

FACULTY OF ENGINEERING AND TECHNOLOGY
DEPARTMENT OF CHEMICAL AND PROCESS ENGINEERING
**DEVELOPMENT OF A SMALL-SCALE MULTI-FRUIT JUICE PROCESSING
LINE**

FINAL YEAR PROJECT REPORT

BY

S/N	NAME	REG. NO	CONTACT
1	NAMUWONGE LUKIYA	BU/UG/2018/2398	0782608210
2	ATIKU IVAN	BU/UG/2018/4133	0789293608
3	NAVUGA BETTY	BU/UG/2018/2418	0703380718
4	AKANDWANAHU ANTONY	BU/UG/2018/1883	0759046665
5	NABWAMI ETHEL JOYCE	BU/UG/2018/2346	0789222108
6	MAKOBA WINFREY NABUMONI	BU/UG/2018/2269	0753173030
7	NABIRYE SARAH	BU/UP/2018/2757	0756723469
8	SEMPAGAMA SULAIMAN	BU/UP/2018/4000	0701534288

SUPERVISORS

S/N	NAME
1	MR. SSERUMAGA PAUL
2	MR. ASHABAHEBWA AMBROSE
3	MR. KILAMA GEORGE

*A final year project report submitted to the Department of chemical and process
Engineering as a partial fulfillment of the requirements for the award of a Bachelor of
Science in Agro processing Engineering*

ABSTRACT

Fruits are among the most important horticultural products from Uganda. Fruits are used as food which has high content of vitamin C, treat diseases most fruit juices act as antioxidants. Fruit pulp is used industrially in making juices, concentrates, flavors, yogurt yet the fruit industry byproducts find application in seed-oil extraction, garden-fertilizer manufacture.

Most fruits are not consumed as a table-fruits but find market value in their processing. Processing of fruits is still a minor activity in Uganda due to lack of appropriate technology and funds despite its high economic potential in the country. Small and medium scale fruit processing industries mostly use unsafe and laborious processes that do not offer a long shelf life to the fruit juice yet time consuming, compromise product quality due to non-aseptic operations that expose products to contamination. The study is therefore intended to design a small-scale juice processing line which simultaneously separates the pulp from fruit fibers, mixes pulp with water, sugar and other required additives, pasteurizes this mixture and packages the product with minimum manual handling to address the above challenges. Implementation of the small-scale juice processing line involved putting together of different components of the line basing on the physical, mechanical and especially chemical properties of the fruits and fruit products. The components of the juice processing line include; the fruit pulper, 3 in-process tanks (i.e., the pulp receiver tank, mixing tank, and overhead tank), pasteurizer, filling machine, and bottle capping machine. From the designs, the fruit pulper operates at a speed of 0.5 tonnes per hour and the pasteurizer operates for 1 hour for 100litres in mango juice production, bottle filling machine able to fill upto 50 bottles per minute. Total maximum transmitted power requirement of 19.7HP. After fabrication and assembly, the performance and economic analysis of the juice processing line were performed in which the following results were obtained; Daily production in 8 hours = 200litres, annual power expenditure = UGX 3300000, Total cost per unit = UGX 824,000, Total cost per year = UGX 272,130,000, Total machine cost = UGX 24,680,000, Return on Investment = 24.5% and pay back-period of 4.1 years. Owing to the performance and economic analysis of the juice processing line, it achieves all its design purposes hence it is recommended for commercialization and adoption by the target groups.

DECLARATION

We the group members of a small-scale multi fruit production line declare to the best of our knowledge that all the material portrayed in this project report is original and has never been submitted for award of any Degree, diploma, or certificate in any university or institution of higher learning.

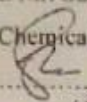
NAME	Signature	DATE
NAMUWONGE LUKIYA		14/01/2023
NAVUGA BETTY		14/01/2023
AKANDWANHO ANTONY		14/01/2023
ATIKU IVAN		14/01/2023
NABWAMI ETHEL JOYCE		14/01/2023
MAKOBA WINFREY NABUMONI		14/01/2023
SEMPAGAMA SULAIMAN		14/01/2023
NABIRYE SARAH		14/01/2023

APPROVAL

This is to certify that the project report under the title "DEVELOPMENT OF A SMALL SCALE MULTI-FRUIT PROCESSING LINE" has been done under the guidance and supervision of the supervisors below and is now ready for examination.

SUPERVISOR: Mr. SSERUMAGA PAUL

Department of Chemical and Process Engineering

Signature: 

Date: 10/5/2023

ACKNOWLEDGMENT

We are very grateful to the Almighty ALLAH for making us reach this far. We would like to express our profound gratitude to our main supervisor Mr. Sserumaga Paul, and co-supervisors Mr. Kilama George and Mr Ashabahebwa Ambrose for their constructive guidance that has enabled us to complete our project successfully.

Our special thanks go to the department of Chemical and Process Engineering of Busitema University for the efforts towards this project.

We also thank BEARD organization for the donations of juice processing equipment made to Busitema University that made our technical project feasible especially during financial crisis.

More thanks go to workshop technicians for their endless help towards the accomplishment of our project.

Lastly but not least we also thank our guardians for continuous support lavished in our education.

Table of Contents

ABSTRACT.....	i
DECLARATION	Error! Bookmark not defined.
APPROVAL	Error! Bookmark not defined.
ACKNOWLEDGMENT.....	iv
Table of Contents.....	v
CHAPTER ONE: INTRODUCTION.....	1
1.1 Background	1
1.2 Problem statement.....	1
1.3 Objectives.....	2
1.3.1 Main objective	2
1.3.2 Specific objectives.....	2
1.4 Justification	2
1.5 Significance of the study	2
1.6 Scope of the study	2
1.7 Conceptual design	3
CHAPTER TWO: LITERATURE REVIEW	4
2.1 Overview of fruits	4
2.2 Overview of the multifruit pulping section.....	5
2.2.1 Considerations for choice of method of Fruit pulp extraction;	5
2.2.2 Methods of fruit pulp extraction.....	6
2.2.3 Mechanical fruit pulping techniques.	6
2.2.4 Advantages of Mechanical fruit pulping technologies.	7
2.2.5 The existing mechanical pulping techniques include the following.....	7
2.2.6 Unit Operations involved in mechanical fruit pulp extraction.	8
2.2.8 Uses of fruit pulp and wastes from pulping unit operations.....	9

2.3 An overview of the jacketed kettle and the buffer tanks	9
2.3.1 Buffer tanks	9
2.3.2 The jacketed kettle.....	10
2.3.3 Types of jacketed kettles	10
2.3.4 Operation of kettles	10
2.3.5 Thermal processing.....	11
2.3.6 The agitation in the buffer tanks and jacketed kettle.....	12
2.3.7 The control system for the kettle	13
2.4 Overview of bottle filling.....	14
2.4.1 The bottle filler	14
2.4.2 Bottle filling Control systems.....	14
2.4.2.1 Piston cylinder	14
2.4.2.2 Arduino filling system.....	15
2.4.2.3 PLC Filling System	15
2.5 AN OVERVIEW ON POWER.....	20
2.6 AC Electrical power supply system	20
2.6.1 The three-phase supply	21
2.6.2 Ways of connecting loads.....	22
2.6.3 Power in three phase system.....	23
2.6.4 Methods of starting induction motors.....	23
2.6.5 Components and devices for AC electrical supply system.....	25
2.6.6 Electric heating element	26
2.7 CLEANING IN PLACE FOR THE JUICE PROCESSING LINE.....	27
2.8 PLUMBING SECTION OVERVIEW (BY LUKIYA AND ATIKU).....	30
2.8.1 Piping system.....	30
2.8.1.2 Mechanical Properties of Pipe Materials.....	31
2.8.1.4 Pipe Grades.....	32

2.8.2 Pump and Pump types	33
2.8.2.2 Pump Comparison: Centrifugal vs Positive Displacement.....	36
2.8.2.3 Priming a pump	36
2.9 AESTHETIC AND ERGONOMICS SECTION OVERVIEW.....	37
2.9.1 Aesthetic	37
2.9.2 ERGONOMICS.....	38
CHAPTER THREE: METHODOLOGY AND MATERIALS.....	40
3.1 conceptualization of juice process line.....	40
3.1.2 Operational principle of the juice process line	41
3.2 Specific objective one: Design of the different material handling components	43
3.2.1 design consideration	43
3.2.2 The slicing table.....	44
3.2.3 the pulper frame and hopper improvement.....	51
3.2.4 design of the tanks	51
3.3 Specific objective two: sizing of juice pump piping system and electrical system	52
3.3.1 sizing and selection of the piping system.	52
3.3.1.1 Pipe sizing.....	52
3.3.1.2 pump sizing.....	52
a) Determining the Total Head.....	53
3.3.2 Pipe selection.....	54
3.4 Specific objective three: fabrication of the designed process line components.	54
3.4.1 selection of the materials	54
3.4.2 fabrication methods	54
3.4.3 Tools and equipment	55
3.5 Specific objective four: testing the performance of the process line	55
3.5.1 testing the performance of the process line	55
3.6 Specific objective five: economic evaluation of the constructed process line.....	55

CHAPTER FOUR: RESULTS AND DISCUSSION	58
4.1 RESULTS.....	58
4.1.1. The slicing table.....	58
4.1.2 pulper frame and hopper improvement	59
4.1.3 construction of tanks.....	61
4.1.4 construction of the tower	64
4.1.5 Water bath construction.....	69
4.2. Specific objective two: sizing of juice pump piping system and electrical system	70
4.2.1 sizing and selection of the piping system.	70
4.1.4 Packaging and product branding section	74
4.3 fabrication and assembly of the prototypes	76
4.3.1 material selection	77
4.3.2 Fabrication assembly of the components of the individual components.....	78
4.4 testing of the process line	79
4.5. Economical evaluation results.....	82
CHAPTER FIVE: CONCLUSION, EXPERIENCE, CHALLENGE AND RECOMMENDATION.	85
5.1 conclusion.....	85
5.2 Experiences	85
5.3 challenges	85
5.4 recommendations.	86
CHAPTER SIX: INDIVIDUAL CHAPTER SECTION	87
6.1 Individual report chapter by NAMUWONGE LUKIYA, BU/UG/2018/2398	87
6.2 ATIKU IVAN	92
6.3 NABIRYE SARAH.....	93
6.4 NAVUGA BETTY BU/UG/2018/2418.....	94
6.5 AKANDWANAHO ANTONY	96

6.6 SEMPAGAMA SULAIMAN	99
6.7 MAKOPA WINFREY	100
6.8 NABWAMI ETHEL JOYCE.....	100
REFERENCES	102
APPENDIX.....	112

LIST OF TABLES

Table 2- 1 shows the characteristics of PP bottles and the differences between EBM and ISBM.....	19
Table 2- 2 shows Different appliances diversity factors Voltage	21
Table 2- 3 shows Comparison of DOL and star-delta starter (Point, Singhal, and Education 2017)	24
Table 2- 4 shows Comparison between centrifugal pumps and positive displacement pumps	36
Table 4- 1 shows pump specification used on the process line	74
Table 4- 2 shows materials that were selected for the construction of different components	77
Table 4- 3 shows tools used for various activities during construction and assembly of different equipment	78
Table 4- 4 shows temperatures and pasteurization time	80
Table 4- 5 shows technical parameters of the filling machine.....	81
Table 4- 6 shows total fixed costs.....	82
Table 4- 7shows daily and annual operating expenses	83
Table 6- 1 shows a brief description of power consumption of those machines in the line	88
Table 6- 2 shows the project cash outflows	95
Table 6- 3 shows the projects total fixed costs	99

LIST OF FIGURES

Figure 1- 1: shows A proposed fruit processing pilot line.....	3
Figure 2- 1 showing the Arduino Uno	15
Source (Salam, 2020) Figure 2- 2: Schematic diagram of a typical AC power system	21
Figure 2- 3: interaction of the three phase in a magnetic field	22
Figure 2- 4: sinusoidal wave of line voltage at 120degree	22
Figure 3- 1 shows the conceptual diagram of the juice process line	40
Figure 3- 2 :shows the material flow diagram	41
Figure 3- 3:shows the variation of the Lower back load with the load position.....	47
Figure 3- 4: shows the Criteria for optimal, acceptable working heights in industrial assembly work.	49
Figure 3- 5: shows Elbow and Shoulder positions.....	50
Figure 3- 6: Shoulder-to-shoulder length to estimate the length of the table	50
Figure 4- 1: 3D of the assembled slicing table	59
Figure 4- 2 shows rubber cautions to absorb vibrations	60
Figure 4- 3:shows platform for the pulper	60
Figure 4- 4 shows the modified pulper hopper	60
Figure 4- 5 shows the pulper stares.....	61
Figure 4- 6 shows the distances on the platform and where the reinforcements were placed .68	
Figure 4- 7 shows the distribution of the distances on each pair of legs on the longer side of the raised platform	69
Figure 4- 8 shows the product logo.....	74
Figure 4- 9 shows the Product label for mango juice	75
Figure 4- 10 shows the Product label for pine apple juice.....	75
Figure 6- 1: shows members working on the slicing table	112
Figure 6- 4 shows the assembled process line	112
Figure 6- 2 shows a member welding the raised platform flame.....	112
Figure 6- 3 shows the finished product.....	112

Figure 6- 5 shows a member weighing a mango	112
Figure 6- 6 shows a member marking out	112
Figure 6- 7 shows a member cutting out circles	113
Figure 6- 8 shows a member cutting a section.....	113
Figure 6- 9 shows a member making a cone for the mixing tank.....	113
Figure 6- 10 shows a member grinding the table.....	113

CHAPTER ONE: INTRODUCTION

1.1 Background

The agricultural sector has been the backbone of the Uganda's economy for decades, employing over 80 percent of the rural population and about 64.3 percent of the working population (UBOS, 2020). Uganda is the second largest fresh fruit producer after Nigeria in Sub-Saharan Africa with about 900,000 ha and 5.8 million tons of exports in a year (Ambrose Gahene, 2021).

The country is appropriate and has rich potential to produce passion fruits, guavas, mangoes, citrus, pineapples, tomatoes and a host of other fruits and vegetables. The fertile soils and conducive climate guarantee fruit and vegetable production throughout the year. Despite this great production potential, the processing of fruits and vegetables is small and is mainly restricted to extraction of juice, drying, bottling and labelling (Uganda Bureau of Statistics (UBOS), n.d.). Due to the large amounts of fruits that are harvested during the fruit harvesting season, there was need to utilize the available unutilized energy to process and package them in order to increase their shelf life and reduce of the postharvest losses.

1.2 Problem statement

In Uganda up to 40% of the Fruit and vegetable goes to waste especially along the supply chain (Background, 2020). The production yield and supply of fresh fruits is usually high during the harvest season of the year and always very low during the rest of the year. Due to the perishable nature, the farmers record abundant wastage during the production season and extreme scarcity during the off season (Becker et al., 2015a). Consequently, farmers are forced to sell their fruits at very low prices therefore, the monetary value obtained is not proportional to their input. Processing the fruit into the form that can easily be stored, preserved, packaged, transported or consumed is crucial to having the product all the year round. This can be achieved by developing a small-scale field-based multi-fruit processing line of 50 liters per hour capacity that can effectively extract pulp from fruits, pasteurize and package the product. This will reduce post-harvest losses of fruits and thus ensure stable supply during off-seasons. This study will also improve the concept of cottage industry.

REFERENCES

- An Overview of Steam-Jacketed Kettles - Foodservice Equipment & Supplies.* (n.d.).
<https://fesmag.com/products/guide/cooking-equipment/steam-jacketed-kettles/11170-when-to-replace-steam-jacketed-kettles>
- Berg, C. (2021). The Complete Guide to Industrial Automation. In *Clarify*.
<https://www.clarify.io/learn/industrial-automation>
- Lebaka, V. R., Wee, Y. J., Ye, W., & Korivi, M. (2021). Nutritional composition and bioactive compounds in three different parts of mango fruit. *International Journal of Environmental Research and Public Health*, 18(2), 1–20.
<https://doi.org/10.3390/ijerph18020741>
- Pankaj, S. K. (2015). Thermal processing of food. *Advances in Food Biotechnology*, 681–692. <https://doi.org/10.1002/9781118864463.ch40>
- Ramesh, K. V., Paul, V., & Pandey, R. (2021). Dynamics of mineral nutrients in tomato (*Solanum lycopersicum* L.) fruits during ripening: part I—on the plant. *Plant Physiology Reports*, 26(1), 23–37. <https://doi.org/10.1007/s40502-020-00546-0>
- Solenoid Valves Introduction.* (n.d.).
- Stoforos, N. G. (2015). Thermal processing. *Handbook of Food Processing: Food Preservation*, 27–56. <https://doi.org/10.1201/b19397>
- Viganó, J., & Martínez, J. (2015). Trends for the Application of Passion Fruit Industrial By-products: A Review on the Chemical Composition and Extraction Techniques of Phytochemicals. In *Food and Public Health* (Vol. 5, Issue 5, pp. 164–173).
<https://doi.org/10.5923/j.fph.20150505.03>
- R.S. Khurmi, J.K. Gupta A Textbook for the Students of B.E. / B.Tech.,U.P.S.C. (Engg. Services); Section ‘B’ of A.M.I.E. (I), Fourteenth Edition, 2005.
- A. D. Eyeowa, B. S. Adesina, P. D. Diabana and O. A. Tanimola, (2017). Design, Fabrication and Testing of a Manual Juice Extractor for Small Scale Applications. Article no.CJAST.33360

Abdulkadir Baba Hassan, Matthew Sunday Abolarin, Olufemi Ayodeji Olugboji and Ikechukwu Celestine Ugwuoke, Department of Mechanical Engineering, Federal University of Technology

Faires, V.M. (1969). *Design of Machine Elements* (4thed.). New York: MacMillan Company.
Flordeliza I. Mercado, Teresito g. Aguinaldo, Helen f. Gavino, Victorino t. Taylan, (2017) medium-scale multi-juice extractor for food processing, *International Journal of Advances in Science Engineering and Technology*, ISSN: 2321-

ASME. 1995. *Design of Transmission Shafting*. American Society of Mechanical Engineering, New York, NY, USA.

José I. Reyes-De-Corcuera, R. M. G.-S., 2016. *Processing of Fruit and*. 1Department of Food Science and Technology, University of Georgia, Athens, 2Food Science and Human Nutrition Department, University of Florida, Gainesville, 3Department of Food Science and Technology, The Ohio State University, Columbus,3Department of Foo, Volume 15, pp. page 1-2.

Mushtaq, Muhammad. (2017). *Extraction of Fruit Juice: An Overview*. 10.1016/B978-0-12-802230-6.00008-4.

Abdelgadir, A., & Abdelrahman, A. (2017). *Sudan University of Science and Technology College of Graduate Studies. April*.

Afolabi, D. I., & Elijah, O. (2017a). *Development of a Belt Conveyor for Small Scale Industry*. 3(8), 70–76.

Afolabi, D. I., & Elijah, O. (2017b). *Development of a Belt Conveyor for Small Scale Industry*. 3(8), 70–76.

An Integrated approach for Mangosolid waste utilization. (n.d.).

Article_ Special Report_ The world is looking beyond India for supplies of mango purée _ IHS Markit. (n.d.).

Asiri, S. (2016). *Design and Implementation of Differential Agitators to Maximize Agitating Performance*. *International Journal of Mechanics and Applications*, November 2012. <https://doi.org/10.5923/j.mechanics.20120206.01>

- Baladhandabany, D., Gowtham, S., Kowsikkumar, T., Gomathi, P., & Vijayasalini, P. (2015). PLC based automatic liquid filling system. *International Journal of Computer Science and Mobile Computing*, 4(3), 684–692.
- Barroso, F. L. (2003). *Geared Motors – Principles , Struture and Applications*. June, 129–154.
- Becker, F. G., Cleary, M., Team, R. M., Holtermann, H., The, D., Agenda, N., Science, P., Sk, S. K., Hinnebusch, R., Hinnebusch A, R., Rabinovich, I., Olmert, Y., Uld, D. Q. G. L. Q., Ri, W. K. H. U., Lq, V., Frxqw, W. K. H., Zklfk, E., Edvhg, L. V, Wkh, R. Q., ... فاطمی, ح. (2015a). No 主観的健康感を中心とした在宅高齢者における 健康関連指標に関する共分散構造分析Title. *Syria Studies*, 7(1), 37–72.
- Becker, F. G., Cleary, M., Team, R. M., Holtermann, H., The, D., Agenda, N., Science, P., Sk, S. K., Hinnebusch, R., Hinnebusch A, R., Rabinovich, I., Olmert, Y., Uld, D. Q. G. L. Q., Ri, W. K. H. U., Lq, V., Frxqw, W. K. H., Zklfk, E., Edvhg, L. V, Wkh, R. Q., ... فاطمی, ح. (2015b). No 主観的健康感を中心とした在宅高齢者における 健康関連指標に関する共分散構造分析Title. In *Syria Studies* (Vol. 7, Issue 1).
- Bhatia, A. (n.d.). Design and Sizing of Solar Photovoltaic Systems. *Continuing Education and Development, Inc*, 877, 2–125.
- Bozorgmehrian, M. (2013). *SIZING AND SELECTION CRITERIA FOR SUBSEA MULTIPHASE PUMPS*. May.
- Brinkworth, B. J. (1974). Solar energy. *Nature*, 249(5459), 726–729. <https://doi.org/10.1038/249726a0>
- cb9412en. (n.d.).
- Choosing a Hot-Fill-Hold Process for Acidified Foods*. (2014). 2014.
- Collins, K. (n.d.). *PLC Programming for Industrial Automation*.
- Conditions, C. (2020). *Optimal Design of a Hybrid PV Solar / Micro-Hydro / Diesel / Battery Energy System for a Remote Rural Village under Tropical*.
- Corporation, D. (1800). *RTD , Resistance Temperature Detector*. 3–5.
- Drives, F. B. (n.d.). *18 18.1*.

ECOTHERM Electric Water Heaters S.A. (n.d.). Stainless Steel Electric Water Heaters. Karlringerstrasse 8 4081 Hartkirchen,. Austria, 0–10.

Eleceng. (2010). *Motor Sizing Principles*. 1–12.

Emenike, O. I., Christopher, A. O., & Sepiribo, B. L. (2020). Design and Construction of Multi-Mode Induction Motor Starter. *Journal of Newviews in Engineering and Technology (JNET)*, 2(2), 52–59.

Extraction of antioxidants from mango seed kernel_ Optimization assisted by microwave - ScienceDirect. (n.d.).

Food Technology-I_ Lesson 13. EQUIPMENTS AND METHODS OF EXTRACTION, CLARIFICATION AND PRESERVATION. (n.d.).

FRUIT JUICE PROCESSING. (n.d.).

Fruit pulp extraction machine for stone fruits and berries. (n.d.).

Gautam, A., Dhiman, A. K., Attri, S., & Kathuria, D. (2020). Optimization of pulping method for extraction of pulp from ripe persimmon (*Diospyros kaki* l.) and its stability during storage. *Journal of Applied and Natural Science*, 12(4), 618–627. <https://doi.org/10.31018/jans.v12i4.2430>

Gedzurs, A., Straume, I., Galins, A., & Laizans, A. (2016). Low-voltage circuit breaker selectivity studies. *Engineering for Rural Development, 2016-Janua*, 612–617.

Geofrey Bakkabulindi, Al-Mas Sendegeya, Izael Pereira Da Silva, & Eriabu Lugujo. (2010). *Technical, Economic and Sustainability Considerations of a Solar PV Mini-Grid as a Tool for Rural Electrification in Uganda. August 2014*.

Griffin, P. W. (2009). *methods for determining agitator mixing.pdf*.

Hariyadi, P. (2000). Hot - Fill Processing. *FOODREVIEW International | VOL. I/NO. 1, I(1)*.

Ibarz, A., Ramos, A. M., Puig-Bargués, J., & Barbosa-Cánovas, G. V. (1998). Heating rates of peach juice in an agitated jacketed vessel. *Journal of Food Science*, 63(6), 1045–1048. <https://doi.org/10.1111/j.1365-2621.1998.tb15851.x>

Ismail. (2015). □□□□□□□□ □□ □□□□□□□□ □□□□□□□□ *Sudan university of Science and Technology College of Graduate Studies. September, 1–88*.

- Itajiba, J. A., Varnier, C. A. C., Cabral, S. H. L., Stefenon, S. F., Leithardt, V. R. Q., Ovejero, R. G., Nied, A., & Yow, K. C. (2021). Experimental comparison of preferential vs. Common delta connections for the star-delta starting of induction motors. *Energies*, *14*(5). <https://doi.org/10.3390/en14051318>
- Jack, H. (2008). *with PLCs (Version.*
- Jacketed Vessels Manufacturer _ Scientific Glass Services.* (n.d.).
- Jirout, T., & Rieger, F. (2011). *Impeller design for mixing of suspensions.*
- John Frank Pietranski, P.E., Ph. D. (2012). *Steam Handbook.*
- Johnson, M. L. (2018a). *The Effect of Hot Fill and Hold Processing on the Performance of Multilayer Packaging Films.*
- Johnson, M. L. (2018b). *The Effect of Hot Fill and Hold Processing on the Performance of Multilayer Packaging Films.*
- Journal, H., & Chemistry, O. F. I. (2011). *PROFIT OPTIMIZATION OF BATCH-CONTINUOUS PRODUCTION SYSTEMS.* *39*(3), 353–358.
- Journal, I., & Gracioli, R. (2017a). *Geometry and Architecture of Mixing Agitator – A Review Geometry and Architecture of Mixing Agitator – A Review.*
- Journal, I., & Gracioli, R. (2017b). *Geometry and Architecture of Mixing Agitator – A Review Geometry and Architecture of Mixing Agitator – A Review.*
- K., V. (2017). An Overview of Factors Affecting the Performance of Solar PV Systems. *Energy Scan, February*, 2–8.
- Kasztenny, B., & Rostron, J. (2018). Circuit breaker ratings - A primer for protection engineers. *71st Annual Conference for Protective Relay Engineers, CPRE 2018, 2018-Janua(dc)*, 1–13. <https://doi.org/10.1109/CPRE.2018.8349782>
- Katutsi, V., Kaddu, M., Migisha, A. G., Rubanda, M. E., & Adaramola, M. S. (2021). Overview of hydropower resources and development in Uganda. *AIMS Energy*, *9*(6), 1299–1320. <https://doi.org/10.3934/ENERGY.2021060>
- Krauter, S. C. W. (2006). Solar electric power generation: Modeling of optical and thermal performance, electrical yield, energy balance, effect on reduction of greenhouse gas emissions. In *Solar Electric Power Generation: Modeling of Optical and Thermal*

Performance, Electrical Yield, Energy Balance, Effect on Reduction of Greenhouse Gas Emissions. <https://doi.org/10.1007/978-3-540-31346-5>

Krishna, H., & Singh, S. K. (2007). Biotechnological advances in mango (*Mangifera indica* L.) and their future implication in crop improvement - A review. In *Biotechnology Advances* (Vol. 25, Issue 3, pp. 223–243). <https://doi.org/10.1016/j.biotechadv.2007.01.001>

Król, R. (2016). *Lech Gładysiewicz Witold Kawalec Selection of carry idlers spacing of belt conveyor taking into account random stream of transported bulk material Dobór rozstawu krążników górnych przenośnika taśmowego z uwzględnieniem losowo zmiennej strugi urobku* *. 18(1), 32–37.

Kurt, S., & Dayan, E. T. (2014). *Belt Conveyor Design and Analysis*. 55(11), 52–55.

Lamo, C., Shahi, N. C., Singh, A., & Singh, A. K. (2019). Pasteurization of guava juice using induction pasteurizer and optimization of process parameters. *Lwt*, 112, 108253. <https://doi.org/10.1016/j.lwt.2019.108253>

Lele, S. (n.d.). *Agitators / Mixers for Vessels*. 20.

Ma, Z., & Dayton, O. (2014). *IMPELLER POWER DRAW IMPELLER POWER DRAW*.

Manrique, V., García, L., & Alfonso, J. (2014). Experimental evaluation of energy efficiency in a gas-heated self-contained steam jacketed kettle. *IOP Conference Series: Materials Science and Engineering*, 59(1). <https://doi.org/10.1088/1757-899X/59/1/012009>

Marwa, V. (n.d.). *Design a VAT milk pasteurizer in Tanzania*. 1–10.

Mayungbe, O. (2017). Development of a Belt Conveyor for Small Scale Industry. *Scientific Review*, 3(8), 70–76.

Morton, J. (1987) *Passionfruit*. In Morton, J., Ed., *Fruits of Warm Climates, Florida Flair Book, Miami*, 320-328. - *References - Scientific Research Publishing*. (n.d.).

N E Nteka and K E Kanyarusoke. (2019a). *IOP Conference Series : Earth and Environmental Science Design and Performance of a 1 . 5 axis Sun tracking Concentrated Photovoltaic System Design and Performance of a 1 . 5 axis Sun tracking Concentrated Photovoltaic System*. <https://doi.org/10.1088/1755-1315/354/1/012008>

N E Nteka and K E Kanyarusoke. (2019b). *IOP Conference Series : Earth and Environmental Science Design and Performance of a 1 . 5 axis Sun tracking Concentrated Photovoltaic*

System Design and Performance of a 1 . 5 axis Sun tracking Concentrated Photovoltaic System. <https://doi.org/10.1088/1755-1315/354/1/012008>

Naga, K., Ananth, S., Rakesh, V., & Visweswarao, P. K. (2013a). Design and Selecting the Proper Conveyor-Belt. *International Journal of Advanced Engineering Technology E, IV(Ii)*, 43–49.

Naga, K., Ananth, S., Rakesh, V., & Visweswarao, P. K. (2013b). Design and Selecting the Proper Conveyor-Belt. *International Journal of Advanced Engineering Technology E, IV(Ii)*, 43–49.

Nainani, S., Rupawate, A., Sayyed, S., Poojary, S., Bodhale, V., & Students, U. G. (1606). Automatic Bottle Filling System Using Arduino Uno. *International Research Journal of Modernization in Engineering Technology and Science Wwww.Irjmets.Com @International Research Journal of Modernization in Engineering, 04*, 2582–5208.

Ngwenyi, E. A. (2020). *Modelling and Evaluation of the Overall Heating and Cooling Performance of Jacketed Reactor.* May.

NMIC. (2011). *Design Data _ WBDG - Whole Building Design Guide.*

Nwaokobia, K., Rachel, O., Nwaokobia, K., Ogoru, R. O., & Idibie, C. A. (2018). Extraction of edible oil from the pulp of *Persea americana* (Mill) using cold process method Sulphonation of synthetic rubber as an alternative membrane for proton exchange membrane fuel cell View project Journals View project Extraction of edible oil from the pulp of *Persea americana* (Mill) using cold process method. In *World News of Natural Sciences* (Vol. 17). www.worldnewsnaturalsciences.com

Park, H. J., Ro, J. S., Yi, K. P., Chung, T. K., & Jung, H. K. (2013). Dynamic analysis and design of an armature for an inter-locking system of a magnetic contactor. *2013 International Conference on Electrical Machines and Systems, ICEMS 2013*, 676–679. <https://doi.org/10.1109/icems.2013.6754503>

Passion Fruits Growing In Uganda_- Greening Uganda_ Hass Ovacado Seedlings _ Coffee Growing In Uganda _ Hass Ovacado Export Farming _ Passion Fruits Growing In Uganda. (n.d.).

Patil, A. J., Rajude, S. B., Thok, M. S., & Pawar, A. R. (2017). Review on design of agitator 1. *International Journal for Research Trends and Innovation, 2(4)*, 243–246.

- Phansopkar, M. (n.d.). *How to Design and Install a Solar PV System - Solved Example*.
- Pipeline design consideration and standards*. (2022). June 2015, 2022.
- Point, C., Singhal, S., & Education, M. (2017). COMPARISON & POWER QUALITY IN DOL & SD STARTER OF IM Sourabh Chourasiya *, Shivangi Singhal * & Md Irfan Ahmed **. *International Journal of Multidisciplinary Research and Modern Education (IJMRME)*, 3(1), 399–404. <https://doi.org/10.5281/zenodo.801193>
- Salam, M. A. (2020). Fundamentals of electrical power systems analysis. In *Fundamentals of Electrical Power Systems Analysis*. <https://doi.org/10.1007/978-981-15-3212-2>
- Santahuhta, H. (2016). *EXAMINING THE USE OF A SOFT-STARTER FOR THE THRUSTER UNIT ' S LUBRICATION AND CONTROL PUMP Electrical Engineering*.
- Sidik, M. H. M., & Ghani, S. A. C. (2017). *Volume Measuring System Using Arduino for Automatic Liquid Filling Machine*. 12(24), 14505–14509.
- Silva, C. E. de F., & Abud, A. K. de S. (2017). Tropical Fruit pulps: Processing, product standardization and main control parameters for quality assurance. *Brazilian Archives of Biology and Technology*, 60. <https://doi.org/10.1590/1678-4324-2017160209>
- Skogestad, S. (2019a). *Buffer Tank Design for Acceptable Control Performance*. May 2003. <https://doi.org/10.1021/ie020525v>
- Skogestad, S. (2019b). *Buffer Tank Design for Acceptable Control Performance*. May 2003. <https://doi.org/10.1021/ie020525v>
- Slim, L. (2021). *Transparent level gauge*. 1–40.
- Solanki, N. A. (2020). Automatic Liquid Filling Machine. *International Journal of Engineering Sciences & Research Technology*, 9(7), 135–146. <https://doi.org/10.29121/ijesrt.v9.i7.2020.13>
- Ssenyimba, S., Kigozi, J., Tumutegyereize, P., & Muyonga, J. H. (2021). *Design and evaluation of a refractance window lab-scale dryer*. <https://doi.org/10.1108/JEDT-12-2020-0523>
- Tank agitator power calculation Power calculation for typical blade turbine impellers*. (2004). 3.

- Trappey, A. F., Johnson, C. E., & Wilson, P. W. (2008). Characterization of juice extraction methods utilizing fresh mayhaw (*Crataegus opaca* Hook.) fruit. *International Journal of Fruit Science*, 8(4), 318–331. <https://doi.org/10.1080/15538360802597697>
- Types of Conveyor Solutions & Their*. (n.d.-a).
- Types of Conveyor Solutions & Their*. (n.d.-b).
- Uganda Bureau of Statistics (UBOS). (n.d.). *COMESA Common Market for Eastern and Southern Africa Directorate of Water Development Government of Uganda Horticultural Promotional Organization of Uganda Internal Rate of Return Prosperity for All Programmes*.
- Umans, S. D., Kingsley, S., & Umans, S. D. (1958). Electric machinery. In *Journal of the Franklin Institute* (Vol. 266, Issue 5). [https://doi.org/10.1016/0016-0032\(58\)90332-6](https://doi.org/10.1016/0016-0032(58)90332-6)
- Units, S. I. (2005a). *A textbook of I*.
- Units, S. I. (2005b). *A textbook of I*.
- US Department of Energy. (2014). Determining Electric Motor Load Ranges. *Motor Challenge*, 1, 1.
- Vessel, T. H. E., & Tubes, D. (n.d.). *mixing and agitation*.
- Zamrodah, Y. (2016). *Electrical and Electronic principls and Technology Third edition* (Vol. 15, Issue 2).
- (2006). التعويضات المتحركة الكاملة و التعويضات الفكية الوجهية. In: الشعراني, إ. ف., & الوزير, غ. ج. (2006). *□□□□ □□□□□ □□□□□□□□* (Vol. 1999, Issue December).
- Kadiri, O., Kolawole, J. T., Olawoye, B., & Kadiri, A. P. (2016). Economic Studies on the Production of Fruit Juice from a Locally Sourced Fruit ‘African Star Apple.’ *Turkish Journal of Agriculture - Food Science and Technology*, 4(6), 438. <https://doi.org/10.24925/turjaf.v4i6.438-445.547>
- Oduwole, O. O., Akinwale, T. O., & Olubamiwa, O. (2001). Economic evaluation of a locally fabricated extraction machine for a cottage cashew juice factory. In *Journal of Food Technology in Africa* (Vol. 6, Issue 1). <https://doi.org/10.4314/jfta.v6i1.19278>
- Scott, F. S. J. (1959). An economic analysis of passion fruit juice processing. *Agricultural Economics Bulletin* 18, April, 5–51.

- BAUER, D. and CAVONIUS, C.R. (1980) Improving the legibility of visual display units through contrast reversal, in Grandjean and Vigliani (1980), pp. 137–42.
- Dost, W. A., & Botsai, E. E. (1990). Wood as a building material. *Wood Detailing for Performance*, 1–2.
- Dul, J., & Weerdmeester, B. (2003). *Ergonomics For Beginners. Ergonomics For Beginners*. <https://doi.org/10.4324/9780203212097>
- Francis, O. O., Martins, O. O., Bolaji, B. O., Adeyemi, O. H., Sanusi, O. M., Omoregie, M., ... Ashwe, A. (2020). Design , Construction and Performance Evaluation o f Citrus Fruits ’ Juice Extractor. *International Journal of Engineering Research & Technology*, 5(2), 1372–1378. Retrieved from https://www.unido.org/sites/default/files/2009-05/Small_scale_fruit_and_vegetable_processing_and_products_0.pdf%0Ahttp://oreilly.com/catalog/errata.csp?isbn=9781449340377%0Ahttp://search.proquest.com.ezp01.library.qut.edu.au/pqdtglobal/docview/304664186/3
- Joinery Handbook. (2020).
- Khurmi, R. S., & Gupta, J. K. (2011). A Textbook Of Machine Design (S.I. Units), Ram Nagar, New Delhi, Eurasia Publishing House (PVT.) LTD. *Machine Design*, 1(I), 200. Retrieved from <https://docs.google.com/file/d/0B7OQo6ncgyFjbW53VEJEclZuSzQ/edit>
- Overview, G. (2020). Chemical Clean In Place (CIP) Chemical Clean In Place (CIP) Chemical Clean In Place (CIP), 0, 29–37.
- SPX. (2013). CIP and Sanitation of Process Plant. *Schneider Electric White Paper PX*, 1–24.
- Tuncer, S., Erden, I., Aydin, N., & Öge, D. (1989). *Acute spinal cord compression in hereditary multiple exostoses: Case report. Paraplegia* (Vol. 27). <https://doi.org/10.1038/sc.1989.63>
- Umans, S. D., Kingsley, S., & Umans, S. D. (1958). *Electric machinery. Journal of the Franklin Institute* (Vol. 266). [https://doi.org/10.1016/0016-0032\(58\)90332-6](https://doi.org/10.1016/0016-0032(58)90332-6)