ASEAN UNIVERSITY SYMPOSIUM FOR SUSTAINABLE FOOD SYSTEM: 18-19 APRIL 2024 (Kasetsart University, Bangkok)

Bio-fertilizers from food wastes for sustainable agriculture in Brunei Darussalam

Presented (On-site) by: Hani' Ariffin
Master of Agricultural Science (By Research)
Academic supervisor: Prof. Dr. Ahmed Osumanu Haruna
Co-supervisor: Dr. Cristalina Jalil Marsal
Institution: UNISSA University, Brunei Darussalam

AGENDA

1. Introduction

- Food wastes
- Bio-fertilizer
- Bio-fertilizer production in Brunei
- Objectives
- Significance of study

2. Methodology

3. Results & Discussion

- a. Inadequate information on Bio-fertilizer production in Brunei Darussalam
- b. Selected food wastes transformation into bio-fertilizers in Brunei Darussalam
- c. Benefits of utilizing food wastes for organic bio-fertilizer production in Brunei Darussalam
- d. Limitations of using bio-fertilizer in Brunei Darussalam

4. Conclusion and Recommendation

- References
- Q & A

1. INTRODUCTION- Food wastes

- Among the ASEAN (Association of Southeast Asian Nations) countries, **Brunei Darussalam** is the **2nd country** (followed by Singapore) which generates more solid wastes per capita.

- **6% of the total wastes generated is used to produce compost** and the **70% of the solid wastes go directly to Brunei Darussalam's six landfills** and the remaining of the wastes are disposed in other standard methods (Shams, Juani & Guo, 2014).

- In the **Association of Southeast Asian Nations (ASEAN) countries**, the ASEAN population produces **food wastes** which is approximately **83 kg** per capita per year (UNEP, 2017)

- Approximately **32%** of the total food waste is produced in **Brunei Darussalam** (Kon, 2019).

- The **food waste is one of the major issues** in ASEAN including Brunei Darussalam.

BIO-FERTILIZER

- Bio-fertilizers are substances **rich in living microorganisms** which when applied to soils, seeds, or plant surfaces,

➢ Unlike chemical fertilizers, bio-fertilizers sustain soil and crop productivity (Arjjumend, Koutouki & Donets, 2020) because their microorganisms such as **bacteria and fungi** promote soil and plant health.

➢ **The bacteria or fungi** in bio-fertilizers often **fix nitrogen, solubilize phosphate, oxidize sulfur, produce plant hormones, or decompose organic substances** (Pirttilä et al., 2021).

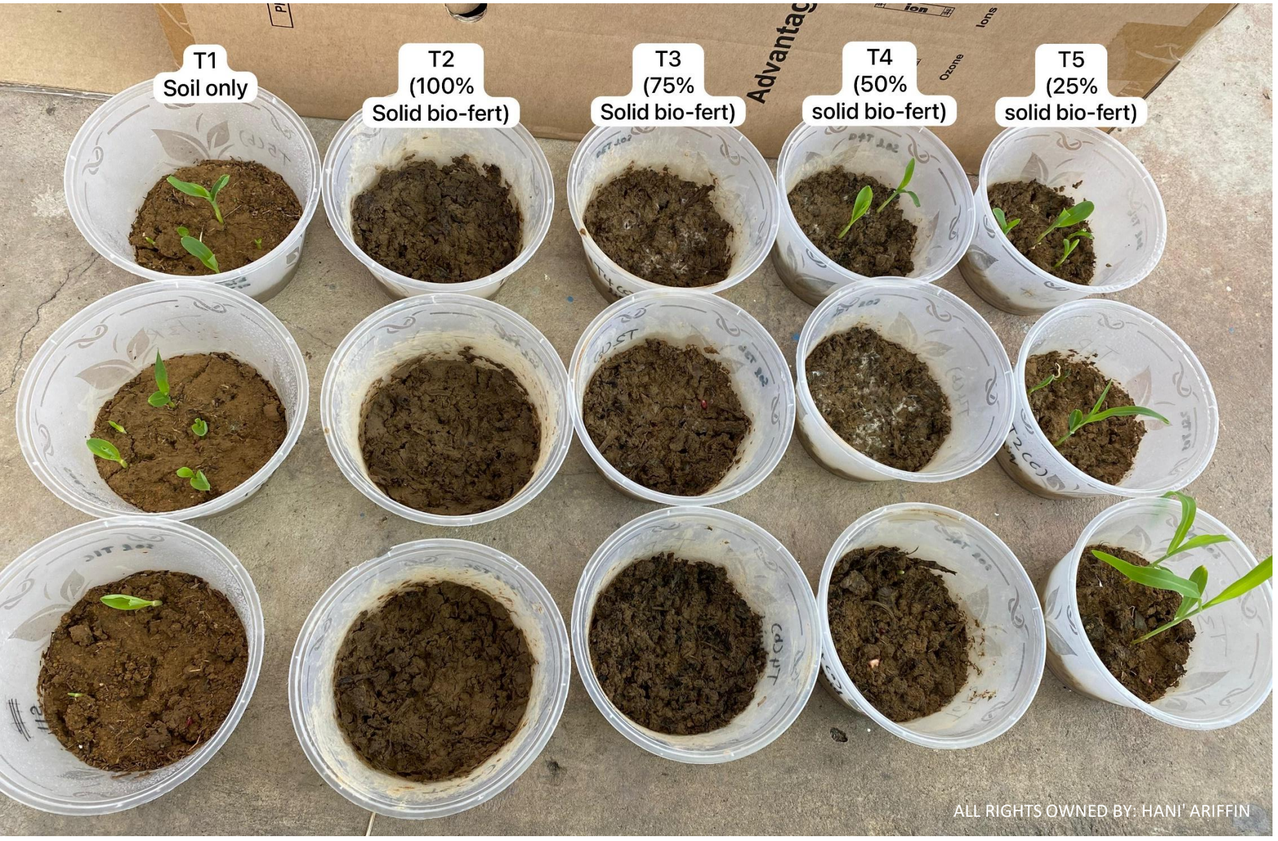
➢ Bio-fertilizers also **neutralize the harmful effects caused by chemical fertilizers** because of the compatibility of their microorganisms with organic wastes (Areeshi, 2022).

Example:

Figure 1. Liquid bio-fertilizer

Figure 2. Solid bio-fertilizer

Day 7



Day 50

BIO-FERTILIZER PRODUCTION IN BRUNEI DARUSSALAM

- **Bio-fields Solutions**, a local Brunei-based company

- Successfully transformed:
<u>Food waste</u> into organic compost fertilizer as their main product

- New & small-scale production

Bio-fields Solutions Brunei

Bio-fields Solutions Brunei

OBJECTIVES

- Review literature on **identifying food waste types** that are prevalent in Brunei Darussalam and evaluate their feasibility and effectiveness for the production of bio-fertilizers.
- **Assesses the effect of bio-fertilizers from food waste** on soil health and crop productivity
- **Recommends strategies** to **reduce food waste** and promote bio-fertilizer use in agriculture in Brunei

RESEARCH GAP

- **Scientific research publications** on utilization of bio-fertilizers made of food wastes in Brunei Darussalam.

SIGNIFICANCE OF STUDY

- The presented review **creates awareness** on the need for **adopting or introducing bio-fertilizers from food wastes** for improving the soil and crop productivity without degrading the quality of the environment in Brunei Darussalam

2. METHODOLOGY

Systematic Review & Meta-Analysis (PRISMA) methodology

Modified by Moher et al. (2010)

- **Scopus database** and **Google Scholar** (non-Scopus database)
- Publications: ranging from year **2010 to 2023**
- **Keywords:** 'Bio-fertilizer', 'food waste', and 'Brunei' 'Food wastes', 'Organic', and 'Bio-fertilizer'
- Combination of automated and manual **de-duplication** techniques (Gallagher et al., 2016)
- **Inclusion** criteria: Relevant materials (articles, abstracts, conference proceedings, and books)
- **Exclusion** criteria: not relevant to the review topic

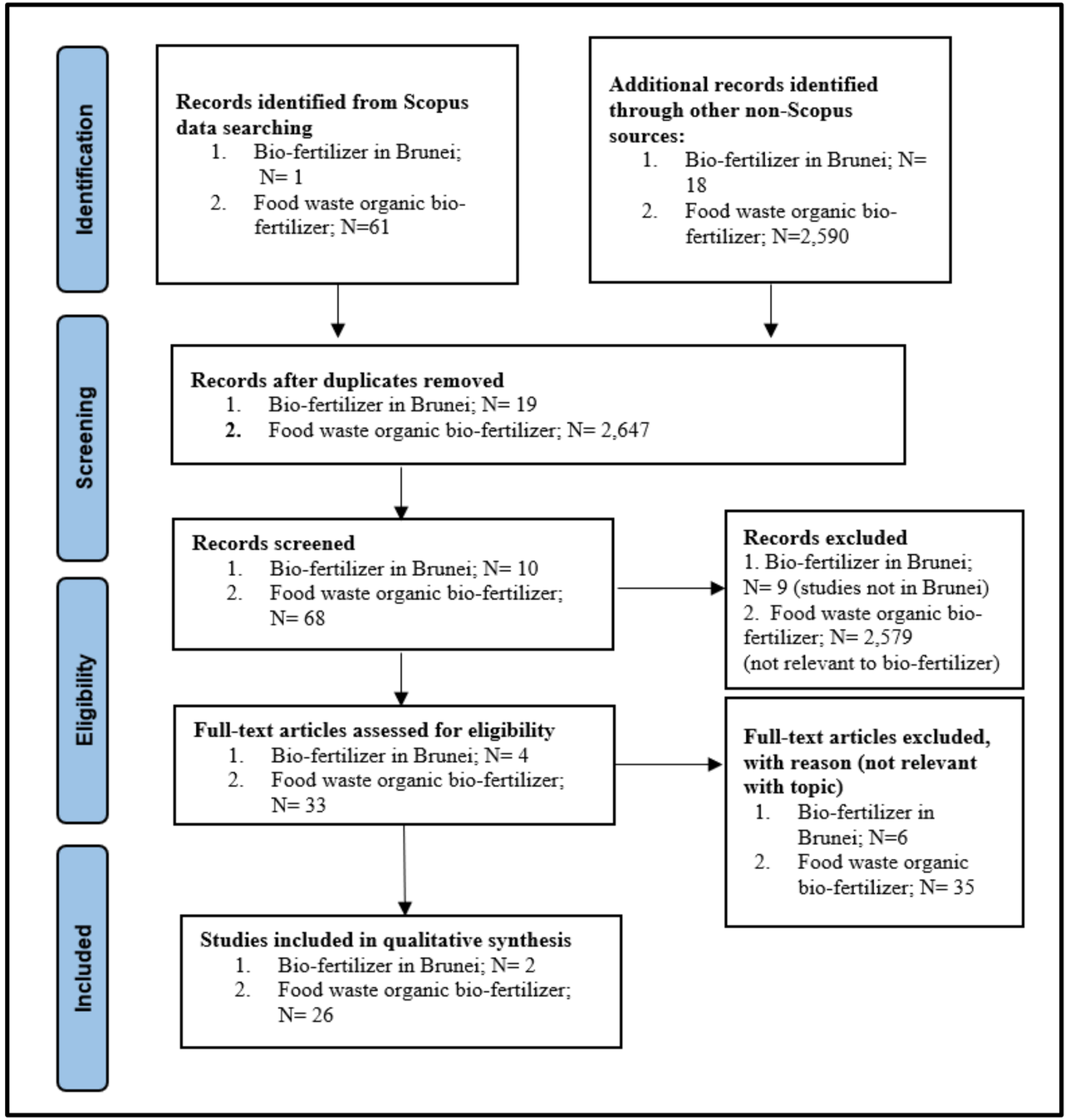


Figure 1. A modified version of Moher et al. (2010) Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flowchart was utilized in this study

3. RESULTS & DISCUSSION

Based on a search conducted on 24 February 2024,

Table 1. Title of publications in the included studies for database searches with keywords on Bio-fertilizer in Brunei (N=2)

No.	Title	Publication year	Author	Type of paper
1	Performance of a selected Trichoderma strain as plant pathogen inhibitor and biofertilizer	2022	Abdul-Halim, Shivanand & Taha, 2022	Article
2	Conversion of kitchen food waste to halal organic fertilizers	2023	Sulaiman et al., 2023	Article

a. Inadequate information on Bio-fertilizer production in Brunei Darussalam

A total of 2 papers were **included** and **eligible** for this review study which was on bio-fertilizer in Brunei **(Table 1).**

1. Study by Sulaiman et al. (2023)

- Plants treated with compost-based fertilizer (CBF) derived from halal organic fertilizers **obtained from kitchen food waste**
- ✓ showed **better growth** and **nutrient levels** than those grown using clay-based soil (CBS) alone.
- ✓ Halal organic fertilizers from food waste (also known as Bio-fertilizer) can have **positive effects** on plant development and nutrient content.

2. Study by Abdul-Halim et al. (2022)

- ✓ Rice plants treated with Trichoderma strains showed **increase in shoot length, fresh shoot weight, and dry shoot weight.**
- ✓ The findings suggest the potential of Trichoderma sp. UBDFM01 as a bio-fertilizer for **improving rice plant growth and controlling Rhizoctonia sp. in rice cultivation in Brunei Darussalam.**
- The production of microbial bio-fertilizer in Brunei may pose certain challenges due to limited accessibility of strains.

The findings suggest a ***dearth of information*** and research on the application and production of bio-fertilizers in Brunei Darussalam, particularly those made from food wastes. Therefore, **another review was performed** to identify different types of food wastes which are potential for production of bio-fertilizer and application in Brunei.

Table 2. Title of publications in the included studies for database searches with keywords on Food waste organic bio-fertilizer (N=26)

No.	Title	Publication year	Author	Type of paper
1	Identification of phenolic compounds from banana peel (Musa paradaisica L.) as antioxidant and antimicrobial agents.	2016	Aboul-Enein et al., 2016	Article
2	Advantages of Using the Biofertilizers in Ukrainian Agroecosystems.	2020	Arjjumend et al., 2020	Article
3	Benefits and limitations of biofertilization in agricultural practices	2012	Carvajal-Muñoz & Carmona García, 2012	Review Article
4	Valorization of fruit and vegetable waste for biofertilizer and biogas	2020	Chakravarty & Mandavgane., 2020	Article
5	Effects of Mixing Garlic Skin on Fermentation Quality, Microbial Community of High-Moisture Pennisetum hydridum Silage	2021	Chen et al., 2021	Article
6	Effect of Different Fruit Peel Powders as Natural Fertilizers on Growth of Okra (Abelmoschus esculentus L.)	2021	Dayarathna & Karunarathna, 2021	Article
7	Exploiting the use of agro-industrial residues from fruit and vegetables as alternative microalgae culture medium.	2020	de Medeiros et al., 2020	Article
8	The Effects of Organic Liquid Fertilizer (Vegetable Waste) on Moisture Retention, Soil Physical Properties and Yield of Lettuce (Lactuca Sativa L.) Grown in the Malkerns Area, a Region in the Kingdom of Eswatini.	2021	Dlamini, Mukabwe & Sibandze, 2021	Article
9	Valorization of food waste into biofertiliser and its field application.	2018	Du et al., 2018	Article
10	Characterizing the variability of food waste quality: A need for efficient valorisation through anaerobic digestion.	2016	Fisgativa, Tremier & Dabert, 2016	Article
11	Local Fruit Wastes as a Potential Source of Natural Antioxidant: An Overview.	2016	Ibrahim et al., 2016	Conference
12	Study on Use of Fruit Peels Powder as a Fertilizer.	2016	Jariwala and Syed, 2016	Conference
13	Effects of Organic Fertilizer Mixed with Food Waste Dry Powder on the Growth of Chinese Cabbage Seedlings.	2021	Kang et al., 2021	Article

Table 2. Title of publications in the included studies for database searches with keywords on Food waste organic bio-fertilizer (N=26) (***Continue***)

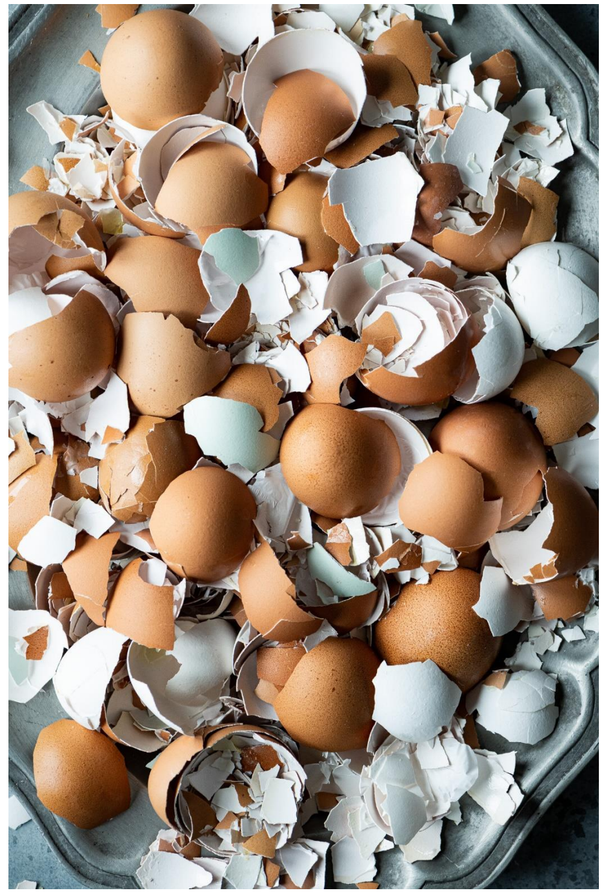
No.	Title	Publication year	Author	Type of paper
14	Food waste as a valuable resource for the production of chemicals, materials and fuels. Current situation and global perspective.	2013	Lin et al., 2013	Article
15	The Effect of Bio-fertilizer on Soil Chemical Properties of Sugarcane in Purwadadi Subang.	2017	Mulyani et al., 2017	Conference
16	Chemical and Microbial Characterization of Washed Rice Water Waste to Assess Its Potential as Plant Fertilizer and for Increasing Soil Health.	2021	Nabayi et al., 2021a	Article
17	Fermentation of Washed Rice Water Increases Beneficial Plant Bacterial Population and Nutrient Concentrations.	2021	Nabayi et al., 2021b	Article
18	Valorization of Fruit Waste for Bioactive Compounds and Their Applications in the Food Industry.	2023	Nirmal et al., 2023	Review article
19	Aplikasi Pupuk Organik Cair Limbah Kulit Nenas Terhadap Pertumbuhan Tanaman Kacang Panjang.	2020	Nurcholis et al., 2020	Article
20	A review on the valorisation of food waste as a nutrient source and soil amendment.	2020	O'Connor et al., 2020	Review article
21	Role of biofertilizers and biopesticides in organic farming.	2021	Parewa et al., 2021	Book
22	Utilization of vegetable dumplings waste from industrial production by anaerobic digestion.	2017	Pilarska et al., 2017	Article
23	An Effect of Onion Peel Water on Various Plant Disease and Plant Growth.	2022	Rajput et al., 2022	Article
24	Preparation of biofertilizer blend from banana peels along with its application in agriculture and plant microbial fuel cell.	2023	Sogani, 2023	Conference
25	Characteristics of Pineapple Waste as Liquid Organic Fertilizer and Its Effect on Ultisol Soil Fertility	2023	Sutikarini et al., 2023	Article
26	Evaluation of Eggshell as Organic Fertilizer on Sweet Basil	2019	Wijaya & Teo, 2019	Article

b. Selected food wastes transformation into bio-fertilizers in Brunei Darussalam

In Table 2, there were total of **21 papers retrieved** which were related to effects of different types of food wastes used for bio-fertilizer.

1. Eggshell

References	Literature review
Wijaya & Teo (2019)	• Eggshell is a rich source of **macronutrients** (Eg: potassium, nitrogen, calcium, magnesium, and phosphorus) and • **Micronutrients** (Eg: copper and zinc), both of which are needed for plant growth and development
Wazir et al. (2018)	• Red clover plants which were planted on eggshell with soil **grew 10 mm larger** than the plants grown on non-eggshell fertilized soil and this relates to the fact that **eggshell is rich in calcium**. • Calcium does not only **neutralize soil's acidity** but it is also a component of cell wall in plants. It is needed for **enzyme formation, nitrate uptake, and root development.**



b. Selected food wastes transformation into bio-fertilizers in Brunei Darussalam

2. Washed Rice Water

In 2022, it was estimated that total consumption of rice per capita in Brunei Darussalam was 27,627 mt and 62.03 kg per year (Department of Agriculture and Agrifood, 2022). Because of the ongoing population growth, it is anticipated that the quantity would increase.

References	Literature review
Nabayi et al. (2021b)	3 billion L of wastewater from washed rice would be produced annually if every 1 kg of rice grains is washed with at least 1 L of water
Nabayi et al. (2021a)	It must be noted that washing rice can significantly **reduce the number of water-soluble nutrients** in rice
Nabayi et al. (2021b)	• Washed rice water is considered wastewater, hence as part of water governance, it must be recycled like other wastewater. • In particular, municipal water demand accounts for 11% of the world's freshwater withdrawal, yet only 3% of this is used, with the other 8% discarded as wastewater

b. Selected food wastes transformation into bio-fertilizers in Brunei Darussalam

3. Fruit Peels

Fruit peels are high in plant essential macro and micronutrients (Ibrahim et al., 2016). Considering the fact that fruit scraps have minerals which are vital for plant growth, they are used as fertilizers and soil amends to improve soil fertility in addition to enhancing soil microbiota (Dayarathna & Karunarathna, 2021).

3. (i) Banana peels

Banana fruits are ranked first for the major type of local fruits production in Brunei Darussalam with a quantity production of 1,673,424 kg in 2022 (Department of Agriculture and Agrifood, 2022).

References	Literature review
Aboul-Enein et al. (2016)	• Banana peels are not only rich in **macronutrients** such as **nitrogen, phosphorus, and potassium** • they are also rich **micronutrients (iron, manganese, zinc and copper**)
Wazir et al. (2018)	• Promote growth of plants from seed germination, flowering, and fruiting. • With these nutrients, banana peels **improves plants' resistance to diseases**
Sogani (2023)	The **high quantities** of **K, growth-stimulants, and amino acids** such as L-tryptophan of banana peels have significant effects several biological characteristics of plants, including a greater rate of seed germination

b. Selected food wastes transformation into bio-fertilizers in Brunei Darussalam

3. (ii) Pineapple peels

Pineapple fruit is one of the major types of local fruits production in 2022 in Brunei Darussalam with estimated total quantity of 223,443 kg (Department of Agriculture and Agrifood, 2022).

The disposal of pineapple peel wastes is on the increased. The use of pineapple wastes as a liquid organic fertilizer is essential.

References	Literature review
Sutarini et al. (2023)	• The pineapple peel is rich in sugars and carbohydrates. • Approximately 81.72% of the pineapple peel is made up of water, followed by 20.87% crude fiber, 17.53% carbs, 4.41% protein, and 13.65% reducing sugar
Nurcholis et al. (2020)	Ultisol soils which are characterized as marginal areas with low organic matter content, may benefit from the application of this liquid organic fertilizer.
	The **best outcomes for the growth and production** of long bean plants were obtained using a liquid organic fertilizer at a concentration of 450 ml/L.

b. Selected food wastes transformation into bio-fertilizers in Brunei Darussalam

4. Vegetable wastes

According to the Food and Agriculture Organization of the United Nations (FAO), **losses and wastes in fruits and vegetables are the largest of all food kinds and could be up to 60%** (Sagar et al., 2018). Industrial vegetable wastes (VWs) can be used as bio-fertilizers through anaerobic digestion (Pilarska et al., 2017). With the participation of microorganisms including bacteria and archaea to decompose organic matter in anoxic circumstances, anaerobic digestion (AD) breaks down complex organic materials in VWs to produce bio-gas as a substitute for biofuel. Bio-fertilizers can be developed from the final effluent from anaerobic digesters (Chakravarty & Mandavgane, 2020).

4. (i) Onion peels

References	Literature review
Rajput et al. (2022)	• A fungal infection on the stem area of the Tulsi plant (Ocimum Tenuiflorum) prevented plant growth because the growth of the plant was halted. • The infection was later reduced after applying onion peel water to the diseased areas of plants for 21 days to 25 days. • New green leaves were also produced at the plant's tip, indicating that the plant's regrowth process had begun.
	• The onion peel water had the potency of **reducing the severity of plant infection, increasing plant growth, flowering, and commencing plant regeneration which have several chemical constituents** • such as flavonoids, phenols, tannins, and others that are good to plants

b. Selected food wastes transformation into bio-fertilizers in Brunei Darussalam

4. (ii) Garlic peels

References	Literature review
Chen et al., 2021	Garlic peels and straw are the examples of garlic wastes, which constitutes approximately 25% to 30% of the weight of the raw material, are usually dumped or incinerated. This improper disposal pollutes the environment
Patil, Jana & Murumkar, 2021	• Garlic peels provide **essential nutrients for plant growth** and **development** • because they are **rich in vitamins, antioxidants, and nutrients such as fiber, calcium, calories, iron, potassium, and magnesium**
Chen et al., 2021	• In fact, the newest findings indicate that garlic peel may have an impact on **bacterial communities**. • Garlic peels enhance the fermentation quality of high-moisture silages by boosting Lactobacillus abundance and reducing the relative abundance of Clostridium

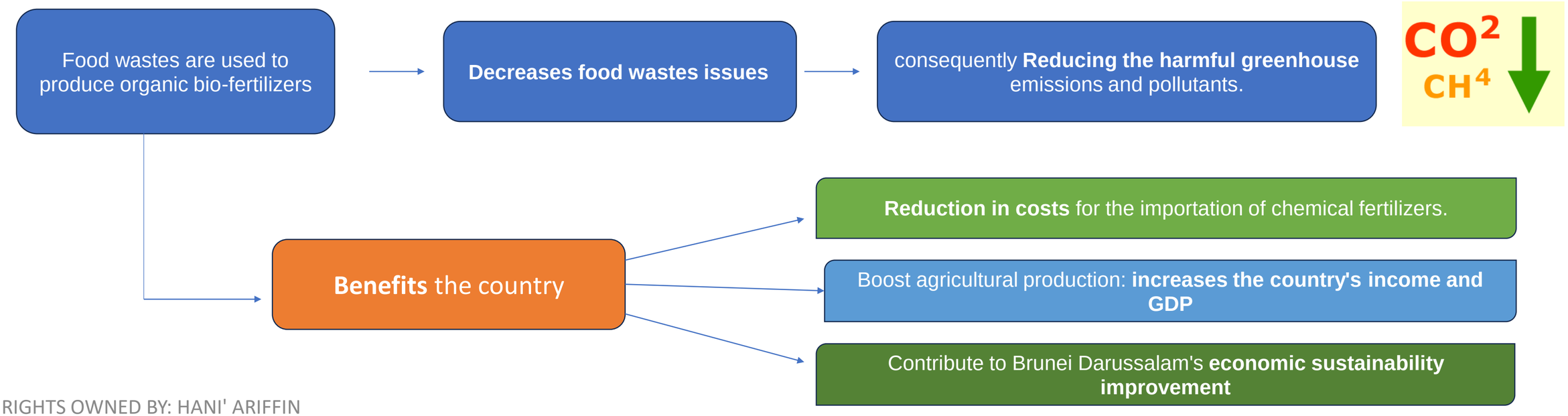
c. Benefits of utilizing food wastes for organic bio-fertilizer production in Brunei Darussalam

In Table 2, there were total of **8 out of 27 papers** recorded which addressed on benefits of utilization of food wastes for bio-fertilizer production.

References	Literature review
Dlamini, Mukabwe & Sibandze (2021)	• To effectively manage compostable wastes, organic fertilization using food waste should be taken into consideration because it **improves crop yield and soil fertility.** • Food waste fertilizers can be used as an alternative to chemical fertilizers to **boost vegetables yield in addition to enhancing the physical properties of soil**
Kang et al. (2021)	• It has been proven that continuous applications of organic fertilizer made from food waste enhances soil quality, increase crop yield, and it even promotes the growth of soil bacteria. • Additionally, it was reported that applying food waste to **soil enhances its physical, chemical, and biological characteristics** and also the growth and development of a variety of crops, including rice, tomato, pakchoi, and common bean
Kang et al. (2021)	• Food waste cannot be used directly as a fertilizer because it contains salt, which is the major deterrent to fertilization using food waste. • As a result, the production of organic bio-fertilizers from food waste is a more sustainable and efficient approach than using conventional chemical fertilizers in agriculture
Fisgativa, Tremier & Dabert (2016)	Food waste disposal in landfills is associated with several negative environmental effects. For example, anaerobic degradation of food waste in landfills causes emission of methane, ammonia, and volatile fatty acids, and a high chemical oxygen demand

c. Benefits of utilizing food wastes for organic bio-fertilizer production in Brunei Darussalam (Continue)

References	Literature review
Bolan et al. (2014)	In addition, landfill leachates have a high potential to of polluting the surrounding surface waters and groundwater
Lin et al. (2013)	There has been promising research outcomes on converting food waste into **value-added products including bio-fertilizers, bio-fuels, and new and existing chemicals**
O'Connor et al. (2020)	Compared with chemical fertilizers, digested food waste fertilizer ought to have several environmental merits because **high-quality energy is gained** in the production process and the **nutrients are preserved** within the effluent, that is, the digestate
Du et al. (2018)	By reducing the demand for synthetic chemical fertilizers and replacing them with bio-fertilizer derived from food wastes, the **environmental impact of food wastes will significantly decrease and directly enhancing food production**



d. Limitations of using bio-fertilizer in Brunei Darussalam

In regards to cost-benefit analysis, however, there may be challenges when utilizing food waste for bio-fertilizer production in Brunei Darussalam.

According to results in Table 2, there were **2 papers recorded** (Mulani et al., 2017; Carvajal-Muñoz & Carmona García, 2012) which addressed on limitations of bio-fertilizer.

- Bio-fertilizers have naturally **lower macronutrients concentration** of **NPK** compared with commercialize chemical fertilizer (Mulyani et al., 2017).

- Therefore, **larger volumes of bio-fertilizer are required** in agriculture (Carvajal-Muñoz & Carmona García, 2012).

- This implies that there will be an **increase in production costs** because of the requirement for additional workforce, transportation and facilities to maximize the effectiveness of bio-fertilizers to the soil and crops in field application.

4. CONCLUSION & RECOMMENDATION

- In summary, a **total of 19 papers** on bio-fertilizer production in Brunei and **2,647 papers** on food waste organic bio-fertilizer were initially recorded using both Scopus database and Google Scholar (non-Scopus database).

- After a thorough screening, **only 2 papers on bio-fertilizer in Brunei** and **26 papers on food waste organic bio-fertilizer** were deemed eligible for the review study.

➢ To conclude, it is evident that **there is a lack of information or data regarding Brunei Darussalam's production and application of biofertilizer,** particularly derived from food wastes. The implications of organic bio-fertilizer appear a new concept in agriculture sector in Brunei Darussalam which might be because of **less awareness** and **confidence** in bio-fertilizer's practices.

➢ Additionally, an **effective strategy for food waste** disposal by **recycling or valorization into value-added products** will significantly enable to further improvement of wastes management matters in the country.

➢ To address the research gaps of application of organic bio-fertilizers production to soils, **field studies in Brunei Darussalam need to be pursued**.

REFERENCES

Abdul-Halim, A. M. A. A., Shivanand, P., & Taha, H. (2022). Performance of a selected Trichoderma strain as plant pathogen inhibitor and biofertilizer. *Malaysian Journal of Microbiology*, *18*(4), 446-454. doi: http://dx.doi.org/10.21161/mjm.211347

Areeshi, M. Y. (2022). Recent advances on organic biofertilizer production from anaerobic fermentation of food waste: Overview. *International Journal of Food Microbiology*, *374*, 109719. doi: https://doi.org/10.1016/j.ijfoodmicro.2022.109719

Arjjumend, H., Koutouki, K., & Donets, O. (2020). Advantages of Using the Biofertilizers in Ukrainian Agroecosystems. *Eurasian Journal of Agricultural Research*, *4*(2), 92–123. Retrieved from https://dergipark.org.tr/en/download/article-file/1315696

Chakravarty, I., & Mandavgane, S. A. (2020). Valorization of fruit and vegetable waste for biofertilizer and biogas. *Journal of Food Process Engineering*, *44*(2), 1–8. doi: https://doi.org/10.1111/jfpe.13512

Carvajal-Muñoz, J., & Carmona García, C. (2012). Benefits and limitations of biofertilization in agricultural practices [Review of Benefits and limitations of biofertilization in agricultural practices]. *Livestock Research for Rural Development*, 3-9. Retrieved from https://www.researchgate.net/publication/280581225_Benefits_and_limitations_of_biofertilization_in_agricultural_practices

Chen, J., Huang, G., Xiong, H., Qin, H., Zhang, H., Sun, Y., Dong, X., Lei, Y., Zhao, Y., & Zhao, Z. (2021). Effects of Mixing Garlic Skin on Fermentation Quality, Microbial Community of High-Moisture Pennisetum hydridum Silage. *Frontiers in Microbiology*, *12*. doi: https://doi.org/10.3389/fmicb.2021.770591

Dayarathna, S. G. A. R. M., & Karunarathna, B. (2021). Effect of Different Fruit Peel Powders as Natural Fertilizers on Growth of Okra (Abelmoschus esculentus L.). *Journal of Agricultural Sciences – Sri Lanka*, *16*(1), 67. doi: https://doi.org/10.4038/jas.v16i1.9184

de Medeiros, V. P. B., Pimentel, T. C., Varandas, R. C. R., dos Santos, S. A., de Souza Pedrosa, G. T., da Costa Sassi, C. F., da Conceição, M. M., & Magnani, M. (2020). Exploiting the use of agro-industrial residues from fruit and vegetables as alternative microalgae culture medium. *Food Research International*, *137*, 109722. doi: https://doi.org/10.1016/j.foodres.2020.109722

Department of Agriculture and Agrifood. (2022). Brunei Darussalam Agriculture and Agri-food statistics in Brief 2022. Retrieved from http://www.agriculture.gov.bn/SiteCollectionDocuments/Statistik/Agriculture%20%26%20Agrifood%20Statistics%20in%20Brief%202022.pdf

REFERENCES

Dlamini, M.P., Mukabwe, W.O, & Sibandze, N.N. (2021). The Effects of Organic Liquid Fertilizer (Vegetable Waste) on Moisture Retention, Soil Physical Properties and Yield of Lettuce (Lactuca Sativa L.) Grown in the Malkerns Area, a Region in the Kingdom of Eswatini. *Advances in Agriculture, Horticulture and Entomology*, *2021*(05). doi: https://doi.org/10.37722/aahae.2021502

Du, C., Abdullah, J. J., Greetham, D., Fu, D., Yu, M., Ren, L., Li, S., & Lu, D. (2018). Valorization of food waste into biofertiliser and its field application. *Journal of Cleaner Production*, *187*, 273–284. doi: https://doi.org/10.1016/j.jclepro.2018.03.211

Fisgativa, H., Tremier, A., & Dabert, P. (2016). Characterizing the variability of food waste quality: A need for efficient valorisation through anaerobic digestion. *Waste Management*, *50*, 264–274. doi: https://doi.org/10.1016/j.wasman.2016.01.041

Food and Agriculture Organization of the United Nations. (2013). The High-Level Multi-Stakeholder Consultation on Food Losses and Food Waste in Asia and the Pacific Region (pp. 1–44). Retrieved from https://www.fao.org/3/i3657e/i3657e.pdf

Gallagher, K. E., Kadokura, E., Eckert, L. O., Miyake, S., Mounier-Jack, S., Aldea, M., Ross, D. A., & Watson-Jones, D. (2016). Factors influencing completion of multi-dose vaccine schedules in adolescents: a systematic review. *BMC Public Health*, *16*(1). doi: https://doi.org/10.1186/s12889-016-2845-z

Jariwala, H., & Syed, H. S. (2016, November). Study on Use of Fruit Peels Powder as a Fertilizer. *Recent Advances in Environmental Sciences and Engineering*. Retrieved from https://www.researchgate.net/publication/319329572_Study_on_Use_of_Fruit_Peels_Powder_as_a_Fertilizer

Kang, S. M., Shaffique, S., Kim, L. R., Kwon, E. H., Kim, S. H., Lee, Y. H., Kalsoom, K., Aaqil Khan, M., & Lee, I. J. (2021). Effects of Organic Fertilizer Mixed with Food Waste Dry Powder on the Growth of Chinese Cabbage Seedlings. *Environments*, *8*(8), 86. doi: https://doi.org/10.3390/environments8080086

Kon, J. (2022, February 25). Making use of food waste. *Borneo Bulletin*. Retrieved from https://borneobulletin.com.bn/making-use-of-food-waste/

Lin, C. S. K., Pfaltzgraff, L. A., Herrero-Davila, L., Mubofu, E. B., Abderrahim, S., Clark, J. H., Koutinas, A. A., Kopsahelis, N., Stamatelatou, K., Dickson, F., Thankappan, S., Mohamed, Z., Brocklesby, R., & Luque, R. (2013). Food waste as a valuable resource for the production of chemicals, materials and fuels. Current situation and global perspective. *Energy & Environmental Science*, *6*(2), 426–464. doi: https://doi.org/10.1039/c2ee23440h

Moher, D., Liberati, A., Tetzlaff, J., & Altman, D. G. (2010). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. *International Journal of Surgery. 8*(5), 336–341. doi: https://doi.org/10.1016/j.ijsu.2010.02.007

REFERENCES

Mulyani, O., Trinurani, E., Sudirja, R., & Joy, B. (2017). The Effect of Bio-fertilizer on Soil Chemical Properties of Sugarcane in Purwadadi Subang. *ICSAFS Conference Proceedings, KnE Life Sciences*, *2*(6), 164–171. doi: https://doi.org/10.18502/kls.v2i6.1035

Nabayi, A., Sung, C. T. B., Zuan, A. T. K., Paing, T. N., & Akhir, N. I. M. (2021a). Chemical and Microbial Characterization of Washed Rice Water Waste to Assess Its Potential as Plant Fertilizer and for Increasing Soil Health. *Agronomy*, *11*(12), 2391. doi: https://doi.org/10.3390/agronomy11122391

Nabayi, A., Sung, C. T. B., Zuan, A. T. K., & Paing, T. N. (2021b). Fermentation of Washed Rice Water Increases Beneficial Plant Bacterial Population and Nutrient Concentrations. *Sustainability*, *13*(23), 13437. doi: https://doi.org/10.3390/su132313437

Nirmal, N. P., Khanashyam, A. C., Mundanat, A. S., Shah, K., Babu, K. S., Thorakkattu, P., Al-Asmari, F., & Pandiselvam, R. (2023). Valorization of Fruit Waste for Bioactive Compounds and Their Applications in the Food Industry. *Foods*, *12*(3), 556. doi: https://doi.org/10.3390/foods12030556

Nurcholis, J., Saturu, B., Syaifuddin and Buhaerah. (2020). Aplikasi Pupuk Organik Cair Limbah Kulit Nenas Terhadap Pertumbuhan Tanaman Kacang Panjang. *Jurnal Agrisistem*, 16(2), 100-107. Retrieved from https://ejournal.polbangtan-gowa.ac.id/index.php/J-Agr/article/view/167/163

O'Connor, J., Hoang, S. A., Bradney, L., Dutta, S., Xiong, X., Tsang, D. C. W., Ramadass, K., Vinu, A., Kirkham, M. B., & Bolan, N. S. (2020). A review on the valorisation of food waste as a nutrient source and soil amendment. *Environmental Pollution*, *272*, 115985. doi: https://doi.org/10.1016/j.envpol.2020.115985

Parewa, H. P., Joshi, N., Meena, V. S., Joshi, S., Choudhary, A., Ram, M., Meena, S. C., & Jain, L. K. (2021). Role of biofertilizers and biopesticides in organic farming. In *Advances in Organic Farming* (pp. 133–159). Woodhead Publishing. doi: https://doi.org/10.1016/b978-0-12-822358-1.00009-2

Pilarska, A. A., Pilarski, K., Ryniecki, A., Tomaszyk, K., Dach, J., & Wolna-Maruwka, A. (2017). Utilization of vegetable dumplings waste from industrial production by anaerobic digestion. *International Agrophysics*, 31(1), 93–102. doi: https://doi.org/10.1515/intag-2016-0033

Pirttilä, A. M., Mohammad Parast Tabas, H., Baruah, N., & Koskimäki, J. J. (2021). Biofertilizers and Biocontrol Agents for Agriculture: How to Identify and Develop New Potent Microbial Strains and Traits. *Microorganisms*, *9*(4), 817. https://doi.org/10.3390/microorganisms9040817

Shams, S., Juani, R. H. M., & Guo, Z. (2014). Integrated and sustainable solid waste management for Brunei Darussalam. In *5th Brunei International Conference on Engineering and Technology (BICET 2014)* (p. 1-6). doi: http://dx.doi.org/10.1049/cp.2014.1066

REFERENCES

Sogani, M., Sonu, K., Syed, Z., & Rajvanshi, J. (2023). Preparation of biofertilizer blend from banana peels along with its application in agriculture and plant microbial fuel cell. *IOP Conference Series: Earth and Environmental Science*, *1151*, 1–7. doi: https://doi.org/10.1088/1755-1315/1151/1/012034

Sulaiman, N. S., Rahim, S. M., Jopry, N. U., Roslan, A., Mohamad, A. S., Irwandy, H. A. A., & Hashim, N. (2023). Conversion of Kitchen Food Waste to Halal Organic Fertilizers. *Journal of Wastes and Biomass Management (JWBM)*, *5*(1), 08-14. doi: http://doi.org/10.26480/jwbm.01.2023.08.14

Sutikarini, S., Masulili, A., Suryani, R., Setiawan, S., & Mulyadi, M. (2023). Characteristics of Pineapple Waste as Liquid Organic Fertilizer and Its Effect on Ultisol Soil Fertility. *International Journal of Multi Discipline Science*, *6*(1), 38–45. doi: https://doi.org/10.26737/ij-mds.v6i1.3754

United Nations Environment Programme (UNEP). (2017). Summary report: Waste Management in ASEAN Countries. Retrieved from https://wedocs.unep.org/bitstream/handle/20.500.11822/21134/waste_mgt_asean_summ%20ary.pdf?sequence=1&%3BisAllowed

Wijaya, V. T., & Teo, S. S. (2019). Evaluation of Eggshell as Organic Fertilizer on Sweet Basil. *International Journal of Sustainable Agricultural Research*, *6*(2), 79–86. doi: https://doi.org/10.18488/journal.70.2019.62.79.86