

**COMPREHENSIVE SEMESTRAL REPORT AT CENTRAL LUZON STATE
UNIVERSITY - CENTER FOR RENEWABLE ENERGY
AND TECHNOLOGY (CLSU-CREaTe)**

ANJOHN M. ADOR DIONISIO

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

**BACHELOR OF SCIENCE IN AGRICULTURAL AND BIOSYSTEMS
ENGINEERING
(AGRICULTURAL MECHANIZATION AND RENEWABLE ENERGY)**

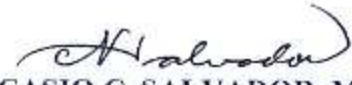
JULY 2024

ACCEPTANCE SHEET

This field practice manuscript entitled, "COMPREHENSIVE SEMESTRAL REPORT AT CENTRAL LUZON STATE UNIVERSITY - CENTER FOR RENEWABLE ENERGY AND TECHNOLOGY (CLSU-CREaTe)" prepared and submitted by ANJOHN M. ADOR DIONISIO as partial fulfillment of the requirements for the degree BACHELOR OF SCIENCE IN AGRICULTURAL AND BIOSYSTEMS ENGINEERING (AGRICULTURAL MECHANIZATION AND RENEWABLE ENERGY), is hereby accepted:


ROLDAN T. QUITOS, M.Sc.
Member, Advisory Committee

June 20, 2024
Date Signed


NICASIO C. SALVADOR, M.Sc.
Member, Advisory Committee

June 28, 2024
Date Signed


MARLON T. BELOS SANTOS, M.Sc.
Chairperson, Advisory Committee

JUNE 20, 2024
Date Signed

Accepted as partial fulfillment of the requirements for the degree BACHELOR OF SCIENCE IN AGRICULTURAL AND BIOSYSTEMS ENGINEERING (Agricultural Mechanization and Renewable Energy):


JOHN PAULO C. SACDALAN, Ph.D.
Head, Department of Agricultural and Biosystems Engineering

June 24, 2024
Date Signed


ROY SEARCA JOSE P. DELA CRUZ, Ph.D.
Acting Dean, College of Engineering

June 24, 2024
Date Signed

BIOGRAPHICAL SKETCH

Anjohn M. Ador Dionisio was born on the 19th day of July 1998 in Cabanatuan City, 25 years of age. He is the youngest child among three children of Celso E. Ador Dionisio and Edith M. Ador Dionisio. He has a brother, namely Anthony, being the oldest. And a sister, namely Anneth, being the middle child. He is from Camella Nueva Ecija, Valle Cruz, Cabanatuan City, Nueva Ecija.

Anjohn accomplished his primary education in March 2011 at Cabanatuan East Central School (CECS) and Secondary Education in March 2015 at Honorato C. Perez Sr. Memorial Science High School (HCPSMSHS), both located in Cabanatuan City, Nueva Ecija. He is an Agricultural and Biosystems Engineering student at Central Luzon State University (CLSU) major in Agricultural Mechanization and Renewable Energy.

Anjohn loves to spend time with his significant other, Mariel. He also loves to stay at home watching movies and playing games. In his spare time and free time, he likes to clean the house, and the car of his father, as that car is important to his father.

ACKNOWLEDGEMENT

The Author wishes to express his sincerest gratitude to his past and present instructors/professors for teaching him enough knowledge to shape this valuable study and to the people who have extended their support, care, knowledge, and prayers which led to the completion of this field practice.

To Engr. Marlon T. Delos Santos, Author's Adviser for his support and guidance throughout this field practice. His encouragement, and patience with the author is deeply appreciated.

To Engr. Roldan T. Quito and Engr. Nicasio C. Salvador, Author's Advisory Committee, for their commitment to help the author to finish the field practice, and their continuous support for the author to keep going. The author appreciated and thanked them.

To Engr. May C. Cabral, field practice coordinator, for her dedication, assistance, and invaluable advice throughout this journey. The author is truly grateful for her commitment and support.

To CLSU-CREaTe for accepting the author as a trainee and for welcoming him wholeheartedly. To Dr. Wendy C. Mateo, CREaTe director, Ma'am Joanna Padua, and Kuya Nato, for sharing their knowledge and experiences, for guiding the author in doing and accomplishing the tasks given, and for their kind consideration. The lessons he learned and inspirational messages he heard from them for a short time will definitely last.

To the author's father Celso for his commitment and everyday encouragement to finish the study, to the author's mother Edith for the never-ending support. The Author wishes to thank them for being a pillar of strength.

To his Ate Anneth for always being on the author's side always, and for being ready to help always. To his kuya Anthony, even if he is not on the Philippines, his kuya instinct is always felt by the author. The Author will love them always.

To his significant other, Mariel. The author wishes to express his greatest gratitude not just for helping him in finishing his course, but also for being the best support system, and for being the best human the author could have. The author wishes Mariel the very best life could ever offer.

To the author's co-trainees, Kuya Eduard, Jcramic, and Kimberly, who stayed with him and helped with all they could do. The author's field practice is even more precious to him knowing that he has a good company that continuously helped him to accomplish the tasks and to become a better person.

TABLE OF CONTENTS

	PAGE
LIST OF TABLES	x
LIST OF FIGURES	xi
LIST OF APPENDIX TABLES	xiii
LIST OF APPENDIX FIGURES	xiv
ABSTRACT	xv
INTRODUCTION	1
Background of the Field Practice	1
Objectives of the Field Practice	1
Activity 1. Performance Evaluation of a 250L Semi-automated Bioreactor Using AC and Solar-Powered Source	2
Activity 2. Design of 800L Capacity Bioethanol Distiller	2
Activity 3. Other Related Tasks and Activities	3
Activity 3.1. Research Innovation and Development Festival 2023 (Ride Fest 2023)	3
Activity 3.2. Assisting Visitors from NIA Gapan	3
Activity 3.3. Testing of the Mobile Solar Pump Irrigation System	4
Activity 3.4. Siting Water Pumps Inside CLSU	4
Activity 3.5. Basic Welding, Repair, and Maintenance of Different Agricultural Machines	4
Significance of the Field Practice	4
Scope and Limitation of the Field Practice	5
Location and Duration of the Field Practice	5
REVIEW OF RELATED LITERATURE	6
Bioreactor	6
Bioprocessing	8
Renewable Energy	9
Biomass	10
Distillation	10
Bioethanol	11
Biofuel	13
METHODOLOGY	15
Conceptualization of the Field Practice	15
Field Practice Area	16

Activity 1. Performance Evaluation of 250L Semi-automated Bioreactor using AC and Solar Powered Source	18
Key Features and Components Typically Found in A Bioreactor	19
Preparation for Instruments and Materials	21
Working Principle	21
Preparation of the Inoculants	22
Yeast Activation Process	23
Fermentation Process	24
Data Gathering	24
Distillation Process	26
Determination of Alcohol Content	26
Determination of Fermentation Efficiency	27
Power Consumption	27
Power Consumption Cost	28
Activity 2. Designing of 800L Tank Capacity Bioethanol Distiller	28
Different Components of a Bioethanol Distiller	29
Condenser	29
Ethanol collection system	29
Frame	29
Furnace assembly	29
Monitoring System	29
Reflux Column	29
Tank	29
Tank Design and Computation	29
Frustum Computation	31
Reflux Column Design	33
Condenser Design	34
Furnace Assembly Design	34
Frame	34
Design Consideration and Requirements	34
Engineering CAD Software	36
Bill of Materials	36
Activity 3. Other Related Tasks and Activities	36
Activity 3.1. Research Innovation and Development Festival (Ride Fest 2023)	36
Activity 3.2. Assisting Visitors from NIA Gapan	37
Activity 3.3. Testing of the Mobile Solar Pump Irrigation System (SPIS)	37
Activity 3.4. Siting Water Pumpss Inside CLSU	37
Activity 3.5. Basic Welding, Repair, and Maintenance of Different Agricultural Machines	37
RESULTS AND DISCUSSION	38
Activity 1. Performance Evaluation of 250L Semi-automated Bioreactor using AC and Solar Powered Source	38
Sugar Reduction as Affected by the Changes in pH During	39

Fermentation	
Sugar Reduction as Affected by the Changes in Temperature During Fermentation	41
Theoretical Ethanol Content	43
Actual Ethanol Content	44
Fermentation Efficiency	44
Power Consumption	45
Power Consumption Cost	45
Other Observations	46
Activity 2. Designing of 800L Tank Capacity Bioethanol Distiller	46
Design and Dimensions of the 800L Capacity Bioethanol Distiller	47
Reflux Column	47
Primary Condenser and Secondary Condenser	48
Frame	48
Bill of Materials	49
Activity 3. Other Related Tasks and Activities	49
Activity 3.1. Research Innovation and Development Festival 2023 (Ride Fest 2023)	49
Activity 3.2. Assisting Visitors from NIA Gapan	50
Activity 3.3. Testing of the Mobile Solar Pump Irrigation System (SPIS)	51
Activity 3.4 Siting Water Pumps inside CLSU	53
Activity 3.5. Basic Welding, Repair, and Maintenance of Different Agricultural Machines	53
SUMMARY, CONCLUSION AND RECOMMENDATION	57
Summary	57
Conclusion	58
Recommendation	59
LITERATURE CITED	62
APPENDICES	67
Appendix Table	68
Appendix Figures	70

LIST OF TABLES

TABLE		PAGE
1	Conceptual Framework of the Field Practice	15
2	Instruments and Materials Used in the Evaluation	21
3	Specification of Semi-Automated Bioreactor	38
4	T-test for pH Using AC and Solar Power in Fermentation Process of Semi-automated Bioreactor	41
5	T-test for Temperature Using AC and Solar Power in Fermentation Process of Semi-automated Bioreactor	43
6	Theoretical Ethanol Content for AC and Solar Power Source	43
7	Actual Ethanol Content	44
8	Computed Fermentation Efficiency	45
9	Power Consumption of Semi-Automated Bioreactor for AC Source	45

LIST OF FIGURES

FIGURE		PAGE
1	CREaTe Location Inside CLSU	17
2	CLSU - CREaTe	18
3	Bioreactor and its Parts	19
4	Bottom and Top Surface Area of Bioethanol Distiller Tank	30
5	Frustum of a Cone	32
6	Pythagorean Theorem	33
7	Picture of Semi-Automated Bioreactor	38
8	Sugar Reduction as Affected by The Change in pH of The Hydrolysates for the Whole Duration of Fermentation of Sugarcane Molasses for AC	39
9	Sugar Reduction as Affected by the Change in pH of the Hydrolysates for the Whole Duration of Fermentation of Sugarcane Molasses for Solar Power Source	40
10	Sugar Reduction as Affected by the Change in Temperature of the Hydrolysates for the Duration of Fermentation of Sugarcane Molasses for AC	42
11	Sugar Reduction as Affected by the Change in Temperature of the Hydrolysates for the Duration of Fermentation of Sugarcane Molasses for Solar Power Source	42
12	800L Tank Capacity Bioethanol Distiller	47
13	Student-Trainee Assisting in Staffing the Voting Booth in Ride Fest 2023	50
14	Demonstrating the Solar Powered Biomass Chopper	51
15	Mobile Solar Pump Irrigation System	52
16	Water Pump Inside CLSU	53
17	Student Leveling the Cut Lumber	54
18	Student-Trainee Assisting in the Making of a Costume	55
19	Student-trainee Cleaning Chains and Gears	55
20	Biomass Shredder	56

LIST OF APPENDIX TABLES

APPENDIX TABLE		PAGE
1	Data Collected on Evaluation of SPIS	68
2	List of Bill of Materials	69

LIST OF APPENDIX FIGURES

APPENDIX FIGURE		PAGE
1	Isometric View of Bioethanol Distiller	70
2	Bioethanol Distiller with Dimensions	70
3	Different Perspectives of Bioethanol Distiller	71
4	Front View of Tank	71
5	Isometric View of Tank	71
6	Top View of Tank	72
7	Reflux Column	72
8	Primary Condenser	72
9	Secondary Condenser	73
10	Frame	73
11	Top View of the Frame with Dimensions	74
12	Front View of the Frame with Dimensions	74
13	Right Side View of the Frame with Dimensions	75
14	Yeast Activation	75
15	Weighing of Additives	76
16	Transferring of Both	76
17	Pouring and Diluting of Molasses with Additives	76
18	Data Gathering Using in pH Meter	76
19	Semi-automated Bioreactor Using AC	77
20	Semi-automated Bioreactor Using Solar Power	77
21	Transferring of Fermented Broth to Distiller	77
22	Painting of Sawing Machine	77
23	Measuring the Area of Farm	78
24	Data Gathering for SPIS	78
25	Weighing of Biomass Materials	78
26	Evaluation of Shredder	78

LIST OF APPENDIX FIGURES

APPENDIX FIGURE		PAGE
1	Isometric View of Bioethanol Distiller	70
2	Bioethanol Distiller with Dimensions	70
3	Different Perspectives of Bioethanol Distiller	71
4	Front View of Tank	71
5	Isometric View of Tank	71
6	Top View of Tank	72
7	Reflux Column	72
8	Primary Condenser	72
9	Secondary Condenser	73
10	Frame	73
11	Top View of the Frame with Dimensions	74
12	Front View of the Frame with Dimensions	74
13	Right Side View of the Frame with Dimensions	75
14	Yeast Activation	75
15	Weighing of Additives	76
16	Transferring of Both	76
17	Pouring and Diluting of Molasses with Additives	76
18	Data Gathering Using in pH Meter	76
19	Semi-automated Bioreactor Using AC	77
20	Semi-automated Bioreactor Using Solar Power	77
21	Transferring of Fermented Broth to Distiller	77
22	Painting of Sawing Machine	77
23	Measuring the Area of Farm	78
24	Data Gathering for SPIS	78
25	Weighing of Biomass Materials	78
26	Evaluation of Shredder	78

ABSTRACT

ADOR DIONISIO, ANJOHN M., Department of Agricultural and Biosystems Engineering, College of Engineering, Central Luzon State University, Science City of Muñoz, Nueva Ecija, Philippines, **June 2024, COMPREHENSIVE SEMESTRAL REPORT ON FIELD PRACTICE AT CENTRAL LUZON STATE UNIVERSITY - CENTER FOR RENEWABLE ENERGY AND TECHNOLOGY (CLSU-CREaTe)**

Adviser: **MARLON T. DELOS SANTOS, M.Sc.**

The field practice was conducted at Central Luzon State University - Center for Renewable Energy and Technology (CLSU-CREaTe) located at CLSU compound, Science City of Muñoz, Nueva Ecija from October to December 2023.

The field practice Activity 1 aimed to evaluate a 250L semi-automated bioreactor using AC and solar-powered source. The objectives of this activity were to 1) evaluate the semi-automated bioreactor using AC and solar-powered source; 2) determine the fermentation efficiency of the semi-automated bioreactor using AC and solar-powered source; and, 3) comparison of power consumption of AC and solar powered source

The field practice activity 2 aimed to design an 800L tank capacity of bioethanol distiller. The specific objectives of this activity were to 1) determine the optimum area and height of an 800L tank capacity bioethanol distiller; 2) determine the other components of the bioethanol distiller; 3) layout a design of a bioethanol distiller; and, 4) prepare a bill of materials of the bioethanol distiller.

The field practice activity 3 aimed to perform other activities. The specific objectives of this activity were to: 1) perform other activities that will be assigned by the director of center, the supervisor of student-trainee or any CLSU-CREaTe personnels; and, 2) promote the student's readiness and flexibility in their respective specialization.

The 250L semi-automated bioreactor was evaluated for fermentation efficiency using AC and solar power sources. The results showed a fermentation efficiency of 81.7% for the AC which consumed 6.25 pesos, and 83.5% for solar power source. The fermentation efficiency is almost identical however, using solar-powered source saves money than using AC. But, the initial cost to build the solar-powered source is much greater.

The bioethanol distiller's design, which holds a capacity of 800L, has been up-scaled to a larger size. The design includes a tank, reflux column, primary condenser, slanted secondary condenser, vertical secondary condenser, and frame. The final dimensions were calculated to ensure the machine's efficiency and durability.

Moreover, the student gained experience with several aspects of renewable energy. The student participated in events, conducting and evaluating machines, and engaging in equipment assembly, which are all agricultural and biosystems-related tasks during the time frame of the field practice.

Keywords: bioreactor, evaluation, distiller, designing

LITERATURE CITED

- Abenes, F. B. and Agrupis, S. (2013). Personal Communications on Protocols of Sugarcane Molasses Fermentation for Bio-ethanol Production.
- Aditiya, H. B., Mahlia, T., Chong, W. T., Nur, H., & Sebayang, A. H. (2016). Second generation bioethanol production: A critical review. *Renewable & Sustainable Energy Reviews*, 66, 631–653. <https://doi.org/10.1016/j.rser.2016.07.015>
- Agrupis, S.C., Mateo, N., Madigal, J., Birganas, M., Lucas, M., and Abenes, F. (2014). "MMSU Hydrous Bioethanol: Properties and Performance of the Different MMSU95hBE Blends with Commercial Gasoline." Mariano Marcos State University
- Ahmed, S. F., Debnath, J., Mehejabin, F., Islam, N., Tripura, R., Mofijur, M., Hoang, A. T., Rasul, M., & Vo, D. N. (2023). Utilization of nanomaterials in accelerating the production process of sustainable biofuels. *Sustainable Energy Technologies and Assessments*, 55, 102894. Amadi, P.U. & Ifeanchio, M.O. (2016). Impact of changes in fermentation time, volume of yeast, and mass of plantain pseudo-stem substrate on the simultaneous saccharification and fermentation potentials of African land snail digestive juice and yeast. <https://doi.org/10.1016/j.jgeb.2016.09.002> <https://doi.org/10.1016/j.seta.2022.102894>
- Apostolou, K. (2023). Experiment 10: Bioreactor Instrumentation. Retrieved September 2023 from: [Pressbooks.pub: Pressbooks.https://ecampusontario.pressbooks.pub/proctech2ec3labmanual/chapter/experiment-10-bioreactor-instrumentation/#:~:text=Bioreactors%20are%20commonly%20cylindrical%2C%20ranging,be%20carried%20out%20in%20suspensions.](https://ecampusontario.pressbooks.pub/proctech2ec3labmanual/chapter/experiment-10-bioreactor-instrumentation/#:~:text=Bioreactors%20are%20commonly%20cylindrical%2C%20ranging,be%20carried%20out%20in%20suspensions.)
- Bar-On, Y. M., & Phillips, R. (2018). The biomass distribution on Earth. *Proceedings of the National Academy of Sciences of the United States of America*, 115(25), 6506–6511. <https://doi.org/10.1073/pnas.1711842115>
- Bioprocess Engineering. (n.d.). Retrieved September 2023 from: https://www.mlsu.ac.in/econtents/1808_Bioprocessengg.pdf Bioenergy: Renewable, Sustainable, Attainable. (2016). Energy.gov. Retrieved September 2023 from: <https://www.energy.gov/eere/articles/bioenergy-renewable-sustainable-attainable#:~:text=Bioenergy%20is%20renewable%20energy%20produced,conversion%20process%20at%20a%20biorefinery.>

- Bello, S. R., (2006). Guide to Agricultural Machinery Maintenance, and Operation. ResearchGate; Fasmen Communications, Okigwe Nigeria. Retrieved September 2023 from: https://www.researchgate.net/publication/275642288_Guide_to_Agricultural_Machinery_Maintenance_and_Operation
- Bondoc, J.K. (2023). Performace Evaluation of Semi-Automated Bioreactor for Bioethanol Production CareerExplorer. (2017). What does a farm equipment mechanic do? Retrieved September 2023 from: Careerexplorer.com; CareerExplorer. <https://www.careerexplorer.com/careers/farm-equipment-mechanic/> Central Luzon State University. (2014). Retrieved September 2023 from: Placeandsee.com. <https://placeandsee.com/wiki/central-luzon-state-university>
- Chang, H. N. (2011). Multistage Continuous High Cell Density Culture. In Elsevier eBooks (pp. 611–650). <https://doi.org/10.1016/b978-0-444-64046-8.00095-1> Distillation: equipment and processes. (n.d.). Google Books. <https://books.google.com/books?hl=en&lr=&id=NwfUAgAAQBAJ&oi=fnd&pg=PP1&dq=distillation&ots=OxVLIfmZ6&sig=O6fqYblQqJE2nJAwWR e9Q9aDcvg>
- Distillation Purification of Liquid Organic Compounds. (n.d.). retrieved September 2023 from: https://acikders.ankara.edu.tr/pluginfile.php/75185/mod_resource/content/0/Distillation.pdf
- Doran, P. M. (2013). Bioprocess Development. Elsevier eBooks. Retrieved September 2023 from: <https://doi.org/10.1016/b978-0-12-220851-5.00001-0>
- Doran, P. M. (n.d). Bioprocess Engineering Principles. Retrieved September 2023 from: <https://books.google.com.ph/books?hl=en&lr=&id=GoOqw3hKIyIC&oi=fnd&pg=PP1&dq=bioprocessing+engineering+principles&ots=ZN4ciw7oiZ&sig=7IJB>
- Ellabban, O., Abu-Rub, H., & Blaabjerg, F. (2014). Renewable energy resources: Current status, future prospects and their enabling technology. *Renewable & Sustainable Energy Reviews*, 39, 748–764. <https://doi.org/10.1016/j.rser.2014.07.113>
- Felkaoui, A., Chaari, F., & Haddar, M. (2018). Rotating machinery and signal processing: Proceedings of the First Workshop on Signal Processing Applied to Rotating Machinery Diagnostics, SIGPROMD'2017, April 09-11, 2017, Setif, Algeria. Springer.

- Fundamentals of renewable energy processes. (n.d.). Google Books. <https://books.google.com/books?hl=en&lr=&id=IeMbEAAAQBAJ&oi=fnd&pg=PP1&dq=renewable+energy&ots=wZkQteBaRi&sig=AqX8thC4HhjdwnrV0DA0RSvjSno>
- Holdings: Rotating machinery and signal processing. (n.d.). <https://tuklas.up.edu.ph/Record/UP-99796217613805503>
- Liang, X., Zuo, M. J., & Feng, Z. (2018). Dynamic modeling of gearbox faults: A review. *Mechanical Systems, and Signal Processing*, 98, 852–876. <https://doi.org/10.1016/j.ymssp.2017.05.024>
- Liu, Y., Cruz-Morales, P., Zargar, A., Belcher, M. S., Pang, B., Englund, E., Dan, Q., Yin, K., & Keasling, J. D. (2021). Biofuels for a sustainable future. *Cell*, 184(6), 1636–1647. <https://doi.org/10.1016/j.cell.2021.01.052>
- Moriarty, P., & Honnery, D. (2016). Can renewable energy power the future? *Energy Policy*, 93, 3–7. <https://doi.org/10.1016/j.enpol.2016.02.051>
- PRODUCTS. (2016). *Water Environment & Technology*, 28(5), 72–75. <http://www.jstor.org/stable/44010679>
- Quaschnig, V. (2014). Understanding renewable energy systems. In Routledge eBooks. <https://doi.org/10.4324/9781315800493>
- Ruano, J., Sommino, A., & Agostino, A. (2010). Bioenergy and the potential contribution of agricultural biotechnologies in developing countries. <https://doi.org/10.1016/j.biombioe.2010.04.011>
- Sánchez, J. R., Curt, M. D., Naeije, R., & Fernández, J. G. (2019b). Biomass resources. In Elsevier eBooks (pp. 25–111). <https://doi.org/10.1016/b978-0-12-813056-8.00002-9>
- Shu, C., Li, X., Li, H., & Gao, X. (2022). Design and optimization of reactive distillation: a review. *Frontiers of Chemical Science and Engineering*, 16(6), 799–818. <https://doi.org/10.1007/s11705-021-2128-9>
- Vohra, M., Manwar, J. V., Manmode, R., Padgilwar, S., & Patil, S. (2014). Bioethanol production: Feedstock and current technologies. *Journal of Environmental Chemical Engineering*, 2(1), 573–584. <https://doi.org/10.1016/j.jece.2013.10.013>
- Yang, R., Liu, C. C., Wang, Y. N., Hou, H. H., & Fu, L. (2017). A comprehensive review of micro-distillation methods. *Chemical Engineering Journal*, 313, 1509–1520. <https://doi.org/10.1016/j.cej.2016.11.041>
- [DQygPrxTJIfmkvdgZ2cw_EE&redir_esc=y#v=onepage&q=bioprocessing%20engineering%20principles&f=false](https://doi.org/10.1016/j.cej.2016.11.041)

- Holt Ag Solutions, (2014). Guide to Farm Equipment Maintenance | Holt Ag Solutions. Retrieved September 2023 from: [Holtags.com. https://www.holtags.com/guide-to-farm-equipment-maintenance](https://www.holtags.com/guide-to-farm-equipment-maintenance)
- Ho Nam Chang. (2011). Multistage Continuous High Cell Density Culture. Elsevier EBooks. September 2023 from: <https://doi.org/10.1016/b978-0-444-64046-8.00095-1>
- Kamen, A. S. (2021). 21st International Conference on Pharmaceutical Microbiology and Biotechnology. Pharmaceutical Bioprocessing. September 2023 from: [https://doi.org/10.37532/2048-9145.2021.9\(4\).32-33](https://doi.org/10.37532/2048-9145.2021.9(4).32-33)
- Lazatin, H. (2022). Everything You Need to Know Before Applying to Central Luzon State University. Retrieved September 2023 from: [Candymag.com. https://www.candymag.com/lifestyle/central-luzon-state-university-a1753-20220429-lfm](https://www.candymag.com/lifestyle/central-luzon-state-university-a1753-20220429-lfm)
- May Win Naing, & Williams, D. J. (2011). Three-dimensional culture and bioreactors for cellular therapies. Retrieved September 2023 from: <https://doi.org/10.3109/14653249.2011.556352>
- Magar, S. T. (2023, May 7). Bioreactor- Definition, Design, Principle, Parts, Types, Applications, Limitations. Microbe Notes. September 2023 from: <https://microbenotes.com/bioreactor/>
- M. Balat, Havva Balat, & O. Cahide. (2008). Progress in bioethanol processing. Retrieved September 2023 from: ResearchGate; Elsevier BV. https://www.researchgate.net/publication/281041405_Progress_in_bioethanol_processing
- Mustafa Balat, & Havva Balat. (2009). Recent trends in global production and utilization of bio-ethanol fuel. Appl. Energ.... Retrieved September 2023 from: ResearchGate; Elsevier BV. https://www.researchgate.net/publication/222403059_Balat_M_Balat_H_Recent_trends_in_global_production_and_utilization_of_bio-ethanol_fuel_Appl_Energ_86_2273-2282
- NIT Sriangar. (n.d.). Nitsri.ac.in. Retrieved September 2023 from: https://nitsri.ac.in/Department/Chemical%20Engineering/Distillation_Notes-PartVI.pdf
- Rasche, U., Challener, C., Yang, Y., Sha, M., & Basics, B. (n.d.). J U N E 2 0 2 0 Bioreactors and Fermenters: Powerful Tools for Resolving Cultivation Bottlenecks Advanced Technologies Facilitate Scale-up and Technology

- Transfer A Beginner's Guide to Bioprocess Modes: Batch, Fed-Batch, and Continuous Fermentation. Retrieved September 2023 from: https://www.eppendorf.com/product-media/doc/en/897339/Fermentors/Bioreactors_Publication_Bioprocess_Bioprocessing-basics.pdf
- Reisfeld, B. (2023). Bioreactors — Introduction to Chemical and Biological Engineering. Retrieved September 2023 from: Colostate.edu. <https://www.engr.colostate.edu/CBE101/topics/bioreactors.html>
- Spier, M. R., Vandenberghe, L. P. D. S., Medeiros, A. B. P., & Soccol, C. R. (2011). Application of different types of bioreactors in bioprocesses. In *Bioreactors: Design, Properties, and Applications*.
- Sustainable Energy Science and Engineering Center. (n.d.). Retrieved September 2023 from: <https://esc.fsu.edu/documents/lectures/ECSI/Bioenergy.pdf>
- Toppr. (2020). What is bioreactor? Explain its functioning. Toppr Ask. Retrieved September 2023 from: <https://www.toppr.com/ask/question/what-is-bioreactor-explain-its-functioning/>
- USDA ERS - Bioenergy. (2017). Usda.gov. Retrieved September 2023 from: <https://www.ers.usda.gov/topics/farm-economy/bioenergy/#:~:text=Bioenergy%20is%20renewable%20energy%20derived,of%20these%20renewable%20energy%20technologies.>
- Uchendu, E. E., Shukla, M. R., Reed, B. M., Brown, D. C., & Saxena, P. K. (2011). Improvement of Ginseng by In Vitro Culture. Elsevier EBooks. Retrieved September 2023 from: <https://doi.org/10.1016/b978-0-08-088504-9.00251-8>
- Zabochnicka, M., & Lucyna Sławik. (2010). Bioethanol-Production and Utilization. Retrieved September 2023 from: ResearchGate; unknown. https://www.researchgate.net/publication/228351087_Bioethanol-Production_and_Utilization#:~:text=Bioethanol%20was%20an%20alternative%20liquid,use%20algae%20to%20produce%20bioethanol.
- Zhang, H., Yang, Z., Wang, Y., Martinson Ankrah Twumasi, & Abbas Ali Chandio. (2023). Impact of Agricultural Mechanization Level on Farmers' Health Status in Western China: Analysis Based on CHARLS Data. *International Journal of Environmental Research and Public Health*, 20(5), 4654–4654. Retrieved September 2023 from: <https://doi.org/10.3390/ijerph20054654>
- Zhong, J.-J. (2011). *Bioreactor Engineering*. Elsevier EBooks. Retrieved September 2023 from: <https://doi.org/10.1016/b978-0-08-088504-9.00097-0>