BIO Web of Conferences **146**, 01016 (2024) https://doi.org/10.1051/bioconf/202414601016
BTMIC 2024

Application of capacity sensor control in the organic waste bioconversion process to optimize standard time and work posture assessment

Ratih Setyaningrum[1*], *Claudia Pitri* Ahmad[1], *Safarudin* Ramdhani[1] *Pramudi* Arsiwi[1]

[1]Industrial Engineering, Faculty of Engineering, Dian Nuswantoro University, Semarang, Central Java, Indonesia

Abstract. Organic waste can be processed into organic products to support agriculture. It is necessary to optimize the bioconversion technology system for processing organic waste into products with added value and selling value. This research aims to evaluate and optimize the stages of bioconversion using capacity sensor control, establish standard processing times, and assess worker posture. The data obtained directly is based on observations and interviews with workers at Repro MSMEs. The primary data taken are: data on the sequence of the maggot production process. Optimizing bioconversion using capacity sensor control. The next process is calculating standard time and assessing REBA work posture. The application of a smart biopoands design that uses capacity sensors is able to optimize standard time and posture assessment. Body posture of production process workers after improvement, namely in enumeration using a REBA score machine of 5 with a medium risk level and sifting using a REBA score machine of 3 with a small risk level.

1 Introduction

Sustainable Waste Indonesia (SWI) conducts research on waste in Indonesia that has not been managed optimally. This is supported by data showing that of the approximately 65 million tons of waste produced by Indonesia every day, around 15 million tons of waste still pollutes the environment and ecosystem, because it is not handled and processed optimally. Meanwhile, 7% of waste is recycled and 69% of waste is in final disposal sites (TPA).

According to Semarang Environment Department in 2022, the waste production in Semarang will reach 1,110 tons per day, this number has increased if it is compared to the beginning of the pandemic, 900 tons per days (Semarang, 2022). With increasing waste production and less than optimal waste management practices, especially in developing areas like Semarang, innovative solutions are needed. One promising approach is the optimization of bioconversion technology to process organic waste, such as maggot production, which has the potential to produce waste.

On the other hand, organic waste can be processed into organic products to support agriculture. Processing organic waste into organic products has several problems, including the production process which needs to be optimized in processing time. It is necessary to optimize the bioconversion technology system for processing organic waste into products with added value and selling value. Bioconversion technology that produces organic products includes maggot, liquid fertilizer, solid fertilizer. The conversion of organic materials (such as wastes) into an energy source (such as methane) by processes (such as fermentation) involving living organism.

The maggot productions process that occurs at UMKM Repro has not optimal conditions because the standard time is not recorded and controlled so that the time for the maggot production process cannot be regulated. The production process takes a long time, resulting in the amount of output produced not reaching the target. And the worker's posture is quite dangerous, namely it has a REBA score, which means it needs immediate. It is necessary to measure the worker's body posture again to determine the risk value that has decreased/increased after repair.

This research aims to evaluate and optimize the stages of bioconversion using capacity sensor control, establish standard processing times, and assess worker posture.

The maggot productions process that occurs at UMKM Repro has not optimal conditions because the standard time is not recorded and controlled so that the time for the maggot production process cannot be regulated. It is necessary to measure the worker's body posture again to determine the risk value that has decreased/increased after repair.

The contribution of this research is capacity sensor-based control of maggot bioconversion which has an impact on standard time and work posture assessment.

1.1 Literature review-research mapping

* Corresponding author: ratih.setyaningrum@dsn.dinus.ac.id

A mapping of the research that has been carried out by the research team and previous research in the field of Smart Waste Management (SWM) is presented in Figure 1. This figure shows that the research carried out by the research team compared to other research still has the potential for novelty because the amount of research in the field of SWM is not large (Figure 1a). Research related to SWM has been carried out since 1973 until now, the research team has carried out structured research in the field of SWM from 2013 to 2023 (Figure 1b). Our research includes those that add to research contributions in the field of waste management.

Details of the research mapping about of waste management and suply chain are presented in Figure 2. Our research in 2022 and 2023 includes increasing the contribution of research in the field of organic products to produce liquid fertilizer and solid fertilizer.

Research position with similar previous research about waste management and Supply Chain Management are presented in Figure 3. Our research this year contributed to research on optimizing the organic waste supply chain management system through designing and building a waste management information system.

Based on figures 1, 2 and 3, it can be seen that the research position of this paper is in accordance with research trends in the field of waste management and supply chain management.

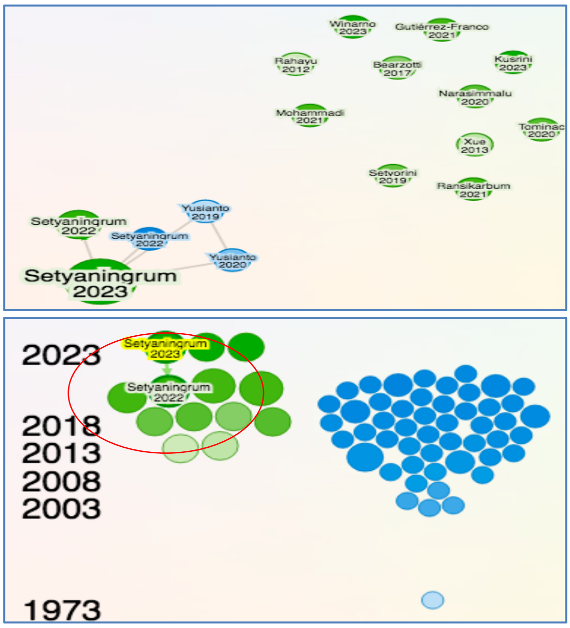

Fig. 1. Mapping research in smart waste management field arroun the world since 1973 until 2023.

Several preliminary studies have been prepared by the research team in a planned manner that supports this research. The concept begins with food security research using various optimization methods (point a) towards achieving successful food products that consider the factors that cause success (point d). This is supported by research on inorganic and organic waste based on Smart Waste Management (SWM) for food security (point b). Several machine optimizations have also been carried out based on lean manufacturing which supports the achievement of successful products for food security (point c).

Preliminary studies have provided the basis for this reaserch, including:

(a) Optimization of food security products based on Supply Chain Management (SCM) and supply chain network (10,15,17); logistic optimization (12,16,17);Interpretive Structural Modeling (ISM), analytical network process, distribution optimization (1,2,3,4,5,7).

(b) Green Environment supports waste management of inorganic (18,20) and organic waste (8,9,21).

(c) Lean manufacturing that supports food security products through optimizing cracker drying machines, machine maintenance, press machines, etc. (6.9)

A successful product supported by several factors that take into account Indonesian culture (11.14).

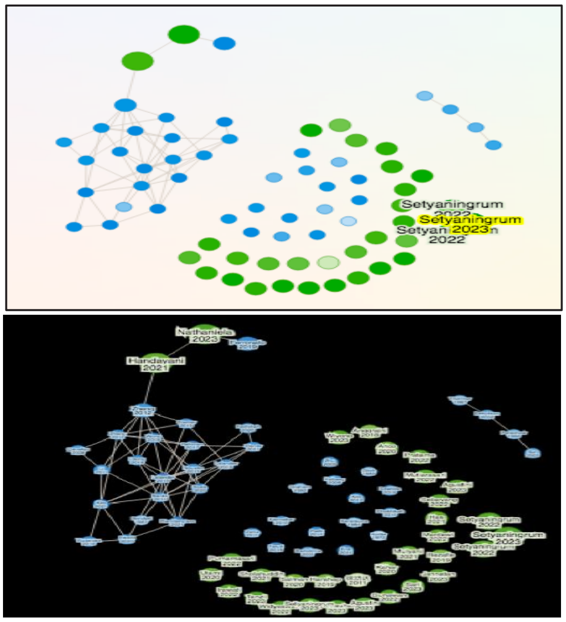

Fig 2. Research position with similar previous research about waste management, maggot and fertilize.

This proposed research was related to the previous since 2018 which had got achievements in the form of 1 monograft book (22), IPR (copyright) 3 copyrights (23,24,25) and an industrial design (26), reputable and indexed international journals with 11 publications (9,10,11,13,14,15,17,18,20,21) and accredited national journals with 9 publications (1,2,3,4,5,6 ,7,12,16).

Several previous studies related to this research include a scheme for empowering the quality of refillable drinking water [27}; model and empowerment scheme for batik waste [28]; implementation of lean manufacturing and empowerment of the salt industry [29]; culture-based mathematical models of successful products [30]; designing inorganic smart waste management [31]; designing organic smart waste management [32] and information systems designing organic smart waste management [32].

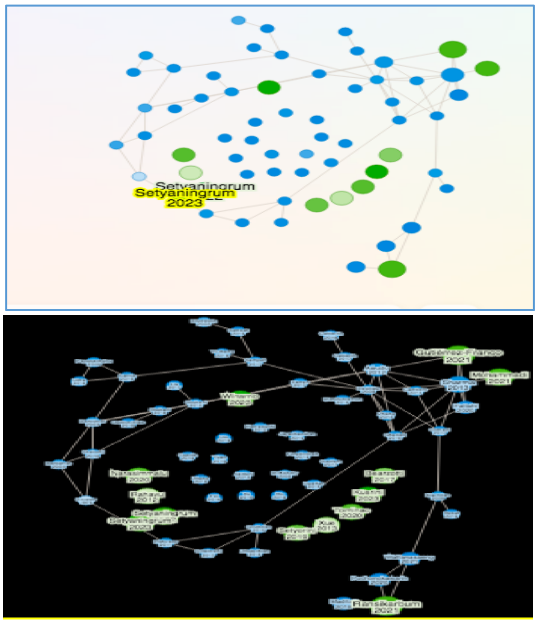

Fig. 3. Research position with similar previous research about waste management and Supply Chain Management.

2 Research methods

Data was collected through direct observations and interviews with workers at Repro MSMEs. Primary data were collected through observations and interviews with workers at Repro MSMEs. This included documenting the sequence of the maggot production process and recording production times for enumeration and sieving. Additionally, data on rating factors and allowances for various stages (chopping, maggot enlargement, and sieving) were gathered for both manual and automatic processes. Production data is collected during working hours in one production cycle.

Optimizing bioconversion using capacity sensor control as presented in Figure 4. Figure 4 shows the IoT Maggot Biopond version 1.0, which utilizes the capacity sensor to monitor and optimize the bioconversion process. The bioconversion process is optimized using a LoadCell 20Kg capacity sensor, detailed specifications of which are provided in Appendix A. Key features include a safety overload rate of 150% and an operating temperature range of -20 to 60°C.Figures and tables, as originals of good quality and well contrasted, are to be in their final form, ready for reproduction, pasted in the appropriate place in the text. Try to ensure that the size of the text in your figures is approximately the same size as the main text (10 point). Try to ensure that lines are no thinner than 0.25 point.

Research stage as presented in Figure 5, includes designing bioconversion based on capacity sensors, then calculating standard bioconversion time, ending with assessing worker posture using REBA workshseed.

The next process is calculating standard time and assessing REBA work posture using the worksheet presented in Figure 6. REBA was developed by Hignett and McAtamney as a means to assess entire body posture for risk. REBA has been developed to fill a perceived need for a practitioner's field tool, specifically designed to be sensitive to the type of unpredictable working postures found in health care and other service industries. Standard time calculations and work posture assessments are performed using the REBA worksheet, as shown in Figure 6. This worksheet helps evaluate the ergonomic risks associated with the maggot production process.

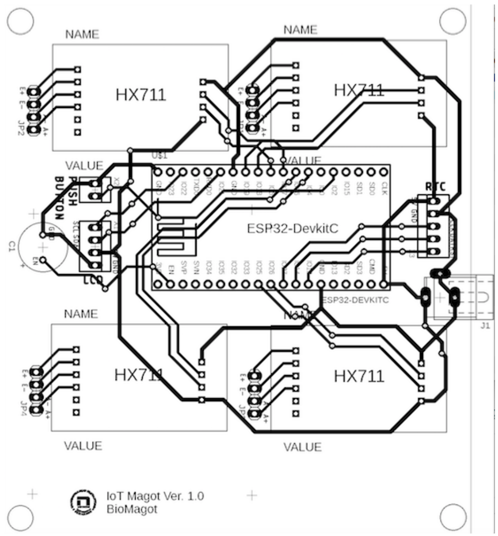

Fig. 4. IoT Maggot Biopond version 1.0 based on capacity sensor.

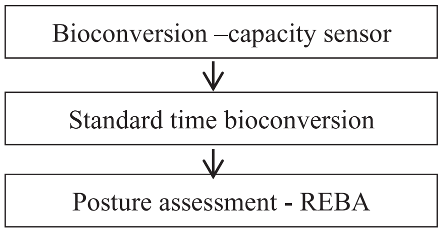

Fig. 5. Main research stage.

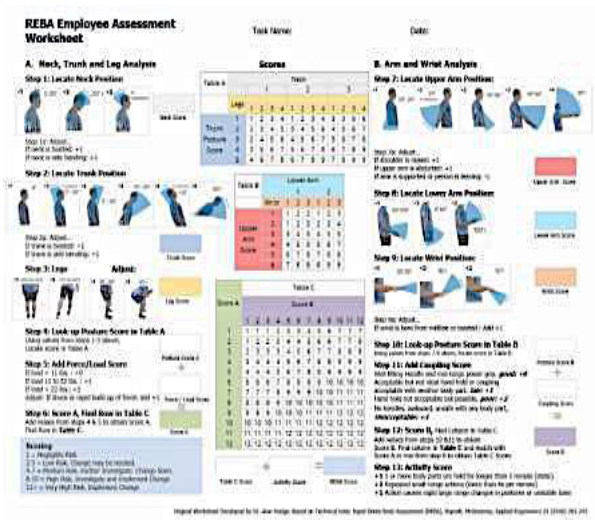

Fig. 6. Worksheet REBA.

Source: Middlesworth, 2022.

3 Equations and mathematics

The maggot production process at UMKM Repro now are: Pre-production of Maggot includes waste shredding: Sort the waste first then chop it using a machine; Waste Fermentation: Shredded waste is placed in a barrel and treated with molasses and EM4 to reduce the smell; Pressing: Reduce the water content in chopped waste that has been fermented, before being given to maggots.

Stages of the Maggot Production process:

1. Egg Hatching: Eggs are placed in a basin container with pressed waste, a wire net topped with tissue as a medium for the eggs to hatch.
2. Maggot Rearing: Eggs that have hatched and become larvae are moved into the biopond. At this stage, the maggots will be fed and filtered to reduce kasgot (maggot waste) so that the maggots do not overheat or become buried. Maggots are at this stage until they are ready to be harvested.
3. Sifting: The maggots that have been harvested are sifted, there are two of

sieving, manual and machine. Sieving is carried out to separate maggots and kasgot (maggot waste).

Figure 6 shows a 2D design of the biopond, illustrating the layout and components involved in the maggot production process. Figure 7 presents the experimental results using capacity sensors, highlighting the performance metrics of the sensor system. The results of experiments using capacity sensors on maggots as presented in Fig. 8.

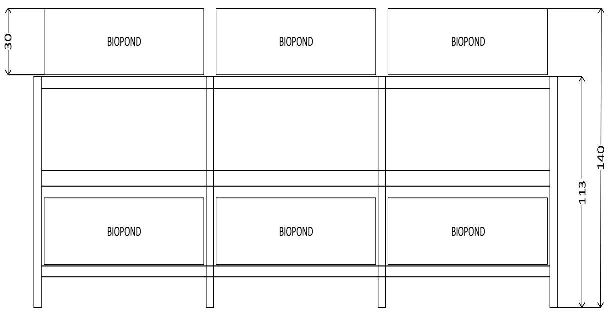

Fig. 7. Design of biopond in 2 dimensions.

The following is a recapitulation of data processing which can be seen in Table 1 and Table 2.

Table 1. Standard time and the output of maggot production process.

No	Maggot production process	Standard time	Standard output
1	Shredding	263 seconds/kg	0,0038 kg/seconds
2	Enlarging maggot	293824 seconds/gr	0,0000034 gr/seconds
3	Machine shieving	366 seconds/kg	0,0027 kg/seconds
4	Manual shieving	131 seconds/kg	0,0076 kg/seconds

Source: (Data processing, 2023).

Based on Table 1 above, the results of the standard time and standard output from the maggot production process in the enumeration, maggot enlargement and sieving (machine and manual) sections are known. In counting, the standard time was obtained at 263 seconds/kg and the standard output was 0.0038 kg/second. In maggot rearing, the standard time was 293824 seconds/gram and the standard output was 0.0000034 grams/second. In manual sieving, a standard time of 366 seconds/kg was obtained and a standard output of 0.0027 kg/second. In sieving using a machine, the standard time was 131 seconds/kg and the standard output was 0.0076 kg/second.

Table 1 summarizes the standard times and outputs for different stages of the maggot production process. The data indicates that manual sieving has the highest output rate compared to machine sieving, but machine sieving is faster. This suggests a trade-off between efficiency and processing speed.

Table 2. Recapitulation of worker body posture.

No	Maggot production process	Score of REBA manual	Score of REBA machine
1	Shredding	-	5
2	Enlarging	4	-
3	Shieving	5	3

Source: (Data processing, 2023).

Table 2 shows the REBA scores for different processes. The score of 5 for manual shredding indicates a medium risk level, suggesting that ergonomic improvements are needed. The score of 3 for machine sieving indicates a lower risk level, reflecting better ergonomic conditions. The absence of a REBA score for manual enumeration was due to a lack of enumeration during initial observations, but improvements in machinery were noted

Based on table 2 above, the REBA scores from manual and machine processes are known. In the enumeration there was no manual reba score, because when researchers carried out observations at Repro MSMEs to identify and formulate waste problems at Repro MSMEs, no enumeration was carried out first. When researchers conducted research, Repro UMKM had made improvements, namely there was a waste chopping machine. After processing the data, the body posture of enumeration workers using machines obtained a REBA score of 5, this score is at a moderate risk level, so further investigation is needed.

The results suggest that optimizing the maggot production process with a focus on reducing processing times and improving ergonomic conditions can enhance overall efficiency and worker safety. The introduction of capacity sensors has provided valuable insights into the production stages and identified areas for improvement.

4 Conclusion

This study aimed to optimize the maggot production process and assess worker posture using a smart biopond design with capacity sensors. The findings indicate that the application of this technology has successfully optimized standard times and improved ergonomic conditions.

The optimal standard times for the maggot production process were achieved as follows: enumeration at 0.0038 kg/second, maggot enlargement at 0.0000034 grams/second, manual sieving at 0.0027 kg/second, and machine sieving at 0.0076 kg/second. These results demonstrate significant improvements in processing efficiency.

Post-improvement, the REBA score for manual enumeration was 5, indicating a medium risk level. This suggests that further ergonomic adjustments may be needed to enhance worker safety. In contrast, the machine sieving process achieved a REBA score of 3, reflecting a lower risk level and improved ergonomic conditions.

5 Recommendation

Based on these results, it is recommended that UMKM Repro continue to refine the biopond design and implement additional ergonomic improvements to further reduce risk levels. Future research could explore the integration of advanced sensor technologies to further enhance process efficiency and worker safety.
The successful application of smart biopond designs and capacity sensors in this study highlights their potential for optimizing similar waste management processes. These innovations can contribute to more efficient and safer waste processing practices in other settings

References

1. P. Arsiwi, P. W. Adi, *Interpretive Structural Modelling Untuk Meningkatkan Daya Saing Rantai Pasok UKM Mina Indo Sejahtera*, Jurnal PASTI, **14**, 1, 26–36, (2020), https://doi.org/10.22441/pasti.2020.v14i1.003
2. P. Arsiwi, P. W. Adi, *Strategi Peningkatan Keunggulan Kompetitif UKM Mina Indo Sejahtera Dengan Metode Interpretive Structural Modelling dan Analytic Network Process*, JURNAL TEKNIK INDUSTRI, **10**, 3, (2020), https://doi.org/10.25105/jti.v10i3.8407
3. P. Arsiwi, P. W. Adi, D. S. Nugroho, P. Kusumo, *Pendampingan Eskalasi Bisnis UKM Mina Indo Sejahtera Melalui Diversifikasi dan Nilai Tambah Produk Olahan Lele Sehat*, ABDIMASKU: JURNAL PENGABDIAN MASYARAKAT, **3**, 2, (2020), https://doi.org/10.33633/ja.v3i2.90
4. P. Arsiwi, D. S. Nugroho, S. Anjani, M. T. J Arrafie, *Pendampingan Perancangan Kursi Kerja Produksi dan Sistem Tandon Air untuk Meningkatkan Produktivitas Pada UKM Mina Indo Sejahtera*, ABDIMASKU: JURNAL PENGABDIAN MASYARAKAT, **5**, 3, (2022), https://doi.org/10.33633/ja.v5i3.692
5. P. Arsiwi, D. K. Wijaya, P. W. Adi, *Optimasi Lokasi Distribution Center UKM Mina Indo Sejahtera dengan Model Matematis Haversin dan Centre of Gravity Adjusting*, JURNAL TEKNIK INDUSTRI, **11**, 3, (2021), https://doi.org/10.25105/jti.v11i3.13070
6. Y. A. A. Huda, P. Arsiwi, *Proposed Machine Maintenance Management To Reduce Breakdown In Kacang Atom Production Process PT. XYZ With Preventive Maintenance Method*, OPSI, **15**, 2, (2022), https://doi.org/10.31315/opsi.v15i2.8046
7. N. Siswaningsih, P. Arsiwi, T. Talitha, *Analisis Rantai Pasok dan Rantai Nilai pada Produk Ikan Asap Manyung Dalam Meningkatkan Penjualan di Sentra Pengolahan Ikan "Asap Indah" Desa Wonosari Demak*, Opsi, **14**, 2, (2021)
8. R. Setyaningrum *et al*., *Pengembangan Sustainable Waste Management (SWM) Pengelolaan Limbah Organik Kota Semarang melalui Smart Production Berbasis Internet of Things melalui kerjasama Kelompok Petani Maggot dan PT. Biomagg Sinergi Internasional untuk Mendukung Industrialisasi dan Ketahanan Pangan - Penelitian Matching Fund Kedaireka*, (2022)
9. R. Setyaningrum, D. Aldo, D. R. Sawitri, *Optimizing the Volume of Plastic Bottle using Mechanical Press Machine Designed Based on Rational Methods*, AES Journal, **54**, 6, (2022)
10. Silvia, R. Setyaningrum, D. N. Izzhati, *Identification of Potato Supply Chain Network Design To Increase Farmer's Income, The International Seminar on Application for Technology of Information and Communication*, IEEE, (2022)
11. R. Setyaningrum, Subagyo, A. R. Wijaya, *Mathematical Model of Successful-Product Development by Considering The Indonesian Culture*, Internasional Journal of Technology, **13**, 3, (2022)
12. R. Setyaningrum, T. Ayu, *Perancangan Jaringan Rantai Pasok Sampah Organik Menjadi Pakan Ternak Lele yang optimal Jurnal llmiah Teknik Industri (Jumal Keilmuan Teknik dan Manajemen Industri)*, WTAR, (2021), http:/iiournal.P-ISSN: 2337-5841 and E-ISSN: 2355-6528
13. R. Setyaningrum, P. Kusumo, *Design of an Ergonomic Cracker Dryer to Increase Production at Rahayu Krupuk SME*, Apcorise, (2021)
14. R. Setyaningrum, Subagyo, A. R. Wijaya, *A Matematical Model of Factor Driving Product Success in an Indonesian market using Design of Experiment*, Internasional Journal of Technology, **11**, 2, (2020)
15. R, Yusianto, *Intelligent Spatial Decision Support System Concept in the Potato Agro-Industry Supply Chain, International Conference on Computer*

Science and Its Application in Agriculture, ICOSICA, (2020)

16. R. Setyaningrum, T. Ayu, *Model dan Simulasi Alur Rantai Pasok Sampah Organik Menjadi Pakan Ternak Lele*, (TEKINFO - Jurnal Ilmiah Teknik Industri dan Informasi, **8**, 2, (2020)
17. R. Yusianto, *Intelligent Spatial Logistics DSS for tracking and tracing in horticultural food security, The International Seminar on Application for Technology of Information and Communication*, (2019)
18. R. Setyaningrum, Vania, D. N. Izzhati, *Penerapan Manajemen Administrasi Pengelolaan Sampah Berbasis Android untuk Meningkatkan Produktivitas Pada Bank Sampah Resik Becik*, (International Conference, 8th Anuual Conference on Industrial and System Engineering (ACISE) 2021 and 1st International Conference on Ergonomics Safety and Healty (ICESH), (2021)
19. R. Setyaningrum, P. Kusumo, *Perancangan alat pengering Krupuk dengan metode Rasional*, (The 4th Asia Pasific Conference on Research in Industrial and System Engineering (APCORISE), (2021)
20. R. Setyaningrum, P. Arsiwi, T. Talitha, D. N. Izzhati, *Dynamic System Simulation to Improve the Effectiveness and Efficiency of Supply Chain Performance and Behaviour on Waste Bank Resik Becik*, International Journal of Technology, (2024)
21. R. Setyaningrum *et al*, *A Supply Chain Flow Information System and Community Behaviour in Waste Management based on Industry 4.0*, Isemantic IEEE, (2023)
22. R. Setyaningrum, P. Arsiwi, S. Rohman, S. Ramdhani, *Kajian Makroergonimi & Sistem Informasi Waste Management Sampah Organik*, Penerbit Nasya Expanding Management, (2024)
23. Setyaningrum, *Buku Panduan Aplikasi Management Admisnistrasi Pengelolaan Sampah Berbasis Android, pengakuan dari Kementerian Hukum dan Hak Asasi Manusia, Tahun 2023*, dengan Surat Pencataan Ciptaan Nomor, (2023)
24. Setyaningrum, *Aplikasi Smart Waste Management Produk Organik Berbasis Website, mendapat pengakuan dari Kementerian Hukum dan Hak Asasi Manusia, Tahun 2023*, dengan Surat Pencataan Ciptaan Nomor: EC00202360481, (2023)
25. Setyaningrum, *desain industri box pengembangan magot, pemeriksaan subtansif 1*, (2023)
26. R. Setyaningrum, D. W. Waluyo, S. Asfawi, *Rancang Bangun e-Health Penjaminan Kualitas Air Minum Isi Ulang untuk Mensukseskan Indonesia Sehat*, Hibah Bersaing, (2012)
27. R. Setyaningrum, Aryati, S. Asfawi, *Implementasi Model Pemberdayaan UKM Batik Dalam Upaya Mengangkat Kearifan Lokal Batik*, Hibah Bersaing, (2013)
28. R. Setyaningrum, D. W. Hartini, S. Asfawi, *Pengembangan Model PUGAR Berbasis Sustainable Manufacturing untuk Meningkatan Swasembada Garam Industri*, Hibah Bersaing, (2014)
29. R. Setyaningrum, Subagyo, A. A. Wijaya, *Mathematical Model of Successful Product Development by Considering The Indonesian Culture*, jurnal ilmiah International Journal of Technology, **13**, 3, 655-663, Universitas Indonesia, (2022)
30. R. Setyaningrum, D. N. Izzhati, R. Sawitri, *Pengembangan Start Up dan Riset. Pengolahan Limbah Plastik Untuk Mewujudkan Kota Semarang*, Matching Fund Kedaireka, (2021)
31. R. Setyaningrum, P. Arsiwi, Jazuli, T. Talitha, *Pengembangan Sustainable Waste Management (SWM) Pengelolaan Limbah Organik Kota Semarang melalui Smart Production Berbasis IoT melalui kerjasama kelompok Petani Magot dan PT Biomagg Sinergi International untuk mendukung industrialisasi*, Matching Fund Kedaireka, (2022)
32. R. Setyaningrum, P. Arsiwi, S. Rohman, S. Yusianto, *Penguatan Sustainable Waste Management (SWM) Pengelolaan Limbah Organik Kota Semarang melalui Circular Supply Chain dan Intellegence Digital SCM Bekerjasama dengan PT Biomagg Sinergi Interntional*, Matching Fund Kedaireka, (2023)
33. N. Z. N. Aminah, A. Muliawati, *Pengelolaan Sampah dalam Konteks Pembangunan Berkelanjutan, Himpunan Mahasiswa Geografi Pembangunan Fakultas Geografi Universitas Gadjah Mada*, (2021)
34. Waste Portal, *Integrated Sustainable Waste Management (ISWM)*, (2023)
35. R. Gaikward, P. Sunnapwar, *The role of Lean Manufacturing Practise in Greener Production: A way to reach Susitanability*, International Journal of Industrial and Manufacturing System Engineering, **5**, 1, 1-5, (2020)