 1560-1565.
- Kieatiwong, S., Nguyen, L. V., Hebert, V. R., Hackett, M., Miller, G. C., Miille, M. J., & Mitzel, R. (1990). Photolysis of chlorinated dioxins in organic solvents and on soils. *Environmental science & technology*, 24(10), 1575-1580.
- Konaka, R., Kasahara, E., Dunlap, W. C., Yamamoto, Y., Chien, K. C., & Inoue, M. (1999). Irradiation of titanium dioxide generates both singlet oxygen and superoxide anion. *Free Radical Biology and Medicine*, 27(3-4), 294-300.
- Kormann, C., Bahnemann, D. W., & Hoffmann, M. R. (1988). Preparation and characterization of quantum-size titanium dioxide. *The Journal of Physical Chemistry*, 92(18), 5196-5201.
- Kushniarou, A., Garrido, I., Fenoll, J., Vela, N., Flores, P., Navarro, G., ... & Navarro, S. (2019). Solar photocatalytic reclamation of agro-waste water polluted with twelve pesticides for agricultural reuse. *Chemosphere*, 214, 839-845.
- Kumar, S., Negi, Y. S., & Upadhyaya, J. S. (2010). Studies on characterization of corncob based Nanoparticles. *Advanced Matteredials Letters*, 1(3), 246-253.
- Lim, J. S., Manan, Z. A., Alwi, S. R. W., & Hashim, H. (2012). A review on utilisation of biomass from rice industry as a source of renewable energy. *Renewable and sustainable energy reviews*, 16(5), 3084-3094.

- Lipman, T. E., & Delucchi, M. A. (2002). Emissions of nitrous oxide and methane from conventional and alternative fuel motor vehicles. *Climatic Change*, 53(4), 477-516.
- Liu, T. (2019). Biogas production from lignocellulosic agricultural residues: microbial approaches for enhanced efficiency. *Acta Universitatis Agriculturae Sueciae*, 2019:5. <https://publications.slu.se/?file=publ/show&id=10423>.
- Louis, L. (2018). Working principle of arduino and using it as a tool for study and working principle of arduino and using it. *International Journal of Control, Automation, Communication and Systems* 1(2), 21-29. <https://doi.org/10.5121/ijcaacs.2016.1203>.
- Majlessi, M., Eslami, A., Saleh, H. N., Mirshafieean, S., & Babaii, S. (2012). Vermicomposting of food waste: assessing the stability and maturity. *Iranian journal of environmental health science & engineering*, 9(1), 25.
- Molchanova, N. P., Morosova, S. V., Kondakov, K. S., Zhelezovskaya, G. I., & Bobyleva, G. A. (2022). Assessment of carbon dioxide effect on agricultural crops productivity by the method of dispersion analysis. *IOP Conference Series: Earth and Environmental Science*, 979(1), 012078. <https://doi.org/10.1088/1755-1315/979/1/012078>.
- Muñoz, C., Paulino, L., Monreal, C., & Zagal, E. (2010). Greenhouse gas (CO₂ and N₂O) emissions from soils: a review. *Chilean journal of agricultural research*, 70(3), 485-497.
- Mvondo, D. N., Navarro-González, R., McKay, C. P., Coll, P., & Raulin, F. (2001). Production of nitrogen oxides by lightning and coroneae discharges in simulated early Earth, Venus and Mars environments. *Advances in Space Research*, 27(2), 217-223.

- Oak Ridge National Library. US Department of Energy (Bioenergy Technologies Office). (2011). Crop residues and agricultural wastes. Retrieved from <https://www1.eere.energy.gov>.
- Ocampo, D. M., & Cotter, J. (nd). White Corn in the Philippines: Contaminated with Genetically Modified Corn Varieties. Greenpeace.org, 1-26.
- Ollis, D. F., Pelizzetti, E., & Serpone, N. (1991). Photocatalyzed destruction of water contaminants. *Environmental Science & Technology*, 25(9), 1522-1529.
- Omid, M. (2004). A Computer-Based Monitoring System to Maintain Optimum Air Temperature and Relative Humidity in Greenhouses. *International Journal of Agricult*
- Paragas, D. S., J.R. Salazar, J.L. Abalos and E.V. Salapare, 1999. Pesticide Decomposition Through Photocatalysis, R & D Highlights 1998-1999. Published by the Research, Extension and Training, Central Luzon State University.
- Paragas, D. S. and Ordonez, I.DS. (2003). Chlordane Degradation by Ultraviolet Irradiation of Semiconductor Powders, *LSC Journal*, Vol. 2, No. 1. June 2003.
- Pareek, S., Sagar, N., Sharma, S., Kumar, V. (2017). Onion (*Allium cepa* L.): Chemistry and Human Health, 2nd Edition. 10.1002/9781119158042.ch58ure & Biology, 8530, 6–5. Retrieved from <http://www.ijab.org>
- Pagal, D.G. (2008). Production of Organic Fertilizer through Photocatalytic Degradation of Rice Straw using Titanoum (IV) Oxide. An Undergraduate Thesis. Central Luzon State University, Science City of Muñoz, Nueva Ecija, Philippines.
- Paz, Y., Luo, Z., Rabenberg, L., & Heller, A. (1995). Photooxidative self-cleaning transparent titanium dioxide films on glass. *Journal of Materials Research*, 10(11), 2842-2848.

- Stewart, C., Moturi, P., Follet, R., & Halvorson, A. (2015). Lignin biochemistry and soil N determine crop residue decomposition and soil priming, 124:335–351, doi:10.1007/s10533-015-0101-8.
- Terzian, R., Serpone, N., Minero, C., & Pelizzetti, E. (1991). Photocatalyzed mineralization of cresols in aqueous media with irradiated titania. *Journal of Catalysis*, 128(2), 352-365.
- Tsai, W. T., Chang, C. Y., Wang, S. Y., Chang, C. F., Chien, S. F., & Sun, H. F. (2001). Utilization of Agricultural Waste Corn Cob for the Preparation of the Carbon Absorbent. *Journal of Environmental Science and Health*, 36(5), 677-686.
- Velmurugan, P., Shim, J., Lee, K. J., Cho, M., Lim, S. S., Seo, S. K., Cho, K. M., Bang, K. S., & Oh, B. T. (2015). Extraction, characterization, and catalytic potential of amorphous silica from corncobs by sol-gel method. *Journal of Industrial and Engineering Chemistry*, 1-6.
- Zhang, C., Zeng, G., Huang, D., Lai, C., Chen, M., Cheng, M., ... & Tan, X. (2019). Biochar for environmental management: Mitigating greenhouse gas emissions, contaminant treatment, and potential negative impacts. *Chemical Engineering Journal*, 373, 902-922.