Published by :
http://www.ijert.org
International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Volume 13, Issue 02, February 2024

Production and Characterization of Bio Fertilizer from Potato Peel

Tsiye Tekleyohanis Hailemariam, Dr Ravikumar Madugula, P Jagadeesh Babu
Chemical Engineering, Debre Brehan University, Debre Brehan, Ethiopia.
Chemical Engineering, Chalapathi institute of Engineering and Technology, lam,Guntur, Andhra Pradesh , India.
Design Engineering, Chalapathi institute of Engineering and Technology, lam,Guntur, Andhra Pradesh , India.

Abstract
In this study potato peels as waste are collected from homes and food processing factories. In which they need to be handled and managed in an appropriate way not only to avoid environmental pollution but also extend further apart by contributing towards economic boost from byproduct utilization. The main objective of this project is the production and characterization of biofertilizers from potato peels. To produce biofertilizer, first potato peels were collected, cleaned and prepared for fermentation. Different ratios of potato peels to water such as R1 (1:1), R2(1;3), R3(1:5) used together with retention days or fermentation days of 15, 20 and 25 days. The prepared raw materials were added to closed plastic bottles to conduct anaerobic fermentation. the fermentation process facilitated by fungas. The experiments were conducted for pH, viscosity and potassium content of the product. Finally, the appropriate product as a biofertilizer was found to be satisfactory from ratios 1 and 25 retention days. The result obtained was 750 ml of liquid biofertilizer with pH of 6.33, a viscosity of 120 and a potassium content of 0.75.

Keyword:- **Potato peels, bio-fertilizers, proximate analysis, retention days, anaerobicfermentation.**

INTRODUCTION

In today's word has dealing with two problems pollution and soil degradation and their solution is biofertilizers. Biofertilizers are containing beneficial microorganisms, offer a natural and cost-effective solution for enhancing soil fertility and improving crop productivity (May & Technologies, 2022).The process involves collection and pre-treatment of agro waste, then due to Fermentation breakdown of organic matter it result in the release of essential nutrients(Ezenwobodo & Samuel, 2022).A fertilizer is any substance, whether of natural or synthetic origin, applied to soil or plant tissues to provide plant nutrients is referred to as a fertilizer. There are numerous natural and man-made sources of fertilizer. With the exception of the sporadic inclusion of supplements like rock dust for micronutrients, fertilization for the majority of modern agricultural methods concentrates on the three basic macronutrients of Nitrogen (N), Phosphorus (P), and Potassium (K). These fertilizers are applied by farmers in a variety of ways: employing dry, pelletized, or liquid application techniques, heavy agricultural machinery, or hand tools (Fnca et al., 2006).

In the past, natural or organic sources of fertilizer included compost, animal or human waste, mined minerals, crop rotations, and byproducts of human-nature activities (such as waste from the processing of fish or blood meal from animal slaughter)(Osorio-Reyes et al., 2023). The usage of nitrogen fertilizers increased specifically because of nitrogen-fixing chemical processes, including the Haber process at the turn of the 20th century, which was made worse by the expansion of manufacturing facilities during World War II. Inthe latter half of the 20th century, increased use of nitrogen fertilizers (800% increase between 1961 and 2019) has been a crucial component of the increased productivity of conventional food systems (more than 30% per capita) as part of the so-called "Green Revolution"(Leila & El-Hafid, 2020).

It has been established that intensive crop production can result in soil degradation, environmental pollution, and lower yields if inorganic fertilizers are used continuously and improperly. Biofertilizers, on the other hand, have the potential to enhance the soil's chemical, physical, and biological properties(Sumathy, 2017). Biofertilizers are well-known for being economical, environmentally friendly, and of high quality. As an alternative to harmful synthetic fertilizers, these work well(Devi & Judia Harriet Sumathy, 2018). Potato peel has been efficiently used for the synthesis of Biofertilizers(Javed et al., 2019). After being broken down by soil microorganisms, PP's protein and starch content yield fertilizers with a high nitrogen content. The bacterial count of vermicompost made from potato peel earthworms (Pheretima elongate) was higher than that of the soil around it. A useful biofertilizer for land application, the slurry from the PP biogas plant

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Volume 13, Issue 02, February 2024

(anaerobic digester) replenishes soil nutrients. Similarly, for the production of biofertilizer, cow dung, neem leaves, potato peel, legume peel, and cow dung were fermented in water for 45 days(Sandhu, n.d.),(Kumar, 2022). Biofertilizers can be made from potato peel, a byproduct of the food processing industry that is valuable, inexpensive, and inexpensive. Every year, between 70 and 140 thousand tons of peels are produced worldwide through industrial processing(Osorio-Reyes et al., 2023).A promising tool in agricultural ecosystems is the production of bio-fertilizers from potato peels as a supplement, renewable, and environmentally friendly source of plant nutrients. because it can transform nutrients into highly attackable forms from non-usable ones without harming the naturalenvironment.

It is believed that applying biological fertilizers is a crucial component in maintaining sufficient crop productivity and soil fertility, both of which are necessary for farming to be sustainable(Guanabara et al., n.d.).By turning organic waste into biofertilizers, polluting power can be reduced and a cheaper or even free source of organic matter fertilizer can be obtained. The purpose of this study is to produce biofertilizer from potato peels, examine the product's fertilizing power, physiochemical analysis of waste, mixing ratio, and moisture content, and more(Javed et al., 2019).

MATERIAL AND METHODS :

The biofertilizer production line was completed set of equipment from raw materials collection to the biofertilizer packing.The sample was prepared in the correct proportion(Rani & Sengar, 2020) and characterization of organic matter; the carbon content and moisture content of the sample were determined(Wyciszkiewicz et al., 2019). Then the sample was sent to the prepared bin for the composting process. After the composting process was performed for four weeks, it was sent to the laboratory to characterize the product.

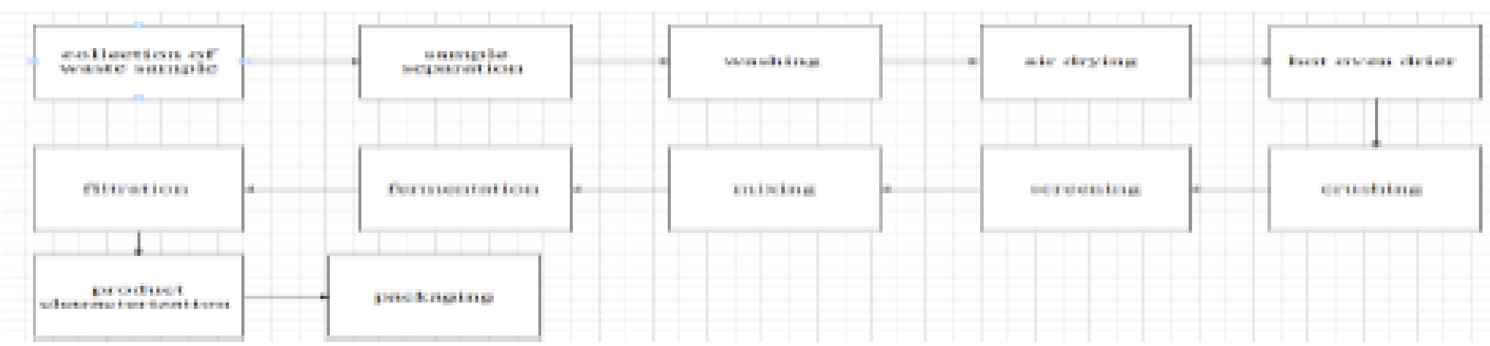

Figure 1. Block flow diagram for the production of biofertilizer

Source: (Sahib & Pradesh, 2021)

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Volume 13, Issue 02, February 2024

COLLECTION AND PREPARATION OF RAW MATERIAL:

Ancording to (Sumathy, 2017): Potato peels were collected from chip-selling shops. The raw materials were pre-treated by the removal of the unwanted substance. The potato peels were washed with water to remove impurities. The potato peels were dried for more than an hour at 100 degrees Celsius in the hot oven(Javed et al., 2019). The potato peels were cooled to lower their temperature after being dried. After that, five 4mm-diameter mesh sieves were used to crush and separate them(Gowthami & Neethu, 2020).

Figure 2. Potato peel separation

Source:- Current Work

Figure 3. Screening

Source:- Current Work

One hundred seventy grams (170 g) of potato peel was measured using a weighing balance. Thebiomass was blended and mixed with water based on the experimental design values was stated (Wyciszkiewicz et al., 2019)

Figure 4.Sample Fermentation

Source:- Current Work

After the retention period of each sample, the substrate was collected and filtered. Thensamples of the soluble product were taken for elemental analysis (Leila & El-Hafid, 2020)

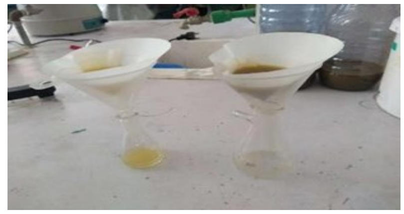

Figure 5.Sample Filtration

Source:- Current Work

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Volume 13, Issue 02, February 2024

CHARACTERIZATION OF RAW MATERIAL:

Moisture content determination

According to (Devi & Judia Harriet Sumathy, 2018b): the mass in grams of clean foil was recorded. On the foil, the sample of wet potato peels was crumbled. Together, the potato peels and foil were weighed in grams (m^2). As a sample, 3 grams of potato peels were taken. The potato peels and foil were cooked in the oven. After that, the sample was dried for 30 minutes in a drying oven that was controlled by a thermostat and kept at 105 degrees Celsius. The dried potato strips were removed from the stove then the mass of the example was estimated on balance.

Moisture content (dry basis), $W = \frac{(wt1-wt2)}{wt2} * 100$ .... (1)

Moisture content (wet basis), $W = \frac{(wt1-wt2)}{wt1} * 100$ .... (2)

Where:-

Wt1 = weight of the original representative sample before drying

Wt2 = weight of the secondary dried sample

Ash Content Determination

The potato peels' moisture content was initially removed. The amount of ash in the potato peel sample was measured by weighing it before and after the ash was added. Three grams of the sample were taken, and it was heated for two hours at 600°C in a muffle furnace. This equation is used to ascertain the potato peels ash content(Yunus et al., 2022).

$$\%Ash(wet\ basis) = \frac{w_3 - w_1}{w_2 - w_1} \quad (3)$$

$$\%Ash(dry\ basis) = \frac{w_2 - w_1}{wet\ sample} \quad (4)$$

Where w1 = weight of the empty crucible

W_2 = weight of crucible + sample before ash, W_3= weight crucible + ash all in grams

Volatile matter

Similar to the ASTM Standard (ASTM 1982), the potato peel waste is heated for seven minutes without coming into contact with air in a vertical tube furnace at 950°C. The sample is weighed after seven minutes of drying at 950°C. The formula is

$$\%VS = \left[\frac{dry\ sample\ weight - ash\ weight}{dry\ sample\ weight}\right] - \%MC \quad (5)$$

Fixed carbon

Fixed carbon content is calculated from 100% reduced by moisture content, ash content and volatile matter (ASTM D3173). The reduced moisture content means that the fixed carbon is higher(Atieno et al., 2020).

Fixed Carbon = 100% – (moisture content % + Ash content % + Volatile matter %) (6)

Organic Matter and Organic Carbon :

The sample of food waste is dried for one hour in an oven at 105°C before being burned in a furnace at 550°C for one hour to determine its organic matter.

$$TOM(\%) = \frac{sample\ weight@105℃ - sample\ weight@550℃}{sample\ weight@105℃} * 100\% \quad (7)$$

Where: TOM = Total organic matter

TOC = total organic carbon.

In the ultimate analysis percentage of C, H, O, and N, of the food wastes were determined.

Total Carbon was determined from the formula:

$$TOC(\%) = \frac{TOM}{1.8}$$

Total Nitrogen is carried out using the standard of hydrogen and oxygen is analyzed from the water content of the sample

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Volume 13, Issue 02, February 2024

$$\%Hydrogen = \frac{\%moisture}{molecular\ weight\ of\ water} * molecular\ weight\ of\ hydrogen \quad (9)$$

$$\%oxygen = \frac{\%moisture}{molecular\ weight\ of\ water} * molecular\ weight\ of\ oxygen \quad (10)$$

Characterization of biofertilizer:

Determination of nitrogen (N):

Digestion:

A Kjeldahl flask was used to measure 20 milliliters of the sample, and 8 grams of K2SO4 and 1 gram of CUSO4 were added to the Kjeldahl flasks. After adding 30 milliliters of H2SO4, the Kjeldahl unit's water aspirator was slowly added. In addition, the fume extraction fan was activated. Burners were set to high for two hours while the sample was digested. After that, a beaker was placed on a heating mantle and heated to a boil. The boiled sample was allowed to cool for two hours(Gowthami & Neethu, 2020).

Distillation

For each run of samples, 50 milliliters of boric acid were measured in 200 milliliter Erlenmeyer flasks. For distillation, the samples were placed on a Kjeldahl unit. Separate burettes containing sodium hydroxide and distilled water were filled, and water was turned on for condensing. The burette was slowly filled with 100 milliliters of sodium hydroxide until the orange-colored boric acid returned to its original color.

Titration:

The liquid in the Erlenmeyer flask was titrated using 0.1N H2SO4. Titration was carried out until the blue liquid turns orange. The burette reading was then taken and the percentage of nitrogen was calculated.

Calculation

$$\%nitrogen = \frac{ml\ titrated - blank}{sample\ wt\ in\ grams}$$

Determination of phosphorus (P)

Treatment of the sample

In a 125 ml Erlenmeyer flask or clean, dry test tube, add

50 milliliters of samples. Phenolphthalein indicator, equivalent to one drop, should be added. To adjust the color's discharge, add 5N H2SO4 solution drop by drop if the color develops. Add 8 milliliters of combined reagent and thoroughly mix. Utilizing the reagent blank as the reference solution, measure the absorbance of each sample at 88 nm after at least 10 but no more than 30 minutes(Karthikeyan & Sivasakthivelan, n.d.).

Figure 6. Samples Before the Addition of Phenolphthalein

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Volume 13, Issue 02, February 2024

Figure 7. Samples After the Addition of Phenolphthalein
Source:- Current Work

PREPARATION OF CALIBRATION CURVE :

Within the phosphate ranges outlined in 4500-P.E.1c, the sample was prepared using individual calibration curves from a series of four to six standards, including a calibration blank. Reagent water and the combined reagents make up the calibration blank. With each set of samples, plot an absorbance versus phosphate concentration graph and test at least one phosphate standard.

Table 1.Standard Concentration and Absorbance of Potassium

Concentration	Absorbance
0.1	0.12756
0.15	0.18734
0.2	0.24712
0.25	0.3069
0.3	0.36668
0.4	0.48624

Source: current work, according to (Wyciszkiewicz et al., 2019), (Rani & Sengar, 2020)

The equation of the line of absorbance versus concentration of phosphorus standard curve in milligram/litre is:- $y = 30.249x – 1.9052$, where y is concentration and x is absorbance.

Table 2. Result of Concentration

The absorbance of the sample	X
The concentration of the sample	Y

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Volume 13, Issue 02, February 2024

Calculation of Phosphorus by Klett Summerson Method

$$\%phosphorus = \frac{Y}{1,000,000} * 50 * \frac{100}{10} * \frac{100}{0.2} \quad (12)$$

Determination of potassium (K)

Estimation of potassium by flame photometer method reagent:

Stock solutions of potassium Preparation of standard curve:-0, 1, 2, 4, 6, 8 and 10 ml of stock solution is pipette out in a 100-ml volumetric flask. The volume is marked up to the mark with the addition of distilled water. It gives 0, 10, 20, 40, 60, 80, and 100 ppm of potassium respectively. The intensity of potassium at the flame photometer is observed. The sample is aliquot directly with a flame photometer. Work out the ppm of potassium from the standard curve and run a blank readi reading.

Generating standard curve and determining the potassium concentration of a sample

Tube	Concentration	Absorbance
1	0.1	184
2	0.15	195
3	0.2	206
4	0.25	228
5	0.4	264

Table 3.Standard Potassium Concentration Absorbance Value

Source: (Wang et al., 2022)

Table 4. Result of Potassium Concentration on The Sample

the absorbance of the sample	y
the concentration of the sample	x

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Volume 13, Issue 02, February 2024

Percentage of potassium = X
x x 100 × 100, x is the concentration of the sample.
0.2
1000,000

PH DETERMINATION OF BIOFERTILIZER :
After the liquid biofertilizer samples have been filtered, the PH value of the biofertilizer was determined using a PH meter. Distilled water was used to remove the unwanted solution from the pH meter device(Asadu et al., 2020).

RESULT AND DISCUSSION :

This chapter focused on studies here include quantitative analyses of product components obtained by laboratory analysis. To thoroughly investigate the effect of operating parameters on the quality of biofertilizers, the focus area in the analysis of the results was directed towards the following points:

- The Physiochemical Characterization of Food Solid Waste
- Product Characterization

Physicochemical Characteristics of potato peel and other biomass

Table 5. Result of physiochemical characteristics of potato peel and other biomass

Biomass(wet Basis)	M	A	VM	FC	TOM	TC	O2	H2	Reference
Potato peel	69	2	27.3	1.7	93	52	3.9	61.3	Current Study
Root and stem plant	22.30±30	0.45±0.19	27.5	2.2	78	61.5	4.4	60	(Lim & Matu, 2015)
Flower and Fruit	19.24±0.21	0.77	26	1.4	88	77	5.1	55	(May & Technologies, 2022)
Leaf crop	15.60	0.42	29	3.4	85	32		58	(Gowthami & Neethu, 2020)

Published by :
http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Volume 13, Issue 02, February 2024

Where: M: Mositure content(%), A: Ash(%), VM: Volatile Matter(%), FC: Fixed Carbon(%), TOM: Total organic matter(%), TC(%): Total Carbon, O: Oxygen(%) and H: Hydrogen(%)

The above table is the result of the physiochemical properties of potato peels that have been experimented with in the laboratory. The physical and chemical properties of potato peels can be changed in terms of their peeling method. The peeling method is a critical factor affecting the chemical composition and further utilization suitability of potato peel. Periodically, the physical and chemical parameters were determined. Compost was created after a 15-day decomposition procedure. When it came to potato waste, the inoculum application signaled the beginning of the decomposition process, which was then clearly seen after 5 days by the development of microbial growth. There was a sudden drop in volume and color, a nice odor developing, changes in texture, and decreased water activity.

The following days showed a quick occurrence of the same observation. On the fifteenth day, the complete decomposition was clearly visible. It was distinguished by a sharp reduction in volume (by about one-fourth of the volume), complete decolorization, complete absence of water content, and complete conversation of finely ground powder, all of which indicate the breakdown of vegetable waste into fine powder. There are two peeling methods

- Steam peeling – requires 100% peel removal.
- Abrasive peeling – don't require 100% peel removal.

The peeling method affects hemicellulose, lignin, cellulose ash, protein content, cellulose, starch content and so many physiochemical properties of potato peel. This research used potato peels extracted using hand with a large amount of starch.

Characteristics Biofertilizer :

Table 6.Result of the characteristics of liquid biofertilizer

Experiment	Factors		Response				
	Days	Ratio	PH	Viscosity	K%	N%	P%
1	15	1:1	4.7	119	2.64	0.73	0.42
2	15	1:3	5.4	122	2.55	0.65	0.38
3	15	1:5	6.71	124	3.52	0.61	0.33
4	20	1:1	4.4	117	3.68	1.43	1.4
5	20	1:3	5.2	120	2.62	1.31	1.08
6	20	1:5	6.4	122	3.63	1.21	1.03
7	25	1:1	3.9	116	1.34	3.16	1.53
8	25	1:3	4.96	119	3.95	2.98	1.15
9	25	1:5	6.33	120	2.75	2.8	1.08
STANDARD[1]			6-7.5		1.6-1.7	0.5 – 3.5	0.4-1.1

Source: Standard[1] ,(Devi & Judia Harriet Sumathy, 2018b)

PH VALUES :

Table 6 shows the results of pH and potassium content analyses for the potato peel of biofertilizers. The pH values show that all the biofertilizers are acidic for all run. The avarage orange biofertilizer has pH value of 4.08, which is the lowest among all the other biofertilizers(Gowthami & Neethu, 2020). These results show that citrus orange biofertilizer has the highest acidity value compared to other biofertilizers meanwhile water melon biofertilizer has the lowest acidity in this study(Lim & Matu, 2015).

POTASSIUM :

Results revealed that the total potassium also increased at the final stage of composting. These increased levels of TK at the final product than the initial feed substrate indicate that the microbial used as facilitator also influences the level of available potassium (Tables 6). Acid production by the micro organisms seems to be prime mechanism for solubilizing the insoluble potassium.

NITROGEN CONTENT **:**

The nitrogen content in the mixture increased gradually in all the samples and this increase was the highest significant at, 2.28%; followed by 3.16%. According to(Wyciszkiewicz et al., 2019) reduction in organic carbon due to substrate uti lization by microbes and earthworms and their metabolic activities as well as water loss by evaporation during mineralization of organic matter might be responsible for nitrogen addition. The study conducted by(Lim & Matu, 2015) indicated increased values of *Azotobacter* (the nitrogen fixing bacteria) in verm icompost as compared to the conventi onal aerobic and anaerobic composts.In the present study the higher amount of potassium was observed in all the experiments while it was lower in raw sago waste (0.36%). The highest potassium (3.68%) was recorded.

PHOSPHORUS

The total phosphorus increased significantly in the experimental setup than the control (Tables 6). Increase inTP during compost formation by bacterial action is probably due to mineralization and mobilizationof phosphorus and enzymatic activity of bacteria.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Volume 13, Issue 02, February 2024

TOTAL CARBON

Total organic carbon decreased more significantly with time in experimental setups compared to control at the final stage of compost formation (6). The final reduction in TOC values was possibly due to the rapid respiration rate that leads to the loss TOC in terms of CO_2 or was probably due to the fact that the organic carbon was utilized by the microbes and resulted in reduction in TOC.

CARBON- NITROGEN RATIO (C: N)

The C N ratio has decreased drastically during compost formation. The CN ratio traditionally
considered as a parameter to determine the degree of maturity of compost. C N ratio below 20 is an indication of acceptable maturity. While a ratio of 15 or below being preferable. (Gowthami & Neethu, 2020) Referring to this study, the CN ratio of the compost prepared using microbial inoculum is also within the acceptable limit (Tables 6). During biofertilizer production from potato peels and other biomass with in the process biogas generation occurred according to (Javed et al., 2019). But further study need to determine the quality and the amount biogass.

CONCLUSION:

Potato peel wastes contain a high fraction of protein and starch which can be transformed to valuable biofertilizer through anaerobic digestion which is technically simple, economically viable and easily adaptable to construct. In this research, the physiochemical property of potato peels and their biofertilizer product was conducted and determined the effect of the ratio of potato peel to water and retention days on the quality of the produced biofertilizer. Higher retention days increase the fermentation time therefore there is a higher amount of nutrients available for soil amendment. The ratio of potato peels to water has a higher effect on the number of nutrients in the biofertilizer. The ratio of potato peels to water with 1:1, 1:3 and 1:5 and used cow dung for the co-digestion process. Co-digestion of cow dung with potato peel helps to reduce the imbalance of nutrients in the product. The result obtained from the ratio of 3(1:5) and 25 retention days is close to the standard value of biofertilizer products. The results of ratio 3 and 25 retention days are with pH of 6.33, a viscosity of 120, potassium of 0.75, a nitrogen content of 2.8% and a phosphorus content of 1.08.

Conflict of interest: The authors have no conflicts of interest regarding this investigation.

Acknowledgments : Iam very happy to write this article and thankful to all authors who supported for this article

REFERENCE :

Asadu, C. O., Ike, I. S., Onu, C. E., Egbuna, S. O., Onoh, M. I., Mbah, G. O., & Eze, C. N. (2020). Investigation of the influence of biofertilizer synthesized using microbial inoculums on the growth performance of two agricultural crops. Biotechnology Reports, 27, e00493. https://doi.org/10.1016/j.btre.2020.e00493

Gowthami, S., & Neethu, C. S. (2020). Production Of Bio Fertilizer From Tuber Crops Waste - An Review. 11(3), 24–28.

Javed, A., Ahmad, A., Tahir, A., Shabbir, U., Nouman, M., & Hameed, A. (2019). Potato peel waste—its nutraceutical, industrial and biotechnological applacations. AIMS Agriculture and Food, 4(3), 807–823. https://doi.org/10.3934/agrfood.2019.3.807

Kumar, S. (2022). Conversion of sago wastes for biofertilizer production using Lampito mauritii and its effect on growth performance of Amaranthus campestris.

Leila, B., & El-Hafid, N. (2020). Biofertilizers and Biopesticides: Microbes for Sustainable Agriculture. 257–279. https://doi.org/10.1007/978-981-15-3208-5_10

Lim, S. F., & Matu, S. U. (2015). Utilization of agro-wastes to produce biofertilizer. International Journal of Energy and Environmental Engineering, 6(1), 31–35. https://doi.org/10.1007/s40095-014-0147-8

May, J., & Technologies, E. (2022). BIOFERTILIZER USING PROTEASE ENZYME OBTAINED FROM PAPER INDUSTRY WASTE. 9(5), 738–750.

Osorio-Reyes, J. G., Valenzuela-Amaro, H. M., Pizaña-Aranda, J. J. P., Ramírez-Gamboa, D., Meléndez-Sánchez, E. R., López-Arellanes, M. E., Castañeda-Antonio, M. D., Coronado-Apodaca, K. G., Gomes Araújo, R., Sosa-Hernández, J. E., Melchor-Martínez, E. M., Iqbal, H. M. N., Parra-Saldivar, R., & Martínez-Ruiz, M. (2023). Microalgae-Based Biotechnology as Alternative Biofertilizers for Soil Enhancement and Carbon Footprint Reduction: Advantages and Implications. Marine Drugs, 21(2). https://doi.org/10.3390/md21020093

Rani, V., & Sengar, R. S. (2020). Use of potassium bio-fertilizers technology for sustainable agriculture in dry areas. Journal of Pharmacognosy and Phytochemistry, 9(6), 1944–1946.

Sumathy, D. V. J. H. (2017). Biofertilizer Production From Agro - Wastes. World Journal of Pharmaceutical Research, November, 1112–1124. https://doi.org/10.20959/wjpr20179-9323

Wyciszkiewicz, M., Sojka, M., & Saeid, A. (2019). Production of phosphorus biofertilizer based on the renewable materials in large laboratory scale. Open Chemistry, 17(1), 893–901. https://doi.org/10.1515/chem-2019-0057