A Systematic Approach for the Paper Review on the Utilization of Citrus Fruit Waste in the Philippines

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Abstract: One of the main contributors to the waste problem in the Philippines is citrus fruits because of their high yield. Various studies have investigated the utilization of citrus fruit waste for different applications. However, there is a lack of a systematic mapping study that can bring these studies together. Thus, this study employed a systematic approach to determine the utilization of citrus fruit wastes which will be beneficial to reduce waste in the landfill. This study sought to: 1) investigate the trends in current research on citrus fruit waste utilization, 2) identify the processes undergone by citrus fruit waste to achieve their respective applications, and 3) observe the techniques that have been utilized to evaluate the efficiency and performance of citrus fruit waste products. The study performed a general search for papers related to citrus fruit waste utilization in Scopus search engine. The documents were organized into specific categories, and data extraction was performed. After the data was analyzed and the following results were obtained: there is a continuous increase in the amount of research on citrus fruit waste utilization, citrus fruit peels are the most commonly used type of waste, citrus fruit wastes undergo rigorous processes that mostly involve heat to reach their applications, and most studies utilize pore size and BET surface area to evaluate fruit waste products. In conclusion, citrus fruit waste utilization is a topic with great potential, and will contribute to solving the waste management problem in the country.

Key Words: citrus fruit waste; waste treatment; environment; systematic mapping study; sustainable management

1. INTRODUCTION

The Philippines is a tropical country with a high production of fruit-related products yielding high amounts of fruit waste (Zafar, 2020; PSA, 2019a, 2019b, 2019c, 2019d). In 2015, it imported over 86,967 metric tons of citrus fruits, contributing to the amount of citrus fruit waste in the country (PSA, 2015). Solid waste management is an issue in the country due to the high rates of waste generation (Atienza, 2020). Thus, the majority is placed into dumpsites or waterways, contributing to flooding and pollution (Flores et. al., 2018). Data shows that 95% of household solid waste can be reused. 43% of which can be recycled and 52% can be composted (Castillo & Otoma, 2013). This implies that there is a lack of awareness for their usefulness and has led to the belief that most solid waste is purposeless.

One topic of interest is the use of citrus fruit waste, which is rich in carbon and has been observed in wastewater treatment as an absorbent for wastewater contaminants (Pathak et.al. 2017). Common and sustainable citrus fruit waste utilization methods such as biochar, nanocatalyst, and activated carbon were discussed in research regarding citrus fruits. Biochar is a crushed carbon material modified through physical and chemical activation processes utilizing raw waste materials such as sewage sludge. It is utilized as an adsorbent of pollutants, catalysts, and soil amendment (Cha et al., 2016). Contrarily, activated carbon (AC) has high levels of porosity, adsorptive capacity, and surface area. It is also activated using either physical or chemical processes through agricultural bio-waste materials such as palm shells. Lastly, nanocatalysts are yielded from nanomaterials and are applied in carbon nanotubes, water purification, and biodiesel production (Chaturvedi et al., 2012).

In this study, a systematic mapping approach will be utilized to gather and synthesize data (Petersen, 2015). This is employed to create an overview of a research area without progressing it. It serves only as a congregation of published knowledge within a given limit and to identify knowledge gaps for future research. (James, 2016). As it stands, there have been numerous studies related to citrus fruit utilizations, but a lack of a systematic mapping study that can collect and bring all of these studies together.

In this paper, we will employ a systematic mapping approach for the utilization of citrus fruit wastes that can be applied in the Philippines. The objective of the study is to create a framework for the systematic mapping of the different applications of citrus fruit waste through literature search, in terms of; their utilization, processes, and performance. Recent trends and advances in the studies will also be examined. The scope of this study will be limited to citrus fruits local to the Philippines, such as calamansi, pomelo, and orange. Aside from this, the study will also be limited to sustainable biomass utilization methods, like activated carbon, biochar, and nanocatalysts. This research will be considered as a desktop study; it will focus on the data analysis of literature for results. Only research published from 2009 to 2020 in the English language found in Scopus will be included.

2. METHODOLOGY

The systematic mapping approach was used in this study to provide an overview of the different utilizations of citrus fruit waste. This study will follow a systematic approach shown in Figure 2.1 which were adapted from a study by Petersen et. al in 2008.

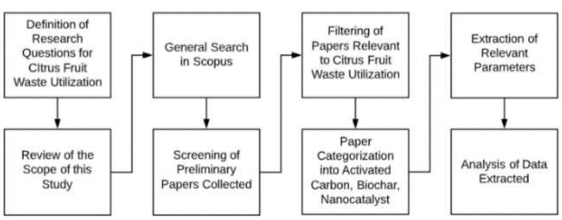

Figure 2.1 *Systematic Mapping Process for Citrus Fruit Waste Utilization*

2.1 Definition of Research Questions and Review of Scope

For this study, the following research questions were identified:

1. What are the trends in the current research on citrus fruit waste utilization?
2. What are the processes undergone by citrus fruit waste to achieve their respective applications?
3. What techniques have been utilized to evaluate the efficiency and performance of citrus fruit waste products?

As a review of scope, this study will focus on citrus fruits that are abundant and originate from the Philippines and will only consider studies published in Scopus between 2009 and 2020.

2.2 General Search

In compliance with the scope mentioned for this study, a search protocol was formulated. Firstly, the search engine chosen for this study was Scopus and the primary method of search was through article title, abstract, and keywords. The search utilized Boolean operators to limit the results appropriately and only considered papers that were published between 2009-2020 and in the English language. The search string utilized for the search was: (TITLE-ABS-KEY (citrus AND (sinensis OR grandis OR microcarpa OR poonensis OR maxima OR citrofortunella)) AND TITLE-ABS-KEY (waste AND material)).

2.3 Filtering of Relevant Papers and Categorization

The papers returned by the search string were filtered by the reading of their abstract, title, and keywords. Only papers deemed relevant to the study were collected for data extraction. The papers would be categorized into activated carbon, biochar, and nanocatalyst.

2.4 Extraction of Relevant Data and Analysis

Extraction of relevant information was then performed. Specific parameters from each paper were observed and recorded for further analysis and comparison. For activated carbon, the parameters that would be observed are particle size, BET surface area, and maximum adsorption capacity. For biochar, the parameters that would be recorded are BET-N2 specific surface area, total pore volume, and ash content. Lastly, for nanocatalysts, the parameters that would be observed are utilization and yield. Then, the recorded data would be analyzed and presented using graphs and figures.

3. RESULTS AND DISCUSSION

RQ1: What are the trends in the current research on citrus fruit waste utilization?

The search string that was previously defined returned 145 papers, 91.7% of which were published as journal articles, while the rest were presented as a conference paper or included in a book chapter. Through a search analysis within Scopus, it can be seen in Figure 3.1 that there has been a progressive increase in the amount of studies related to citrus fruit waste utilization. Of the 145 results, only 55 were found to be relevant to this study, 38% of which were related to activated carbon, 29% of which were under biochar, and 33% were under nanocatalyst as seen in Figure 3.2.

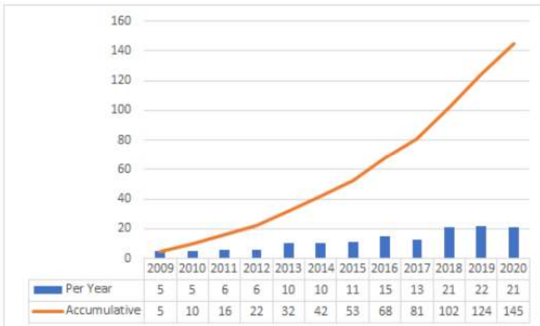

Figure 3.1 *Number of papers throughout 2009-2020.*

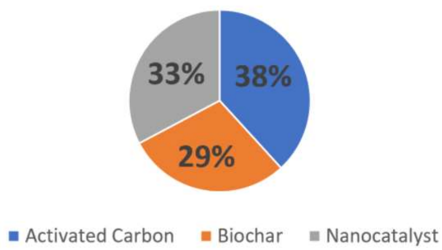

Figure 3.2 *Classification of selected papers based on type of citrus fruit waste utilization.*

RQ2: What are the processes undergone by citrus fruit waste to achieve their respective applications?

Biochar

The production of biochar requires the heating of a biomass with little to no oxygen. This was observed to be commonly through pyrolysis, as 13 of the 16 collected studies utilized this method. The figure below shows the process of biochar production.

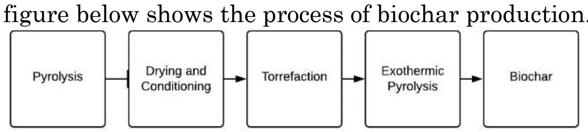

Figure 3.3 *Process of Biochar Production*

In pyrolysis, Drying and Conditioning occurs when biomass is dried in the temperatures between 100°C and 150°C for a moisture content of 15%. Next, Torrefaction enables the biomass to be grinded as it is heated to higher temperatures between 200°C and 280°C. Exothermic Pyrolysis then occurs when the temperature reaches 250°C to 300°C up until 400°C where the molecular bonds are broken further (Biochar for Sustainable Soils, n.d.).

Activated Carbon

Activated carbon production requires activation of a biomass. In the context of citrus fruit waste, peels are the most commonly used biomass. This is subjected through activation to produce porous material and can occur physically or chemically. Seven (7) of the 21 researched papers utilized physical activation, while 14 utilized chemical activation. The figure below shows the process of activated carbon production.

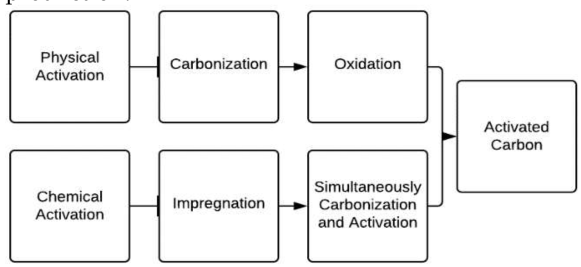

Figure 3.4 Process of Activated Carbon Production

In physical activation, the material undergoes carbonization before activation. During carbonization, the material is placed into a furnace where it is cooked at extreme temperatures ranging from 600-900°C for several hours. Certain studies have noted that higher carbonization temperatures have led to higher adsorptive capacity (Zeng et. al., 2013). Next, oxidation occurs through a process involving steam, where the carbonized material is exposed to oxidizing atmospheres in the form of steam at temperatures above 250°C.

In chemical activation, the carbon material is impregnated with certain chemicals, typically acids or strong bases. This is done by crushing and milling the material into small particles which are then mixed with the desired chemicals. Once the impregnation process is finished, the material is subjected to temperatures between 250-600°C where it is simultaneously carbonized and chemically activated. Then, the resulting carbon is washed with water to remove remaining acid and is subsequently dried.

Nanocatalysts

Nanoparticle production is mostly done through green synthesis as it is environmentally friendly and efficient. All 18 studies collected for nanocatalysts utilized green synthesis as their method of production. The figure below shows the process of nanocatalyst production.

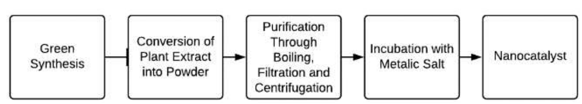

Figure 3.5 *Process of Nanocatalyst Production*

Green synthesis utilizes microorganisms to produce nanoparticles and is achieved through the selection of an environmentally acceptable solvent and appropriate reducing agents (Jegadeeswaran et. al., 2012). In the context of citrus fruit waste, fruit peels are regularly utilized as the reducing agents.

The process of green synthesis begins with the chosen parts of the plant, which are washed then cut into small pieces. Afterwards, the small pieces are finely grinded and boiled in water for several hours. The extract can be further purified through filtration and centrifugation. Once the extract is complete, the appropriate metallic salt is incubated with the extract in water to produce the nanoparticles of the desired metal ion.

RQ3: What techniques have been utilized to evaluate the efficiency and performance of citrus fruit waste products?

Biochar

BET-N2 Specific Surface Area

Figure 5.3.1.1 illustrates the surface areas of the biochar wherein the largest surface area is found to be 2457.367 m2/g in Cheng et al. (2020). For the least of the biochar, it would be 0.21 m2/g in Abdelhafez (2016). It can also be observed that the majority of the results ranged from 6.7 - 53 m2/g.

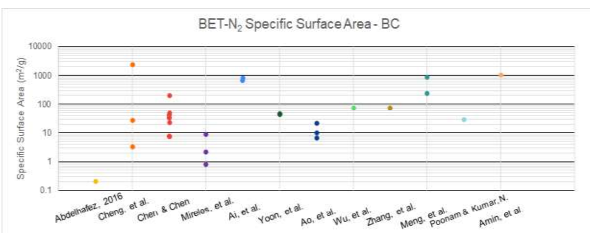

Figure 3.6 *BET-N2 Specific Surface Area*

Total Pore Volume

For Figure 5.3.1.2, it illustrates the total pore volume of gathered works. The largest pore volume of 1.14 cm3/g found in Cheng et al. (2020) and the least in Abdelhafez (2016) with 0.00016 cm3/g. The majority of the results appear to lie within 0.008 - 0.035 cm3/g.

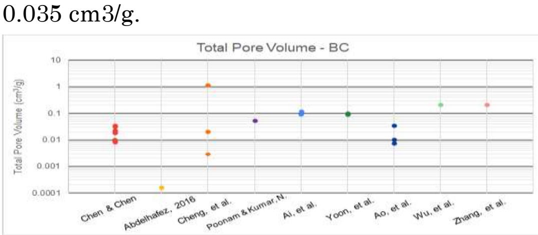

Figure 3.7 *Total Pore Volume - BC*

Ash Content

In Figure 3.8, the study with the highest ash content observed was 34.22% in Ai, et al. (2020). Meanwhile, the least observed was 0.30% found in Chen and Chen (2009), utilizing similar materials to Ai et al. (2020), but differing in their preparation and processes.

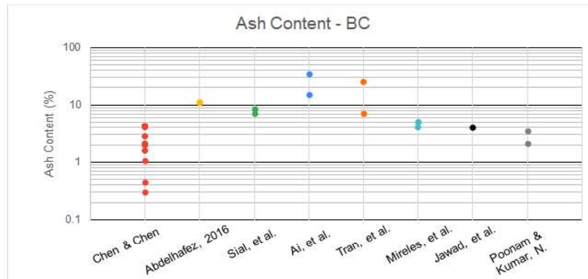

Figure 3.8 *Ash Content - BC*

Activated Carbon

Particle Size

In Figure 3.9, the activated carbon with the smallest particle size is ≤0.063 mm from Nemr et al. (2009) and the largest is 0.5 mm from both Fernandez, et al. (2015), and Oruc, et al. (2019).

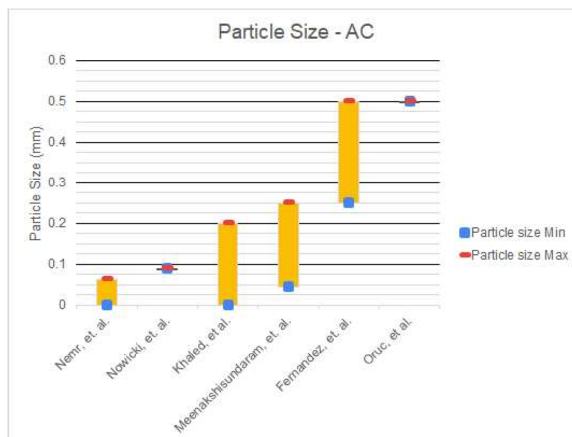

Figure 3.9 *Particle Size - AC*

BET Surface Area

The largest BET surface area observed was 2209.17 m2/g in Wei et al. (2019) as they chemically activated orange peels with phosphoric acid. For the smallest BET surface area, it was 2.6 in Li et al.(2016).

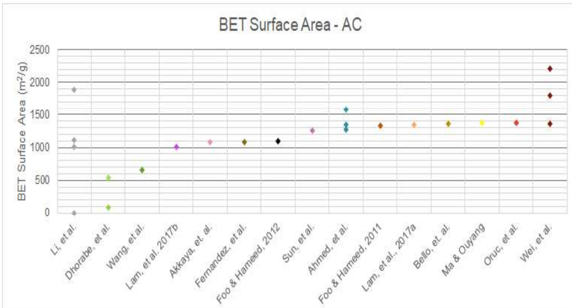

Figure 3.11 *BET Surface Area - AC*

Maximum Adsorption Capacity

The highest maximum adsorption capacity observed was 680 mg g-1 from Li et al. (2016) wherein they tested for their chemically activated pomelo peels with potassium hydroxide, with a ratio of KOH to the pre-carbonized product for 3:1. And the lowest capacity observed was 1.210 mg g-1 in Meenakshisundaram et. al. (2009) for their physically activated lemon peel.

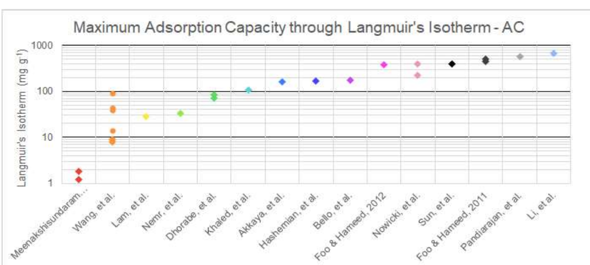

Figure 3.12 *Maximum Adsorption Capacity through Langmuir's Isotherm - AC*

Nanocatalysts

The smallest particle size observed is 5 nm in Dalul et al. (2020) while the largest size observed was from Ain Samat and Md Nor (2013) with 200 nm.

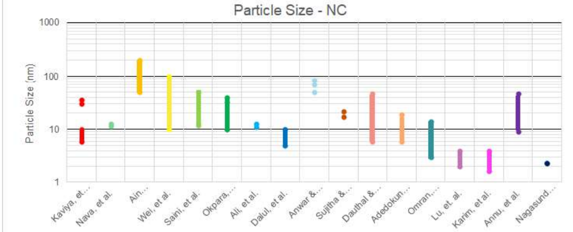

Figure 3.13 *Particle Size – NC*

4. CONCLUSIONS

This study has reviewed the state of the field of citrus fruit waste utilization through a systematic mapping approach. It was concluded that citrus fruit waste has a wide range of possible utilizations. This paper only focused on the applications related to waste management, thus, there is still a potential to expand the scope of this research field. Furthermore, there is an increasing trend in research related to citrus fruit waste utilization since there is a growing interest in its use due to its abundance and accessibility. Additionally, the published papers on citrus fruit waste utilization were sorted into three categories -- biochar, activated carbon, and nanocatalyst. Of the 55 papers collected, 38% were related to activated carbon, 29% were under biochar, and 33% were under nanocatalyst. Citrus fruit waste undergoes rigorous processes in order to achieve their respective applications, most of which involve subjection to high temperatures, such as pyrolysis and carbonization. Most studies evaluate citrus fruit waste products through pore size, adsorption capacity, and BET surface area.

6. REFERENCES

Abdelhafez, A.A., & Li, J. (2016). Removal of Pb(II) from aqueous solution by using biochars derived from sugar cane bagasse and orange peel. Journal of the Taiwan Institute of Chemical Engineers, 61, 367-375. doi: 10.1016/j.jtice.2016.01.005

Adedokun, O., Roy, A., Awodugba, A.O., & Devi, P.S. (2017). Fluorescent carbon nanoparticles from Citrus sinensis as efficient sorbents for pollutant dyes. Luminescence, 32(1), 62-70. doi: 10.1002/bio.3149

Ahmed, S., Rafat, M., & Ahmed, A. (2018). Nitrogen doped activated carbon derived from orange peel for supercapacitor application. Advances in Natural Sciences: Nanoscience and Nanotechnology, 9(3), 035008. doi: 10.1088/2043-6254/aad5d4

Ai, T., Jiang, X., Zhong, Z., Li, D., & Dai, S. (2020). Methanol-modified ultra-fine magnetic orange peel powder biochar as an effective adsorbent for removal of ibuprofen and sulfamethoxazole from water. Adsorption Science and Technology, 38(7-8), 304-321. doi: 10.1177%2F0263617420944659

Ain Samat, N., & Md Nor, R. (2013). Sol-gel synthesis of zinc oxide nanoparticles using Citrus aurantifolia extracts. Ceramics International, 39, S545-S548.

Akkaya Sayğılı, G., Sayğılı, H., Yılmaz, C., & Güzel, F. (2020). Lead recovery from aqueous environment by using porous carbon of citrus fruits waste: equilibrium, kinetics and thermodynamic studies. Separation Science and Technology (Philadelphia), 55(15), 2699-2712. doi: 10.1080/01496395.2019.1653917

Amin, M.T., Alazba, A.A., & Shafiq, M. (2019). Comparative study for adsorption of methylene blue dye on biochar derived from orange peel and banana biomass in aqueous solutions. Environmental Monitoring and Assessment, 191(12), 735. doi: 10.1007%2Fs10661-019-7915-0

Annu, Ahmed, S., Kaur, G., Sharma, P., Singh, S., & Ikram, S. (2018). Fruit waste (peel) as bio-reductant to synthesize silver nanoparticles with antimicrobial, antioxidant and cytotoxic activities. Journal of Applied Biomedicine, 16(3), 221-231. doi: 10.1016/j.jab.2018.02.002

Anwar, Y., & Alghamdi, K.M. (2020). Imparting antibacterial, antifungal and catalytic properties to cotton cloth surface via green route. Polymer Testing, 81, 106258. doi: 10.1016/j.polymertesting.2019.106258

Atienza, V. (2020). Waste Management in the Philippines. In Pariatamby, A., Shahul Hamid, F., & Bhatti, M. S. (Eds.), Sustainable Waste Management Challenges in Developing Countries, 270-286. IGI Global. doi: 10.4018/978-1-7998-0198-6.ch011

Ao, H., Cao, W., Hong, Y., Wu, J., & Wei, L. (2020). Adsorption of sulfate ion from water by zirconium oxide-modified biochar derived from pomelo peel. Science of the Total Environment, 708, 135092. doi: 10.1016/j.scitotenv.2019.135092

Bello, O.S., Ahmad, M.A., & Semire, B. (2015). Scavenging malachite green dye from aqueous solutions using pomelo (Citrus grandis) peels: kinetic, equilibrium and thermodynamic studies. Desalination and Water Treatment, 56(2), 521-535. doi: 10.1080/19443994.2014.940387

Biochar for Sustainable Soils. (n.d.). Biochar production and by-products. Biochar for Sustainable Soils. Retrieved January 4, 2021, from https://biochar.international/the-biochar-opportunity/biochar-production-and-by-products/

Castillo, A. L., & Otoma, S. (2013). Status of Solid Waste Management in the Philippines. Retrieved January 24, from: https://www.jstage.jst.go.jp/article/jsmcwm/24/0/24_677/_pdf

Cha, J. S., Park, S. H., Jung, S. C., Ryu, C., Jeon, J. K., Shin, M. C., & Park, Y. K. (2016). Production and utilization of biochar: A review. In Journal of Industrial and Engineering Chemistry, 40, 1–15. Korean Society of Industrial Engineering Chemistry. doi: 10.1016/j.jiec.2016.06.002

Chaturvedi, S., Dave, P. N., & Shah, N. K. (2012). Applications of nano-catalyst in new era. Journal of Saudi Chemical Society, 16(3), 307–325. doi:10.1016/j.jscs.2011.01.015

Chen, B., & Chen, Z. (2009). Sorption of naphthalene and 1-naphthol by biochars of orange peels with different pyrolytic temperatures. Chemosphere, 76(1), 127-133. doi: 10.1016/j.chemosphere.2009.02.004

Cheng, D., Ngo, H.H., Guo, W., Chang, S.W., Nguyen, D.D., Zhang, X., Varjani, S., & Liu, Y. (2020). Feasibility study on a new pomelo peel derived biochar for tetracycline antibiotics removal in swine wastewater. Science of the Total Environment, 720, 137662. doi: 10.1016/j.scitotenv.2020.137662

CSI Designs (2020). WHAT IS PRESSURE DROP AND HOW DOES IT AFFECT YOUR PROCESSING SYSTEM? Retrieved March 24, from: https://www.csidesigns.com/blog/articles/what-is-pressure-drop-and-how-does-it-affect-your-processing-system

Dalal, U., Gupta, V.K., Reddy, S.N., & Navani, N.K. (2020). Eradication of water borne pathogens using novel green nano Ag-biocomposite of Citrus Limetta peels. Journal of Environmental Chemical Engineering, 8(2), 103534. doi: 10.1016/j.jece.2019.103534

Dauthal, P., & Mukhopadhyay, M. (2015). Agro-industrial waste-mediated synthesis and characterization of gold and silver nanoparticles and their catalytic activity for 4-nitroaniline hydrogenation. Korean Journal of Chemical Engineering, 32(5), 837-844. doi: 10.1007/s11814-014-0277-y

DeSilva, F. (2000). Activated Carbon Filtration. Retrieved March 24, from: https://www.watertreatmentguide.com/activated_carbon_filtration.htm

Dhorabe, P.T., Lataye, D.H., & Ingole, R.S. (2017). Adsorptive removal of 4-nitrophenol from aqueous solution by activated carbon prepared from waste orange peels. Journal of Hazardous, Toxic, and Radioactive Waste, 21(2), 04016015. doi: 10.1061/(ASCE)HZ.2153-5515.0000332

Domingues, R. R., Trugilho, P. F., Silva, C. A., Melo, I. C. N. A. de, Melo, L. C. A., Magriotis, Z. M., & Sánchez-Monedero, M. A. (2017). Properties of biochar derived from wood and high-nutrient biomasses with the aim of agronomic and environmental benefits. PLoS ONE, 12(5), e0176884. doi: 10.1371/journal.pone.0176884

Fernandez, M.E., Nunell, G.V., Bonelli, P.R., & Cukierman, A.L. (2014). Activated carbon developed from orange peels: Batch and dynamic competitive adsorption of basic dyes. Industrial Crops and Products, 62, 437-445. doi: 10.1016/j.indcrop.2014.09.015

Flores, R. M., Feratero, V. J., Soneja, S. K. C., Gonzales, R. P. A. R. (2018). A Case Study about the Improper Waste Disposal in Barangay Mojon Tampoy, Philippines. Retrieved January 24 from: https://www.researchgate.net/project/A-Case-Study-about-the-Improper-Waste-Disposal-in-Barangay-Mojon-Tampoy-Philippines

Foo, K.Y., & Hameed, B.H. (2011). Microwave assisted preparation of activated carbon from pomelo skin for the removal of anionic and cationic dyes. Chemical Engineering Journal, 173(2), 385-390. doi: 10.1016/j.cej.2011.07.073

Foo, K. Y., & Hameed, B. H. (2012). Preparation, characterization and evaluation of adsorptive properties of orange peel based activated carbon via microwave induced K 2CO 3 activation. Bioresource Technology, 104, 679–686. doi: 10.1016/j.biortech.2011.10.005

Gunamantha, I. M., & Widana, G. A. B. (2018). Characterization the potential of biochar from cow and pig manure for geoecology application. IOP Conference Series: Earth and Environmental Science, 131(1), 12055. doi: 10.1088/1755-1315/131/1/012055

Hashemian, S., Salari, K., & Yazdi, Z.A. (2014). Preparation of activated carbon from agricultural wastes (almond shell and orange peel) for adsorption of 2-pic from aqueous solution. Journal of Industrial and Engineering Chemistry, 20(4), 1892-1900. doi: 10.1016/j.jiec.2013.09.009

James, K. L., Randall N. P., & Haddaway, N. R. (2016). A methodology for systematic mapping in environmental sciences. Environmental Evidence, 5, 7. doi:10.1186/s13750-016-0059-6

Jawad, A. H., Al-Heetimi, D. T. A., & Mastuli, M. S. (2019). Biochar from orange (Citrus sinensis) peels by acid activation for methylene blue adsorption. Iranian Journal of Chemistry and Chemical Engineering, 38(2), 91–105.

Jegadeeswaran, P., Shivaraj, R., & Rajendran V. (2012). Green synthesis of silver nanoparticles from extract of Padina tetrastromatica leaf. Digest Journal of Nanomaterials and Biostructures, 7(3), 991-998.

Karim, N.A., Rubinsin, N.J., Burukan, M.A.A., & Kamarudin, S.K. (2019). Sustainable route of synthesis platinum nanoparticles using orange peel extract. International Journal of Green Energy, 16(15), 1518-1526. doi: 10.1080/15435075.2019.1671422

Kaviya, S., Santhanalakshmi, J., Viswanathan, B., Muthumary, J., & Srinivasan, K. (2011). Biosynthesis of silver nanoparticles using citrus sinensis peel extract and its antibacterial activity. Spectrochimica Acta - Part A: Molecular and Biomolecular Spectroscopy, 79(3), 594-598. doi: 10.1016/j.saa.2011.03.040

Khaled, A., Nemr, A.E., El-Sikaily, A., & Abdelwahab, O. (2009). Removal of Direct N Blue-106 from artificial textile dye effluent using activated carbon from orange peel: Adsorption isotherm and kinetic studies. Journal of Hazardous Materials, 165 (1-3), 100-110. doi:10.1016/j.jhazmat.2008.09.122

Lam, S.S., Liew, R.K., Wong, Y.M., Azwar, E., Jusoh, A., & Wahi, R. (2017). Activated Carbon for Catalyst Support from Microwave Pyrolysis of Orange Peel. Waste and Biomass Valorization, 8(6), 2109-2119. doi: 10.1007%2Fs12649-016-9804-x

Lam, S.S., Liew, R.K., Wong, Y.M., Yek, P.N.Y., Ma, N.L., Lee, C.L., & Chase, H.A. (2017). Microwave-assisted pyrolysis with chemical activation, an innovative method to convert orange peel into activated carbon with improved properties as dye adsorbent. Journal of Cleaner Production, 162, 1376-1387. doi: 10.1016/j.jclepro.2017.06.131

Li, H., Sun, Z., Zhang, L., Tian, Y., Cui, G., & Yan, S. (2016). A cost-effective porous carbon derived from pomelo peel for the removal of methyl orange from aqueous solution. Colloids and Surfaces A: Physicochemical and Engineering Aspects, 489, 191-199. doi: 10.1016/j.colsurfa.2015.10.041

Ma, X., & Ouyang, F. (2013). Adsorption properties of biomass-based activated carbon prepared with spent coffee grounds and pomelo skin by phosphoric acid activation. Applied Surface Science, 268, 566-570. doi: 10.1016/j.apsusc.2013.01.009

Makarov, V. V., Love, A. J., Sinitsyna, O. V., Makarova, S. S., Yaminsky, I. V., Taliansky, M. E., & Kalinina, N. O., (2014). "Green" nanotechnologies: synthesis of metal nanoparticles using plants. Acta Naturae, 6(1), 35-44.

Meenakshisundaram, M., Kannan, N., & Rejinis, J. (2009). Removal of azure a from aqueous solution by CAC and new activated carbon form orange peel and lemon peel. Electronic Journal of Environmental, Agricultural and Food Chemistry, 8(8), 574-583.

Meng, H., Nie, C., Li, W., Duan, X., Lai, B., Ao, Z., Wang, S., & An, T. (2020). Insight into the effect of lignocellulosic biomass source on the performance of biochar as persulfate activator for aqueous organic pollutants remediation: Epicarp and mesocarp of citrus peels as examples. Journal of Hazardous Materials, 399. doi: 10.1016/j.jhazmat.2020.123043

Mireles, S., Parsons, J., Trad, T., Cheng, C. L., & Kang, J. (2019). Lead removal from aqueous solutions using biochars derived from corn stover, orange peel, and pistachio shell. International Journal of Environmental Science and Technology, 16(10), 5817–5826. doi: 10.1007/s13762-018-02191-5

Nagasundaram, N., Kokila, M., Sivaguru, P., Santhosh, R., & Lalitha, A. (2020). SO3H@carbon powder derived from waste orange peel: An efficient, nano-sized greener catalyst for the synthesis of dihydropyrano[2,3-c]pyrazole derivatives. Advanced Powder Technology, 31(4), 1516-1528. doi: 10.1016/j.apt.2020.01.012

Nava, O.J., Soto-Robles, C.A., Gómez-Gutiérrez, C.M., Vilchis-Nestor, A.R., Castro-Beltrán, A., Olivas, A., & Luque, P.A. (2017). Fruit peel extract mediated green synthesis of zinc oxide nanoparticles. Journal of Molecular Structure, 1147, 1-6. doi: 10.1016/j.molstruc.2017.06.078

Nemr, A.E., Abdelwahab, O., El-Sikaily, A., & Khaled, A. (2009). Removal of direct blue-86 from aqueous solution by new activated carbon developed from orange peel. Journal of Hazardous Materials, 165 (1), 102-110. doi: 10.1016/j.jhazmat.2008.03.060

Nowicki, P., Kazmierczak-Razna, J., & Pietrzak, R. (2016). Physicochemical and adsorption properties of carbonaceous sorbents prepared by activation of tropical fruit skins with potassium carbonate. Materials and Design, 90, 579-585. doi: 10.1016/j.matdes.2015.11.004

Okpara, E.C., Fayemi, O.E., Sherif, E.M., Junaedi, H., & Ebenso, E.E. (2020). Green wastes mediated zinc oxide nanoparticles: Synthesis, characterization and electrochemical studies. Materials, 13(19), 4241.

Omran, B.A., Nassar, H.N., Fatthallah, N.A., Hamdy, A., El-Shatoury, E.H., & El-Gendy, N.S. (2018). Waste upcycling of Citrus sinensis peels as a green route for the synthesis of silver nanoparticles. Energy Sources, Part A: Recovery, Utilization and Environmental Effects, 40(2), 227-236. doi: 10.1080/15567036.2017.1410597

Oruç, Z., Ergüt, M., Uzunoğlu, D., & Özer, A. (2019). Green synthesis of biomass-derived activated carbon/Fe-Zn bimetallic nanoparticles from lemon (Citrus limon (L.) Burm. f.) wastes for heterogeneous Fenton-like decolorization of Reactive Red 2. Journal of Environmental Chemical Engineering, 7(4), 103231. doi: 10.1016/j.jece.2019.103231

Pandiarajan, A., Kamaraj, R., Vasudevan, S., & Vasudevan, S. (2018). OPAC (orange peel activated carbon) derived from waste orange peel for the adsorption of chlorophenoxyacetic acid herbicides from water: Adsorption isotherm, kinetic modelling and thermodynamic studies. Bioresource Technology, 261, 329-341. doi: 10.1016/j.biortech.2018.04.005

Pathak, P. D., Mandavgane, S. A., & Kulkarni, B. D. (2017). Fruit peel waste: Characterization and its potential uses. Current Science, 113(3), 444–454. doi: 10.18520/cs/v113/i03/444-454

Petersen, K., Feldt, R., Mujtaba, S., Mattsson, M. (2008). Systematic Mapping Studies in Software Engineering. In: Proceedings of the 12th international conference on evaluation and assessment in software engineering. BCS Learning & Development Ltd., Swindon, pp 68 - 77

Petersen, K., Vakkalanka, S., & Kuzniarz, L. (2015). Guidelines for conducting systematic mapping studies in software engineering: An update. Information and Software Technology, 64, 1-18. doi: 10.1016/j.infsof.2015.03.007 https://www.sciencedirect.com/science/article/pii/S0950584915000646?via%3Dihub

Poonam, & Kumar, N. (2020). Experimental and kinetic study of removal of lead (Pb+2) from battery effluent using sweet lemon (Citrus limetta) peel biochar adsorbent. Environment, Development and Sustainability, 22(5), 4379–4406. doi: 10.1007/s10668-019-00389-2

PSA. (2015). Foreign Trade Statistics of the Philippines. PSA. Retrieved from http://www.psa.gov.ph/sites/default/files/Volume%20I%20-%20IMPORTS_FTS%202015%20e-Book_as%20of%2003-18-17.pdf

PSA. (2019a). Major Fruit Crops Quarterly Bulletin: January - March 2019. PSA. Retrieved April 16, 2020, from https://psa.gov.ph/sites/default/files/Major%20Fruit%20Crops%20Quarterly%20Bulletin%2C%20January-March_1.pdf

PSA. (2019b). Major Fruit Crops Quarterly Bulletin: April - June 2019. PSA. Retrieved April 16, 2020, from https://psa.gov.ph/sites/default/files/Major%20Fruitcrops%20Quarterly%20Bulletin%2C%20April%20-%20June%202019_0.pdf

PSA. (2019c). Major Fruit Crops Quarterly Bulletin: July - September 2019. PSA. Retrieved April 16, 2020, from https://psa.gov.ph/sites/default/files/Major%20Fruitcrops%20Quarterly%20Bulletin%2C%20July%20-%20September%202019_2.pdf

PSA. (2019d). Major Fruit Crops Quarterly Bulletin: October - December 2019. PSA. Retrieved April 16, 2020, from https://psa.gov.ph/sites/default/files/Major%20Fruitcrops%20Quarterly%20Bulletin%2C%20October-December%202019_1.pdf

Sahetya, T. J., Dixit, F., & Balasubramanian, K. (2015). Waste citrus fruit peels for removal of Hg(II) ions. Desalination and Water Treatment, 53(5), 1404–1416. doi:10.1080/19443994.2013.852483

Saini, J., Garg, V.K., & Gupta, R.K. (2020). Green synthesized SiO2@OPW nanocomposites for enhanced Lead (II) removal from water. Arabian Journal of Chemistry, 13(1), 2496-2507. doi: 10.1016/j.arabjc.2018.06.003

Siddiqui, N., Masum, A.A., Uddin, M.R., Mandal, S., Sengupta, M., Islam, M.M., & Mukhopadhyay, S. (2019). Elucidating the chemical and biochemical applications of Citrus sinensis-mediated silver nanocrystal. Journal of Biomolecular Structure and Dynamics, 37(18), 4863-4874. doi: 10.1080/07391102.2018.1559763

Sujitha, M.V., & Kannan, S. (2013). Green synthesis of gold nanoparticles using Citrus fruits (Citrus limon, Citrus reticulata and Citrus sinensis) aqueous extract and its characterization. Spectrochimica Acta - Part A: Molecular and Biomolecular Spectroscopy, 102, 15-23. doi: 10.1016/j.saa.2012.09.042

Sun, Y., Li, H., Li, G., Zhou, W. Yue, Q. & Li, X. (2016). Characterization and ciprofloxacin adsorption properties of activated carbons prepared from biomass wastes by H3PO4 activation. Bioresource Technology, 217, 239-244. doi: 10.1016/j.biortech.2016.03.047

Tran, H. N., You, S. J., & Chao, H. P. (2016). Effect of pyrolysis temperatures and times on the adsorption of cadmium onto orange peel derived biochar. Waste Management and Research, 34(2), 129–138. doi:10.1177/0734242X15615698

Wang, Y., Wang, S.-L., Xie, T., & Cao, J. (2020). Activated carbon derived from waste tangerine seed for the high-performance adsorption of carbamate pesticides from water and plant. Bioresource Technology, 316, 123929. doi: 10.1016/j.biortech.2020.123929

Wei, Q., Chen, Z., Cheng, Y., Wang, X., Yang, X., & Wang, Z. (2019). Preparation and electrochemical performance of orange peel based-activated carbons activated by different activators. Colloids and Surfaces A: Physicochemical and Engineering Aspects, 574, 221-227. doi: 10.1016/j.colsurfa.2019.04.065

Wei, Y., Fang, Z., Zheng, L., Tan, L., & Tsang, E.P. (2016). Green synthesis of Fe nanoparticles using Citrus maxima peels aqueous extracts. Materials Letters, 185, 384-386. doi: 10.1016/j.matlet.2016.09.029

Wu, Y., Cha, L., Fan, Y., Fang, P., Ming, Z., & Sha, H. (2017). Activated Biochar Prepared by Pomelo Peel Using H3PO4 for the Adsorption of Hexavalent Chromium: Performance and Mechanism. Water, Air, and Soil Pollution, 228(10). doi:10.1007/s11270-017-3587-y

Yoon, K., Cho, D. W., Bhatnagar, A., & Song, H. (2020). Adsorption of As(V) and Ni(II) by Fe-Biochar composite fabricated by co-pyrolysis of orange peel and red mud. Environmental Research, 188. doi:10.1016/j.envres.2020.109809

Zafar, S. (2020, July 23). Agricultural Wastes in the Philippines. Retrieved January 24, from: https://www.bioenergyconsult.com/agricultural-resources-in-philippines/

Zeng, R., Tang, W., Feng, Y., Liu, M., Huang, B., & Wu, A. (2013). Adsorption of bisphenol-A by using carbonized pomelo peel. Chinese Journal of Environmental Engineering, 7(10), 3797-3801.

Zhang, B., Wu, Y., & Cha, L. (2020). Removal of methyl orange dye using activated biochar derived from pomelo peel wastes: performance, isotherm, and kinetic studies. Journal of Dispersion Science and Technology, 41(1), 125–136. doi: 10.1080/01932691.2018.1561298

Zhao, T., Yao, Y., Li, D., Wu, F., Zhang, C., & Gao, B. (2018). Facile low-temperature one-step synthesis of pomelo peel biochar under air atmosphere and its adsorption behaviors for Ag(I) and Pb(II). Science of the Total Environment, 640–641, 73–79. doi:10.1016/j.scitotenv.2018.05.251