

PROTOTYPE MODEL OF SPROUTS PRODUCTION CABINET (SPC)

**AGUSTIN, JAZFER L.
ANTONIO, ZSANELLE KAYE D.**


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 Muñoz, 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)**


JULY 2024

ACCEPTANCE SHEET


This undergraduate thesis entitled "**PROTOTYPE MODEL OF SPROUTS PRODUCTION CABINET**" prepared and submitted by **JAZFER L. AGUSTIN** and **ZSANELLE KAYE D. ANTONIO**, in partial fulfillment of the requirements for the degree of **BACHELOR OF SCIENCE IN AGRICULTURAL AND BIOSYSTEMS ENGINEERING**, is hereby accepted:

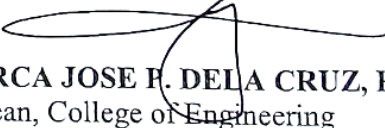

ELMAR M. VILLOTA, Ph.D.
Member, Advisory Committee
04-22-24
Date Signed


ROLDAN T. QUITOS, M.Sc.
Member, Advisory Committee
04-18-24
Date Signed


RUEL G. PENEYRA M.Sc.
Chair, Advisory Committee
06-14-24
Date Signed

Accepted as partial fulfillment of the requirements for the degree of **BACHELOR OF SCIENCE IN AGRICULTURAL AND BIOSYSTEMS ENGINEERING**:


ELMAR M. VILLOTA, Ph.D.
Chair, Department of Agricultural and Biosystems Engineering
04-22-24
Date Signed


ROY SEARCHA JOSE F. DELA CRUZ, Ph.D.
Dean, College of Engineering
06-18-24
Date Signed

BIOGRAPHICAL SKETCH

The researcher, Zsanelle Kaye D. Antonio, was born on November 3, 2002, in the Science City of Muñoz, Nueva Ecija. She is the eldest among two children of Mr. Rodrigo Q. Antonio Jr. and Mrs. Minda Luz D. Antonio, who have given her unwavering support and guidance throughout her journey.

She started her primary education at Bical Elementary School and then transferred to Muñoz North Central School, where she graduated. Zsanelle showed early signs of her future path by showing an early interest in science and mathematics. She also participated in school extracurricular activities, such as taekwondo and badminton. Aside from that, she participated in school contests like poetry contests, slogan contests, and poster making.

She took her secondary education at Muñoz National High School-Main and continued her senior high school studies at Muñoz National Senior High School-Main. She is a consistent honor student. She enrolled in HUMSS Strand, which allowed her to write plays for the school theater. The researcher passionately pursued her tertiary education in Agricultural and Biosystems Engineering at Central Luzon State University. Zsanelle set out on her college journey, determined to achieve academic success.

ZSANELLE KAYE D. ANTONIO

BIOGRAPHICAL SKETCH

Jazfer L. Agustin, the author, was born in Liberty, Pantabangan, Nueva Ecija, on February 14, 2002. He is the third of four siblings born to Mr. Romeo D. Agustin and Mrs. Jocela L. Agustin. He showed early signs of his future path through his interest in mathematics. He actively works on developing essential life skills through various experiences, understanding the importance of personal growth and self-improvement.

He finished his primary education at Liberty Elementary School and graduated as a class salutatorian because of his perseverance and dedication. He took junior high school at Pantabangan National High School and graduated with honors. Then, he left his comfort zone to continue his senior high school journey as a Science, Technology, Engineering, and Mathematics (STEM) student at Honorato C. Perez Sr. Memorial Science High School in Cabanatuan City, Nueva Ecija, and graduated with honors. He is pursuing a Bachelor of Science in Agricultural and Biosystems Engineering with a Major in AB Machinery and Power Engineering at Central Luzon State University. With his relentless pursuit of excellence and commitment to pushing the boundaries of what is possible, he continues to make a significant impact in the field of agricultural and biosystems engineering, driving progress and shaping the future of technology in agriculture.

JAZFER L. AGUSTIN

ACKNOWLEDGMENT

This thesis would not have been completed or possible without the invaluable support and guidance of specific individuals who encouraged, inspired, morally supported, and directed the researchers throughout this journey.

To Sir Ruel G. Peneyra, the assigned thesis adviser of the researchers, whose unwavering guidance, expertise, and encouragement propelled this research forward. His suggestions and ideas have been indispensable in shaping the direction and quality of this thesis.

Sir Elmar M. Villota and Sir Ronald T. Quitos's contributions are also deeply appreciated. Their insightful feedback, scholarly advice, and constructive criticism have greatly enriched the content and rigor of this research.

The College of Engineering, Prof. Theody Sayco, the Dean, and all faculty members and staff are responsible for providing resources and support for this research.

To PhilMech and Mrs. Frances Luisa M. Gallema, thank you for providing the researchers with the guidance and resources they needed to perform microbial enumeration for this research.

To the respected guardians of the researchers, Mrs. Jocela L. Agustin and Mr. Rodrigo Q. Antonio Jr., their steadfast support, invaluable guidance, pearls of wisdom, financial assistance, and unwavering inspiration were indispensable throughout this remarkable journey.

To my friends and colleagues, your encouragement and willingness to lend a helping hand have been invaluable. Your presence has made this journey more enjoyable and meaningful.

TABLE OF CONTENTS

	PAGE
BIOGRAPHICAL SKETCH	iii
ACKNOWLEDGMENT	v
LIST OF TABLES	xii
LIST OF FIGURES	xv
LIST OF APPENDIX TABLES	xvii
LIST OF APPENDIX FIGURES	xx
ABSTRACT	xxii
INTRODUCTION	1
Background of the Study	1
Statement of the Problem	2
Significance of the Study	4
Objectives of the Study	4
Scope and Limitation of the Study	5
Time and Place of the Study	5
REVIEW OF RELATED LITERATURE	6
Mung bean	6
Mung bean Sprouts	6
Status of Mung Bean Sprouts Production in the Philippines	7
Prospects of the Mung Bean Industry	7
Mung bean Sprouts Consumption	8
Health Benefits	8
Restaurants	9
Mung bean Sprouts Production in the Neighboring Country	9
Conventional Sprouting	10
Procedure	10
Mung Beans Deteriorate After Harvest	11

Improper Timing of Water	11
Uncontrolled Environment	11
Controlled Environment Agriculture	12
Sprouting Cabinet	12
Prototype	13
Germination Method	13
Disinfection by Ozone	13
Ozone Generator	14
Ozone Capacity	14
Thermoelectric Cooling	15
Target Temperature	15
Optimal Temperature	15
Default Temperature	16
Hydroponics	16
Irrigation Method	17
Drip	17
Sprinkler	18
Ebb and Flow	18
Reservoir	19
NFT	19
Capillary	19
Irrigation Frequency Control	20
Volume	20
Timing	21
Temperature Controller	21
Datalogger	21
Influence of the Environment on Sprouting	22
Air Temperature	22
Air Circulation	23
Relative Humidity	23
Cabinet Material	23

Metal	24
Glass	24
Acrylic	25
Polycarbonate	25
Metal	26
Stainless	26
Aluminum	26
Iron	27
Tray Material	27
PVC	27
Acrylic	28
Glass	28
Growing Media	28
Polyfill Fiber Sheets	29
Plumbing Materials	29
PVC	29
Stainless Pipes	30
Electric Materials	30
Cost Analysis	31
Total Cost	31
Breakeven Point	32
Return of Investment	32
Payback Period	32
METHODOLOGY	33
Conceptualization of the Study	33
Design Requirements	37
Design Considerations and Criteria	37
Materials	39
Design of the Sprouting Cabinet	40
The Sprouting Cabinet	41
The Watering System	42
Cultivation Practices and Management	43
Seedlings	43
Sprouting	43
Harvesting	43

Irrigation Frequency	43
Temperature and Humidity	44
Principles of Operation	44
Experimental Design	45
Experimental Layout	45
Data Analysis	47
Data to be Gathered	47
Color	48
Length	48
Stem Diameter	48
Weight	48
Changes in Storage	48
Microbial Count	49
Simple Cost Analysis	49
Total Cost	49
Breakeven Point	50
Return on Investment	50
Payback Period	51
RESULTS AND DISCUSSION	52
Specification of Materials	53
Preliminary Run	53
Final Design Adjustments	55
Sprouts Performance in the Production Cabinet	55
Color	55
Length	58
Stem Diameter	60
Weight	62
Changes in Storage	64
Microbial Analysis	66
Sensory Analysis	67
Appearance	69
Color	69
Taste	70
Texture	70
Flavor	71
Juiciness	71
Odor	72

Appearance	73
Color	74
Taste	74
Texture	75
Flavor	75
Juiciness	76
Odor	76
Temperature and Relative Humidity Conditions	77
Cost Analysis	85
SUMMARY, CONCLUSION, AND RECOMMENDATIONS	91
Summary	91
Conclusion	95
Recommendations	95
CITED LITERATURE	97
APPENDICES	103
Appendix Tables	104
Appendix Figures	122
Technical Plan	140

LIST OF TABLES

TABLE		PAGE
1	Criteria for materials and mechanism selection.	38
2	Materials used for the study	39
3	Research Design	47
4	Components and specifications of the sprouting cabinet	53
5	Preliminary Findings During Initial Run	54
6	Visual representation using RGB values	56
7	Average length of mung bean sprouts grown in SPC, mm	59
8	Mean of mung bean sprouts stem diameter, mm	61
9	Mean final weight of the mungbean sprouts, g	63
10	Comparative images of mung bean sprouts from day 1-10	64
11	Analysis of variance in terms of appearance	69
12	Analysis of variance in terms of color	69
13	Analysis of variance in terms of taste	70
14	Analysis of variance in terms of texture	70
15	Analysis of variance in terms of flavor	71
16	Analysis of variance in terms of juiciness	71
17	Analysis of variance in terms of odor	72
18	Analysis of variance in terms of appearance	73
19	Analysis of variance in terms of color	74

TABLE	PAGE	
20	Analysis of variance in terms of taste	74
21	Analysis of variance in terms of texture	75
22	Analysis of variance in terms of flavor	75
23	Analysis of variance in terms of juiciness	76
24	Analysis of variance in terms of odor	76
25	Water Temperatures (°C), Air Temperatures (°C), and Relative Humidity (%) of the 1 st trial inside the Spouts Production Cabinet.	78
26	Water Temperatures (°C), Air Temperatures (°C), and Relative Humidity (%) of the 2 nd trial inside the Spouts Production Cabinet.	79
27	Water Temperatures (°C), Air Temperatures (°C), and Relative Humidity (%) of the 3 rd trial inside the Spouts Production Cabinet.	80
28	Water Temperatures (°C), Air Temperatures (°C), and Relative Humidity (%) of the 4 th trial inside the Spouts Production Cabinet.	81
29	Water Temperatures (°C), Air Temperatures (°C), and Relative Humidity (%) of the 5 th trial inside the Spouts Production Cabinet.	82
30	Water Temperatures (°C), Air Temperatures (°C), and Relative Humidity (%) of the 6 th trial inside the Spouts Production Cabinet.	83
31	Water Temperatures (°C), Air Temperatures (°C), and Relative Humidity (%) of the 7 th trial inside the Spouts Production Cabinet.	84
32	Water Temperatures (°C), Air Temperatures (°C), and Relative Humidity (%) of the 8 th trial inside the Spouts Production Cabinet.	85
33	Cost of the Sprouting Cabinet	86
34	Cost per kg Sprouts	86
35	Breakeven Point	87

TABLE		PAGE
36	Actual Fixed Cost	87
37	Depreciation	88
38	Variable Cost	89
39	Return of Investment	89
40	Payback Period	90

LIST OF FIGURES

FIGURE		PAGE
1	Conceptual framework of the study	35
2	Flowchart of Activity	36
3	Isometric View of the Cabinet	41
4	Randomization Layout of the Study	46
5	Prototype model of sprouts production cabinet	52
6	Utilization of poly fiber	54
7	Four days sprouting and three days sprouting	54
8	The longer the mung bean is soaked in water, the more it deteriorates	55
9	Shows the mean length of mung bean sprouts for all trials after two days of sprouting.	58
10	Mung bean sprouts' stem diameter at the different combinations of factors	60
11	Mung bean sprouts' final weight at the different combinations of factors	62
12	Mung bean bacterial count per gram	66
13	Results of sensory evaluation (sauteed)	68
14	Results of sensory evaluation (fried spring roll)	73
15	A2B1C1 Water Temperatures (°C), Air Temperatures (°C) and Relative Humidity	77
16	A2B1C2 Water Temperatures (°C), Air Temperatures (°C) and Relative Humidity	78
17	A2B2C1 Water Temperatures (°C), Air Temperatures (°C)	79

FIGURE		PAGE
18	A2B2C2 Water Temperatures (°C), Air Temperatures (°C) and Relative Humidity	80
19	A1B1C1 Water Temperatures (°C), Air Temperatures (°C) and Relative Humidity	81
20	A1B2C1 Water Temperatures (°C), Air Temperatures (°C) and Relative Humidity	83
21	A1B2C2 Water Temperatures (°C), Air Temperatures (°C) and Relative Humidity	84

LIST OF APPENDIX TABLES

APPENDIX TABLE	PAGE
1 Analysis of variance of ΔE	104
2 Mean values of ΔE	104
3 Post hoc comparisons of factors	105
4 Side scoring of different treatments in terms of ΔE	106
5 Analysis of variance of sprouts' length	106
6 Post hoc comparisons of mean length as affected by ozone addition	106
7 Post hoc comparisons of mean length as affected by micro sprinkler addition	107
8 Post hoc comparisons of mean length as affected by irrigation frequency * micro sprinkler addition	107
9 Side scoring of irrigation frequency * micro sprinkler addition	107
10 Post hoc comparisons of mean length as affected by ozone addition * micro sprinkler addition	108
11 Side scoring of ozone addition * micro sprinkler addition	108
12 Analysis of variance of sprouts stem diameter	108
13 Mean values of sprout stem diameter	109
14 Post hoc comparisons of mean diameter as affected by irrigation frequency	109
15 Post hoc comparisons of mean stem diameter as affected by irrigation frequency * ozone addition	110
16 Side scoring of irrigation frequency * ozone addition	110

APPENDIX TABLE		PAGE
17	Post hoc comparisons of mean stem diameter as affected by ozone addition * micro sprinkler addition	111
18	Side scoring of ozone addition * micro sprinkler addition	111
19	Post hoc comparisons of mean stem diameter as affected by irrigation frequency * micro sprinkler addition * ozone addition	112
20	Analysis of variance on total weight	113
21	Post hoc comparisons mean weight as affected by micro sprinkler addition	113
22	Post hoc comparisons of mean weight as affected by ozone addition	113
23	Analysis of variance in terms of appearance	114
24	The mean value of appearance	114
25	Analysis of variance in terms of color	114
26	Mean value of color	114
27	Analysis of variance in terms of taste	116
28	Mean value of taste	115
29	Analysis of variance in terms of texture	115
30	Mean value of texture	115
31	Analysis of variance in terms of flavor	116
32	Mean value of flavor	116
33	Analysis of variance in terms of juiciness	116
34	Mean value of juiciness	116
35	Analysis of variance in terms of odor	117

	APPENDIX TABLE	PAGE
36	Mean value of odor	117
37	Analysis of variance in terms of appearance	117
38	Mean value of appearance	117
39	Analysis of variance in terms of color	118
40	Mean value of color	118
41	Analysis of variance in terms of taste	118
42	Mean value of taste	118
43	Analysis of variance in terms of texture	119
44	Mean value of texture	119
45	Analysis of variance in terms of flavor	119
46	Mean value of flavor	119
47	Analysis of variance in terms of juiciness	120
48	Mean value of juiciness	120
49	Post Hoc Comparisons of different sprout types in term of juiciness	120
50	Analysis of variance in terms of odor	121
51	Mean value of odor	121

LIST OF APPENDIX FIGURES

APPENDIX FIGURE	PAGE
1 Sprouting Cabinet	122
2 Sprouting Tray	122
3 Sunflow Blower Fan	123
4 Peltier Semiconductor Cooling Plate Refrigerator	123
5 Micro sprinkler	124
6 Temperature Sensor	124
7 WP-6000 100W Submersible Water Pump	125
8 ½ in PVC Water Pip	125
9 45L Storage Container for Reservoir	126
10 Sinometer TM616W-2 30A 220V Digital Timer	126
11 Ozone Generator	127
12 Soaking of Mung bean seeds for 8-12 hours	127
13 Transferred the seeds to the Sprouting Cabinet	128
14 Day 1 on the sprouting Cabinet	128
15 Day 2 on the Sprouting Cabinet	129
16 Harvested mung bean sprouts	129
17 Mung bean sprouts produced on the sprouting cabinet	130
18 Measuring the length using a digital caliper	130
19 Measuring the length using a digital caliper	131
20 Weighing of Sprouts	131

APPENDIX FIGURE	PAGE
21 Sprouts from Cabinet	132
22 Sprouts from the local market	132
23 Sprouts from supermarket	133
24 1 st Sensory Evaluation	133
25 2nd Sensory Evaluation	134
26 Random students evaluating the samples from 1st sensory evaluation	134
27 Random student evaluating the samples from 2nd sensory evaluation	135
28 Mung bean sprouts with peptone water	135
29 Preparation and weighing of materials	136
30 Plate Count Method in Safety Cabinet	136
31 Bacterial Counting	137
32 Parts of the Autocad Drawing of the Sprouting Cabinet	137
33 Sensory Evaluation Form (Front)	138
34 Sensory Evaluation Form (Back)	139

ABSTRACT

AGUSTIN, JAZFER L. AND ANTONIO, ZSANELLE KAYE D., Department of Agricultural and Biosystems Engineering, College of Engineering, Central Luzon State University, Science City of Muñoz, Nueva Ecija, Philippines, April 2024, **PROTOTYPE MODEL OF SPROUTS PRODUCTION CABINET**

Adviser: RUEL G. PENEYRA, M.Sc.

The insufficient availability of fresh, high-quality mung bean sprouts in fast-food restaurants and public markets in the Philippines can be attributed to the utilization of conventional sprouting methods. These traditional techniques often lead to low-quality sprout production due to improper irrigation timing, resulting in unhealthy sprouts, unpleasant odors, and potential microbial activity. A novel approach employing a controlled irrigation system, cooling mechanism, and water disinfection method has been developed to address these issues. Implementing a sophisticated irrigation mechanism with simple controllers optimizes the irrigation timing, ensuring ideal conditions for sprout growth and development while regulating temperature and inhibiting microbial activity in the sprout production cabinet. Unlike conventional sprouting, where water is constantly replaced, this sprouting machine uses circulating water, contributing to water conservation. Experimental trials utilizing sprouting trays with dimensions of 54 cm x 28 cm x 5 cm, each containing one hundred fifty grams of mung bean seeds soaked for eight hours, were conducted inside the sprouting cabinet. These trials followed a 2x2x2 factorial design arranged in a Complete Randomized Design (CRD), allowing for a comprehensive analysis of the interplay between variables. Factors such as irrigation frequency, micro sprinkler addition, and ozone treatment have been identified as critical contributors to mung bean

sprout development. With these, harvesting was achieved within two days after transplanting. The results of this study have shown that trials A1B1C1 (one-hour irrigation interval, ozone addition, and micro sprinkler addition) and A2B1C1 (two-hour irrigation interval, ozone addition, and micro sprinkler addition) have a significant impact on the germination of mung bean sprouts, yielding average mung bean weights, diameters, and lengths of 849.67 g, 2.25 mm, and 79.94 mm, and 720 g, 2.28 mm, and 79.41 mm, respectively. Additionally, the removal of sprout shells and non-sprouting seeds was facilitated easily. Using RGV values, trials A1B2C1, A1B2C2, A2B1C1, and A2B1C2 exhibit no significant difference in color change. In contrast, A1B1C1, A1B2C2, A2B2C1, and A2B2C2 show substantial differences from each other and the treatment mentioned above combinations. These findings suggest that the absence of ozone and micro sprinkler, along with infrequent irrigation, impacts the color change observed after ten days. Regarding the storage of mung bean sprouts, the trial A1B1C1 produced the most extended sprouts. After ten days of observation, elongation, root formation, and leaf growth were evident, and no deterioration was observed. Regarding sensory analysis, there is no significant difference between mung bean sprouts from local markets and supermarkets and sprouts produced by the cabinet in terms of appearance, color, taste, flavor, texture, and odor. However, there is a significant difference in juiciness between the sprout sample from the local market (Sample 1) and the sprouting cabinet (Sample 3), but not substantial to the sprout sample from the supermarket. The trial A1B1C1 also results in notably advantageous outcomes across various parameters such as color, length, weight, storability, sensory characteristics, and microbial activity. Additionally, trial A2B1C1 results in greater stem diameter among all trials. One main advantage of having a sprouting cabinet

is the shortened production period, requiring only two days instead of four to six days using the traditional sprouting method. Furthermore, the addition of ozone in trials A1B1C1, A2B1C1, A1B1C2, and A2B1C2 has effectively controlled unwanted microbial activity compared to trials without ozone. This underscores the efficacy of the sprout production cabinet in generating high-quality sprouts compared to traditional methods.

CITED LITERATURE

- AGGARWAL, D. V., & POEHLMAN, J. (1977). Effects of photoperiod and temperature on flowering in mungbean (*Vigna radiata* (L.) Wilczek). *Euphytica*, 26(1), 207–219.
- AMERICAN WATER WORKS ASSOCIATION. 2002. PVC. Pipe—Design and Installation. AWWA MANUAL M23. (Second Edition). Science and Technology.
- ANLAUF, R., REHRMANN, P., and SCHACHT, H. 2012. Simulation of water uptake and redistribution in growing media during ebb-and-flow irrigation. *Journal of Horticulture and Forestry*, 4(1), 8–21. <https://doi.org/10.5897/jhf11.058>.
- ARSHAD, I., 2020. Importance of Drip Irrigation System Installation and Management - A Review. *PSM Biol. Res.*, 5(1): 22-29.
- AWASTHI, D., R. JAGGI, and PADMANAND. 2006. *A Manual for Entrepreneurs*. Tata McGraw-Hill Publishing Company Limited. New Delhi, India.
- BADHIYE, SAGARKUMAR, CHATUR, B., and WAKODE. 2011. Data Logger System: A Survey. 2249-6343.
- BARBOSA G, GADELHA F, KUBLIK N ET AL. 2015. Comparison of land, water, and energy requirements of lettuce grown using hydroponic vs. conventional agricultural methods. *International Journal of Environmental Research and Public Health*, 12 (6), 6879–6891. <https://doi.org/10.3390/ijerph120606879>.
- BENKE, K. and TOMKINS, B. 2017. Future food-production systems: Vertical farming and controlled-environment agriculture. *Sustain. Sci. Pract. Policy* 2017, 13, 13–26. <https://doi.org/10.1080/15487733.2017.1394054>.
- BOMBON, M.A. 2017. Hydroponic Production of Celery (*Apium Graveolems* L.) Using Different Growing Media Under Greenhouse Condition [Unpublished manuscript]. Central Luzon State University.
- BOUSTED, I. 2005. Polycarbonate. Eco-profiles of the European Plastics Industry. *PlasticsEurope*. Association of Plastic Manufacturers. [pc_31116f03-fabd-11da-974d-0800200c9a66.pdf](https://www.inference.org.uk/pc_31116f03-fabd-11da-974d-0800200c9a66.pdf) (inference.org.uk).

- BUAL, C. L. C., CUNANAN, R. D., BEDRUZ, R. A., BILLONES, R. K. C., and VICERRA, R. R. P. (2019). Microcontroller-based Irrigation System for Experimental Design of Mung Bean Sprouts Cultivation. In International Conference on Humanoid, Nanotechnology, Information Technology, Communication and Control, Environment and Management. <https://doi.org/10.1109/hnicem48295.2019.9072801>.
- CASTILLO, F.S., PEREZ, E.C., and MAGAA, E.C. 2012. Development of alternative crop systems for the production of vegetables in hydroponics. *Acta Hort.*, 947: 399–408. <https://doi.org/10.17660/actahortic.2012.947.22>.
- CHOU, Y., & TING, Y. (2023). Plasma-activated water regulated transcriptome gene expression, leading to high germination and growth of mung beans. *Chemical and Biological Technologies in Agriculture*, 10(1). <https://doi.org/10.1186/s40538-023-00497-2>
- COHEN, N., and JOHNSON, B. 2016. Performance & Validation of Ozone Generation for Pharma Water Systems. International Society for Pharmaceutical Engineering. Performance & Validation of Ozone Generation for Pharma Water Systems. Pharmaceutical Engineering (ispe.org).
- DANVER, TREX, and JORDAN, B. 2021. Outdoor Kitchen Design with Stainless Steel Cabinetry. AIA Continuing Education Provider.
- DEPARTMENT OF AGRICULTURE. 2020. Investment Guide for Mung Bean. Agribusiness and Marketing Assistance Service. Agribusiness Promotion Division. Mung Bean.cdr (da.gov.ph).
- DESIGN GUIDELINES FOR THE SELECTION AND USE OF STAINLESS STEEL. 1977. Committee of Stainless Steel Producers, American Iron and Steel Institute. Washington, D.C. DHILLON, A. 2020. Effect of Temperature on Mung Bean Growth Rate. Vol. 10 (2020)
- DUIGNAN, B. 2024. Total Cost. The editors of Encyclopaedia Britannica. <https://www.britannica.com/money/total-cost>
- DZULKEFLI, N., ABDULLAH, R. B., JAAFAR, A., SHAFIE, R., YASSIN, I. M., RIZMAN, Z. I., and ABIDIN, H. Z. 2018. Design an automatic temperature control system based on a picture controller for a smart ventilation fan. *Journal of Fundamental and Applied Sciences*. <https://doi.org/10.4314/jfas.v9i3s.60>.
- ELENA-DIANA, U., GHINEA, C., CA, M. R., and GAVRILESCU, M. (2020).

- Environmental Impacts of Polyvinyl Chloride (PVC) Production Process. ResearchGate. (PDF) Environmental Impacts of Polyvinyl Chloride (PVC) Production Process (researchgate.net).
- EYUPOGLU, Ş. (2020). Sustainable Plant-Based natural fibers. In Sustainable textiles (pp. 27–48). https://doi.org/10.1007/978-3-030-38541-5_2
- FRANCY, R. J., LLC, P. C. M. E., SOORI, P. K., and CHACKO, S. 2016. Intelligent In-House Mini-Automated Farming. *Journal of Advanced Agricultural Technologies*. <https://doi.org/10.18178/joaat.3.4.286-291>.
- FORD, M, A., and G. N. THRONE. 1974. Effects of atmospheric humidity on plant growth. *Annals of Botany*, 38(2), 441-452.
- GABRIEL, A. (2005). Microbial Quality of Chlorine Soaked Mung Bean Seeds and Sprouts. Department of Food Science and Nutrition, College of Home Economics, University of the Philippines, Diliman, ++++ Quezon City, Philippines. *Food Sci. Technol. Res.*, 11 (1), 95-100, 2005. https://www.jstage.jst.go.jp/article/fstr/11/1/11_1_95/_pdf
- GABRIEL, A. A., BERJA, M. C., ESTRADA, A. C., LÓPEZ, M. A., NERY, J. G. B., and VILLAFLORES, E. J. B. 2017. Microbiology of retail mung bean sprouts ended in public markets of the National Capital Region, Philippines. *Food Control*, 18(10), 1307–1313. <https://doi.org/10.1016/j.foodcont.2006.09.00>.
- GALAD, M. N. 2016. Design, Fabrication, and Performance Evaluation of a Mushroom Substrate Maker Machine. Central Luzon State University.
- GARCIA, J. 2018. Miniature Vertical Farming. Central Luzon State University.
- GARG, A., and R. BALODI. 2014. Recent trends in agriculture: vertical farming and organic farming. *Adv Plans Agric Res*, 1(4), 00023.
- GATBONTON, C., MOLON, R., AGATEP, C., LOLITA, and LOLI. 2022. Mungbean sprout production is in the CALABARZON region of the Philippines. *International Journal of Advanced Research*. 10. 904-911. 10.21474/IJAR01/14469.
- HELMY, H. (2016, October 19). Nutrient Film Technique (NFT) Hydroponic Monitoring System. JAICT (polines.ac.id).
- HOU, D., YOUSAF, L., XUE, Y., WU, X., WU, J., HU, X., FENG, N., and SHEN, Q. 2019. Mung Bean (*Vigna radiata* L.): Bioactive Polyphenols, Polysaccharides,

- Peptides, and Health Benefits. *Nutrients*, 11(6), 1238. <https://doi.org/10.3390/nu11061238>.
- JINNEMAN, K. C., TROST, P. A., HILL, W. E., WEAGANT, S. D., BRYANT, J. L., KAYSNER, C. A., & WEKELL, M. M. (1995). Comparison of Template Preparation Methods from Foods for Amplification of Escherichia coli O157 Shiga-Like Toxins Type I and II DNA by Multiplex Polymerase Chain Reaction. *Journal of Food Protection*, 58(7), 722–726. <https://doi.org/10.4315/0362-028x-58.7.722>
- KANG, M. H., PENGKIT, A., CHOI, K., JEON, S. W., CHOI, H. W., SHIN, D. M., CHOI, E. H., UHM, H. S., and PARK, G. 2015. Differential Inactivation of Fungal Spores in Water and on Seeds by Ozone and Arc Discharge Plasma. *PLOS ONE*, 10(9), e0139263. <https://doi.org/10.1371/journal.pone.0139263>.
- KIM, B. C., LIM, I., JEON, S. Y., KANG, M., & HA, J. M. (2021). Effects of Irrigation Conditions on Development of Mungbean (*Vigna radiata* L.) Sprouts. *Plant Breeding and Biotechnology*, 9(4), 310–317. <https://doi.org/10.9787/pbb.2021.9.4.310>
- LEARNING MODULE 2: FUNDAMENTALS OF ELECTRICITY. 2019. Cutler-Hammer. (101 BASIC SERIES). DOC 20190417-WA0001.
- LI H, ISSAKA Z, JIANG Y, TANG P, and CHEN C. 2019. Overview of emerging technologies in sprinkler irrigation to optimize crop production. *Int J Agric & Biol Eng*, 2019; 12(3): 1–9. <https://doi.org/10.25165/j.ijabe.20191203.4310>.
- METROPOLITAN CEBU WATER DISTRICT. 2009. MCWD technical standards and specifications for unplasticized polyvinyl chloride (upvc) pipes, ø 63 mm through ø 450 mm for potable water supply. SP01-02:2009 (Revisions of SP01-01:2003).
- NATIONAL MASTER PLUMBERS ASSOCIATION OF THE PHILIPPINES. 1999. Revised National Plumbing Code of the Philippines. RA NO. 1378.
- ONDER, S., CALISKAN, M. E., ONDER, D., and CALISKAN, S. 2005. Different irrigation methods and water stress effects on potato yield and yield components. *Agricultural Water Management*, 73(1), 73–86. <https://doi.org/10.1016/j.agwat.2004.09.023>.
- PANDISELVAM, R., MAYOOKHA, V., KOTHAKOTA, A., SHARMILA, L., RAMESH, K. P., BHARATHI, C., GOMATHY, K., and SRIKANTH, V. 2020. Impact of Ozone Treatment on Seed Germination – A Systematic Review. *Ozone-science & Engineering*, 42(4), 331–346 <https://doi.org/10.1080/01919512.2019.1673697>.

- PHILIPPINE AGRICULTURAL STANDARD. 2016. Determination of Irrigation Water Requirements. PAES 602:2016.
- PRETTY, J. 2020. New opportunities for the redesign of agricultural and food systems. *Agriculture and Human Values*. <https://doi.org/10.1007/s10460-020-10056-2>.
- RAJARAMAKRISHNA, R., and KAEWKHAO, J. 2019. Glass materials and their advanced applications. *KnE Social Sciences*. <https://doi.org/10.18502/kss.v3i18.4769>.
- RANAWAKE, A., & WDRJ, R. (2012). Effect of Water Stress on Growth and Yield of Mung Bean (*Vigna radiata* L). <https://www.semanticscholar.org/paper/Effect-of-Water-Stress-on-Growth-and-Yield-of-Mung-Ranawake-Wdrj/e37062b033d188844e1d40173f395c10a42bfb9b>
- RESH, H.M. 2012. *Hydroponic Food Production: A Definitive Guidebook for the Advanced Home Gardener and the Commercial Hydroponic Grower*; CRC Press: Boca Raton, FL, USA.
- RIYADH 11457. Kingdom of Saudi Arabia. *Brochure_Acrylic-Sheets.pdf* (rowadplastic.com).
- ROKADE, B. V., KAMBALE, P. S., JADHAV, J., and MADANE, K. T. 2015. Crop growth rate leaf area index as affected by sowing dates in linseed (*Linum usitatissimum* L.). *Advance Research Journal of Crop Improvement*, 6(1), 39–42. <https://doi.org/10.15740/has/arjci/6.1/39-42>.
- ROSA, C. C., DE ALENCAR, E. R., SOUZA, N. O. S., BASTOS, C. S., SUINAGA, F. A., & DE SOUZA FERREIRA, W. F. (2021). Physiological Quality of Corn Seeds Treated with Gaseous Ozone. *Ozone: Science and Engineering/Ozone: Science & Engineering*, 44(1), 117–126. <https://doi.org/10.1080/01919512.2021.1940836>
- ROWAD NATIONAL PLASTIC CO. LTD. 2016. *Acrylic Sheet*. Second Industrial City. P.O. Box 29452.
- SEMANANDA, N. P. K., WARD, J., and MYERS, B. 2018. A Semi-Systematic Review of Capillary Irrigation: The Benefits, Limitations, and Opportunities. *Horticulturae*, 4(3), 23. <https://doi.org/10.3390/horticulturae4030023>.
- SINAGA, A., MARETTA, G., DARMAWAN, A., MARPAUNG, D., KHUSNUL, R., and HANDAYANI, S. 2021. Community Empowerment through Mung Bean Sprouts Production Training Program. 1. 7-14.

- SÖYLEMEZ, G., BRASHEARS, M. M., SMITH, D. A., & CUPPETT, S. L. (2001). Microbial Quality of Alfalfa Seeds and Sprouts after a Chlorine Treatment and Packaging Modifications. *Journal of Food Science*, 66(1), 153–157. <https://doi.org/10.1111/j.1365-2621.2001.tb15598.x>
- YOUSEF. 2020. Twenty-three different types of metals and their properties & uses. The Engineering Post. (theengineerspost.com).
- YULIANTO, E., RESTIWIJAYA, M., SASMITA, E. R., ARIANTO, F., KINANDANA, A. W., and NUR, M. 2019. Power analysis of ozone generator for high capacity production. *Journal of Physics*, 1170, 012013. <https://doi.org/10.1088/1742-6596/1170/1/012013>.
- ZAR, K. T., AUNG, N., and HTWAY, N. 2020. Microcontroller Control Thermoele heating and Cooling System using TEC1-12706 of the Creative Comm International Journal of Trend in Scientific Research and Development (IJTSRD). www.ijtsrd.com e-ISSN: 2456 – 6470.