

**DESIGN, FABRICATION, AND PERFORMANCE EVALUATION
OF SPIRAL GRAVITY SEPARATOR
FOR SOYBEANS (*Glycine max* L.)**

**KRISTINE MAE T. BAGAPURO
LERAINE JOI R. CUSTODIO**

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)**

JUNE 2023

TABLE OF CONTENTS

	PAGE
LIST OF APPENDICES	ix
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 Study	1
Statement of the Problem	2
Objectives of the Study	3
Significance of the Study	3
Scope and Limitation of the Study	4
Time and Place of the Study	4
REVIEW OF RELATED LITERATURE	5
Soybean Production	5
Soybeans in Central Luzon State University	7
Soybean Threshing	8
Sorter Machine	10
Gravity Spiral Separator	11
Existing Soybeans Separators in the Philippines	16
Seed Quality from Gravity Spiral Separator	17
Static Separator and Rotary Separator for Impurities	18
Capacity of Separators for Soybeans	19
Spiral Diameter	20
Spiral Gravity Separator Good Seeds Loss	20
Harvest and Sun Drying of Soybeans	21
Soybean Cleaner Efficiency	21
Spiral Gravity Separator Seed Mechanical Damage	21
Performance Evaluation of Spiral Gravity Separator	22
Input Capacity	22
Cleaning Loss	22

Cleaning Efficiency	22
Mechanical Damaged Good Seeds	22
Specific Energy Requirement	23
Cost Analysis	23
METHODOLOGY	24
Conceptualization of the Study	24
Design Considerations	25
Process Flowchart	26
Flowchart of Activities	27
Design Machine Components	29
Spiral	30
Frame	31
Discharge Chute	31
Hopper	32
Transmission System	33
Final Design	34
Principle of Operation	35
Fabrication of the Machine	35
Test Material Preparation	36
Testing Instruments and Materials Used for Evaluation	37
Preliminary Testing of the Device	38
Final Testing and Evaluation	39
Data Gathered	39
Experimental Design and Layout	41
Determination of Performance Characteristics	42
Input Capacity	42
Cleaning Loss	42
Cleaning Efficiency	42
Mechanical Damage	43
Energy Consumption	43
Cost Analysis	44
Investment Cost	44
Fixed Cost	44
Depreciation	44
Interest on Investment	45
Insurance	45
Labor Cost	45

Electrical Cost	45
Repair and Maintenance	45
Total Operating Cost	46
Operating Cost	46
Cost of Use	46
Payback Period	46
Break-even Point	46
RESULTS AND DISCUSSION	48
Soybean Seed Sample Analysis	48
Machine Description and Specification	48
Problems Encountered and Modifications	50
Spiral	50
Discharge Chute	51
Transmission System	52
Frame	53
Hopper	54
Testing and Evaluation	55
Input Capacity	56
Cleaning Loss	57
Cleaning Efficiency	59
Mechanical Damage	60
Noise Level	62
Energy Consumption	63
Cost Analysis	64
SUMMARY, CONCLUSION AND RECOMMENDATIONS	67
Summary	67
Conclusion	68
Recommendation	70
LITERATURE CITED	71

LIST OF APPENDICES

TABLE		PAGE
1	List of tables	x
2	List of figures	xi
3	List of appendix tables	xiii
4	List of appendix figures	xiv

LIST OF TABLES

TABLE		PAGE
1	Components and specifications of machine elements	29
2	Instruments and materials used during the preliminary testing and performance evaluation	37
3	Experimental lay-out of the study	41
4	Specifications of the spiral gravity separator	48
5	Average input capacity of the separator as affected by the different speeds of the shaft, kg/hr	56
6	Average cleaning loss of the separator as affected by the different speeds of the shaft, %	58
7	Average cleaning efficiency of the separator as affected by the different speeds of the shaft, %	59
8	Average mechanical damage of the separator as affected by the different speeds of the shaft, %	61
9	Average noise level of the separator as affected by the different speeds of the shaft, db	62
10	Average specific energy consumption of the separator as affected by the different speeds of the shaft, kwh	63
11	Assumptions used on the cost analysis of the spiral gravity separator	64
12	Cost charges when operating the spiral gravity separator	65

LIST OF FIGURES

FIGURE		PAGE
1	Soybean threshing machine	8
2	Threshing chamber of soybean threshing	9
3	Vibrating soybean separating machine	11
4	Eightfold soy flight gravity spiral separator	11
5	Screw cone for dosing and even distribution to the eight spirals	13
6	Seed dams for slowing down the crop flow on the same level in all 8 flights	14
7	The end of the eightfold spiral: the adjustment is done by means of a gate valve	14
8	Impurities from gravity spiral separator based on spiral separator taifun-test using three spirals	15
9	Gravity-operated spiral separator	16
10	Soybean sorter	17
11	Static separator	19
12	Rotary separator	19
13	Conceptual framework of the study	25
14	Flow chart of activities in separating impurities from soybean seeds	27
15	Flow chart from the design to evaluation of the machine	28
16	Spiral	30
17	Frame	31
18	Discharge chutes for good seeds (A) and impurities (B)	32
19	Hopper	33

20	Transmission system	34
21	Designed spiral gravity separator for soybean	34
22	The spiral gravity separator for soybean	49
23	The four (4)-fold spiral of the machine	51
24	The discharge chute of the machine for impurities (A) and good seeds (B)	52
25	The transmission system of the machine	53
26	The frame of the machine	54
27	The hopper of the machine	55
28	Good seeds (A) impurities (B), and the mixture of the two (C) prior to separation process	56

LIST OF APPENDIX TABLES

APPENDIX TABLE		PAGE
1	Data gathered per replicate of the performance characteristics of spiral gravity separator at different levels of speed	80
2	Average data gathered of the performance characteristics of spiral gravity separator at different levels of speed	80
3	Analysis of variance of the input capacity and cleaning loss of spiral gravity separator at different levels of speed	80
4	Analysis of variance of the mechanical damage, cleaning efficiency and specific energy consumption of spiral gravity separator at different levels of speed	81
5	Analysis of variance of the noise level of spiral gravity separator at different levels of speed	81
6	Multiple comparison among means of the mechanical damaged and cleaning efficiency of spiral gravity separator affected by different levels of speed	82
7	Multiple comparison among means of the noise level of spiral gravity separator affected by different levels of speed	82
8	Optimum performance checklist for different levels of shaft speed	83

LIST OF APPENDIX FIGURES

APPENDIX FIGURE		PAGE
1	Wiring diagram	79
2	Measuring the soybean seed's angle of friction	84
3	Measuring the soybean seed's angle of repose	84
4	Measuring the materials for fabrication	85
5	Cutting the materials using a cut-off machine	85
6	Fabrication of the frame	86
7	Fabrication of the spiral	86
8	Manual sorting of the samples using bare hands	87
9	Measuring a sample of 900g for good seed	87
10	Measuring a sample of 100g for impurities	88
11	Mixing 1000g samples for each treatment	88
12	The loading operation	89
13	Determining the speed of shaft using tachometer	89
14	Determining the specific power consumption of the machine using volt-ampere meter	90
15	Determining noise using noise level meter	90
16	Impurities on the impurities discharge chute after the separation process	91
17	Weighing of impurities in the impurities discharge chute	91
18	Weighing of impurities in the good seeds discharge chute	92
19	Weighing of good seeds in the good seeds discharge chute	92

20	Weighing of good seeds in the impurities discharge chute	93
21	Spiral gravity separator perspective, top view, front view and sideview	94
22	Spiral design	95
23	Spiral gravity separator – hopper	96
24	Spiral gravity separator – frame isometric view, front view, and rear view	97
25	Spiral gravity separator – frame top view	98
26	Spiral gravity separator – transmission system	99

ABSTRACT

BAGAPURO, KRISTINE MAE T. and CUSTODIO, LERAINÉ JOI R., Department of Agricultural and Biosystems Engineering, College of Engineering, Central Luzon State University, Science City of Muñoz, Nueva Ecija, Philippines, **June 2023,** **DESIGN, FABRICATION, AND PERFORMANCE EVALUATION OF SPIRAL GRAVITY SEPARATOR FOR SOYBEANS (*Glycine max* L.)**

Adviser: ROLDAN T. QUITOS, M.Sc.

Soybean (*Glycine max* L.) is the fourth most important grain crop worldwide, after wheat, maize, and rice (Grassini, 2021). At present, the Philippines imports over 99 percent of its soybean requirements from the United States, while the remaining 1% is produced domestically; as estimated by the Department of Agriculture. Separating the soybeans from impurities is an essential post-harvest activity in soybean production.

In CLSU, the existing soybean cleaner lacks cleaning capability as it only removes lightweight impurities, while heavier impurities stay intact with the good seeds. The study was carried out to design, fabricate, and evaluate the performance of a spiral gravity separator for soybean in separating good seeds from impurities. In addition, this was conducted to determine the optimum shaft speed to facilitate the machine's separation performance and conduct a simple cost analysis. The developed soybean separation technology will decrease the labor time and effort, and increase the market value of soybeans.

The spiral gravity separator was designed and drawn based on the physical characteristics of the soybean seeds. It was fabricated based on the design plans and specifications with five (5) main components: hopper, discharge chute, spiral, frame, and transmission system.

Three shaft speeds were evaluated: 20 rpm, 25 rpm, and 30 rpm. One (1) kilogram of samples were used for the three treatments, each with three replications. Results showed that 30 rpm produced the highest cleaning efficiency (93.25%), highest input capacity (31.1 kg/hr), and lowest cleaning loss (1.43%), while 20 rpm made the least mechanical damage (0.83%).

Keywords: Soybean seeds; soybean cleaner; spiral gravity separator; impurities; cleaning efficiency

LITERATURE CITED

- Adekanye, T.A., Osakpamwan, A.B., & Osaivbie, I.E. (2016, June). Evaluation of a Soybean Threshing Machine. *ResearchGate*. Retrieved May 31, 2022, from https://www.researchgate.net/publication/329337266_Evaluation_of_a_Soybean_Threshing_Machine
- Adeyeye, O. A., Sadiku, E. R., Osholana, T. S., Reddy, A. B., Olayinka, A. O., Ndamase, A. S., Makgatho, G., Selvam, P., Perumal, A. B., Nambiar, R. B., Fasiku V. O., Ibrahim, I. D., & Areo, K. A. (2019, May 23). Construction and evaluation of soybeans thresher. *ACADEMIC JOURNALS*. Retrieved May 31, 2022, from <https://academicjournals.org/journal/AJAR/article-full-text-pdf/273853961061>
- Agcopra, J. S., & Piadozo, M. E. (2020, October 6). Cost and Price Competitiveness of Soybean Production in Isabela, Philippines. *Journal of Economics, Management & Agricultural Development*. Retrieved May 31, 2022, from <https://jemad.cem.uplb.edu.ph/articles/cost-and-price-competitiveness-of-soybean-production-in-isabela-philippines/>
- Akatuhurira, W., Tumutegyereize, P., Oluk, I., Baidhe, E., Kigozi, J., Mayanja, I., & Kivumbi, H. B. (2021). Development and performance evaluation of a Pedal Operated Seed Cleaner (POS-Cleaner). *SN Applied Sciences*, 3(6). Retrieved April 27, 2023, <https://doi.org/10.1007/s42452-021-04612-6>
- Akyürek Technology LTD. (n.d.). Spiral Separator - Akyurek Technology. AKYUREK TECHNOLOGY. Retrieved June 1, 2022, from <https://akyurekltd.com/en/Spiral-Separator-118s.html>
- Anwar, A., Taib, S., Salah, W. A., & Mokhzaini, A. (2008). Importance of Energy Efficiency: From the Perspective of Electrical Equipments. *ResearchGate*. https://www.researchgate.net/publication/235640818_Importance_of_Energy_Efficiency_From_the_Perspective_of_Electrical_Equipments
- Aradwad, P. P., Sinha, J. P., T, A. T. V., V., Yadav, R. S., & Samuel, D. V. K. (2018). Development of solar powered screen cleaner. *Indian Journal of Agricultural Sciences*, 88(12), 1914–1919. <https://doi.org/10.56093/ijas.v88i12.85447>
- Badole, S.L. and Bodhankar, S.L. (2013) Glycine max (Soybean) Treatment for Diabetes. Bioactive Food as Dietary Interventions for Diabetes
- Beesten, F. (2021, November 30). Gravity spiral separators for cleaning soybeans. Legumehub.Eu. Retrieved on June 1, 2022, from https://www.legumehub.eu/is_article/gravity-spiral-separators-for-cleaning-soybeans/

- Calderon, V. J. F., Aquino, R. M. G., Olinares, R. B., Batang Jr, E. F., Atalin, V. U., Manaligod, K., & de Guzman, S. (2018). Enhancing soybean productivity and local availability in Region 2 [Cagayan Valley, Philippines]. *AGRIS: International Information System for the Agricultural Science and Technology*. Retrieved June 1, 2022, from <https://agris.fao.org/agris-search/search.do?recordID=PH2019000570>
- Choe, K. J., Park, P. K., Cho, N. H., Cho, K. H., & Mun, Y. H. (1989). Effect on the cleaning of soybean and adzuki bean by helices width of spiral-type separator. *AGRIS: International Information System for the Agricultural Science and Technology*. Retrieved June 11, 2022, from <https://agris.fao.org/agris-search/search.do?recordID=KR8935723>
- DA Provides Inputs for Sustained Soybeans Production. (2020, June 10). Department of Agriculture. Retrieved May 31, 2022, from <https://www.sra.gov.ph/wp-content/uploads/2020/06/DA-News-6-10-2020-05.pdf>
- Desai, R. (2019). Spiral Grain Separator: A Post-Harvest Technology In Soybean Production. International Society of Extension Education. Retrieved June 1, 2022, from http://www.inseeworld.com/jsite/download/injee_v15/07-pg-7-50-54.pdf
- Desai, R., & Sajjan, P. (2019, April 24). Spiral grain separator: A post harvest technology in soybean production. *RESEARCH JOURNALS*. Retrieved June 6, 2022, from [http://researchjournal.co.in/online/AJHS/AJHS-14\(1\)/14_72-75_A.pdf](http://researchjournal.co.in/online/AJHS/AJHS-14(1)/14_72-75_A.pdf)
- Edomah, N. (2018). Economic Analysis. Elsevier. Retrieved June 7, 2022, from <https://www.sciencedirect.com/topics/earth-and-planetary-sciences/economic-analysis#:~:text=Economic%20analysis%20essentially%20entails%20the,welfare%20impact%20of%20a%20project.>
- Fayedibi, A. and Ajao, O.F. (2020). Design and Performance Evaluation of a Multi-tuber Peeling Machine, (2) 1, pp 55-71. <https://doi.org/10.3390/agriengineering2010004>
- Field, H. L., J. B. Solie. (2000). Equipment Efficiency and Capacity. Introduction to Agricultural Engineering Technology, pp. 118-128.
- Gagre, K.C., Bharud, R.W., and Karjule, A.P. (2014). Study of mechanical damage of soybean due to different threshing and processing methods by using sodium hypochlorite test. *American-Eurasian Journal of agricultural & Environmental Sciences* 14(6), 570-574.
- Galang, V. M. (2020, January 12). Soybean industry targeted for improved production, logistics — DoST. BusinessWorld Online. Retrieved May 31, 2022, from <https://www.bworldonline.com/editors-picks/2020/01/13/272880/soybean-industry-targeted-for-improved-production-logistics-dost/#:%7E:text=Mr.,P120%20million%20to%20P180%20million.>

- Gimžauskaitė, D., Aikas, M., & Tamošiūnas, A. (2022). Recent progress in thermal plasma gasification of liquid and solid wastes. *Academic Press eBooks*, 155–196. <https://doi.org/10.1016/b978-0-12-823532-4.00007-0>
- Grassini, P. and Specht S. (2021). Soybeans. *Crop Physiology Case Histories for Major Crops*
- Hancock, J.N., Swetnam, L. D., and Benson, F. J. (1991). Calculating Farm Machinery Field Capacities. *Agricultural Engineering Extension Publications*. 20. University of Kentucky, College of Agriculture Cooperative Extension Services. Volume V:1991, Pp 1-5. Retrieved June 6, 2022, from https://uknowledge.uky.edu/aen_reports/20
- Harmond, J., Klein, L., & Brandenburg, R. (1961). Seed cleaning and handling. NALDC. from <https://naldc.nal.usda.gov/catalog/CAT87208830>
- Hyfoma. (2018, March 6). Sorting - Safe Food Factory. Safe Food Factory. Retrieved May 31, 2022, from <https://www.safefoodfactory.com/en/knowledge/85-sorting/>
- Lantican, R. M. (2022, February 26). Soybean Production in Asia | Ricardo M. Lantican | Taylor & Francis Gr. Taylor & Francis. Retrieved June 1, 2022, from <https://www.taylorfrancis.com/chapters/edit/10.1201/9780429267932-197/soybean-production-asia-ricardo-lantican>
- Minimizing Mechanical Damage to Soybean Seed. (1984). IOWA STATE UNIVERSITY. Retrieved April 12, 2023, from <https://store.extension.iastate.edu/Product/Minimizing-Mechanical-Damage-to-Soybeans-PDF>
- Minimizing Mechanical Damage to Soybean Seed. (n.d.). Iowa State University. Retrieved April 26, 2023, from <https://store.extension.iastate.edu/Product /Minimizing-Mechanical-Damage-to-Soybeans-PDF>
- Moylan, S. (2020). Chapter 8: Machine Performance Evaluation. NIST. Retrieved June 6, 2022, from <https://www.nist.gov/publications/chapter-8-machine-performance-evaluation#:~:text=Machine%20performance%20evaluation%20is%20vital,to%20best%20use%20their%20resources.>
- Ocampo, K. R. (2020, February 27). PH farmers harvest 1st export-grade batch of edamame for Japan | Inquirer News. INQUIRER.net. Retrieved June 13, 2023, from <https://newsinfo.inquirer.net/1233971/ph-farmers-harvest-1st-export-grade-batch-of-edamame-for-japan>
- Open Spiral Separator. (n.d.). Profile Industries. https://www.profile-ind.com/wp-content/uploads/2019/08/Rotary_600.png

- Open Spiral Separator. (n.d.). Profile Industries. https://www.profile-ind.com/wp-content/uploads/2019/08/Single-Open-Spiral-Separator_600.png
- Potts, H., and Vaughan, C.E. (1977). Soybean Seed Processing. Proceedings of the Short Course for Seedsmen, 332. Retrieved March 10, 2023 from <https://scholarsjunction.msstate.edu/seedsmen-short-course/332>.
- Rapoza, A. and Fleming, G. (2002). Determination of a Sound Level for Railroad Horn Regulatory Compliance. Environmental Measurement and Modeling Division, DTS-34 Kendall Square Cambridge, MA 02142-1093. Retrieved June 13, 2023 from <https://rosap.ntl.bts.gov/view/dot/23182>
- Shepelev. (2020). Results of the Experimental Studies of Grain Cleaning with an Air-Spiral Separator. E3S Web of Conferences. Retrieved December 28, 2022, from https://www.e3s-conferences.org/articles/e3sconf/pdf/2020/70/e3sconf_itse2020_10002.pdf
- Soybean Sorter. (n.d.). GOVPH. Retrieved October 31, 2022, from <https://www.philmech.gov.ph/?page=technology-postharvest&techCategory=soybean>
- Spiral Separators vs. Rotary Sorters - Profile Industries. (2020, June 12). Profile Industries. Retrieved March 16, 2023, from <https://www.profile-ind.com/spiral-separators-vs-rotary-sorters/>
- Subaba, J. M. (2017). Fully-mechanized operations, vital to the rise of soybean industry. Philippine Center for Postharvest Development and Mechanization. Retrieved June 1, 2022, from <https://www.philmech.gov.ph/assets/publication/Newsletter/2017/Newsletter%203rd%20Quarter%202017.pdf>
- Subaba, J. M. (2017). Newsletter 3rd Quarter 2017. PHILMECH. Retrieved December 28, 2022, from <https://www.philmech.gov.ph/assets/publication/Newsletter/2017/Newsletter%203rd%20Quarter%202017.pdf>
- Taculao, P. B. (2020, April 17). Nueva Ecija cooperative promotes soybean production while creating livelihood opportunities for farmers. Agriculture Monthly. Retrieved May 31, 2022, from <https://www.agriculture.com.ph/2020/04/20/nueva-ecija-cooperative-promotes-soybean-production-while-creating-livelihood-opportunities-for-farmers/>
- Wanitchang, J., Kantakam, S., & Pomohan, S. (1998). Development of spiral separator for grain. AGRIS: International Information System for the Agricultural Science and

Technology. Retrieved June 10, 2022, from <https://agris.fao.org/agris-search/search.do?recordID=TH2002000875>