International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 08 Issue: 08 | Aug 2021 www.irjet.net p-ISSN: 2395-0072

A REVIEW OF BIO ABSORBENT PROPERTIES DERIVED FROM FRUIT AND VEGETABLE PEELS

Lavanya M*, Bindhu M[1], Malarvizhi M[2], Mani Deepa P[3], Neha S[4]

*Professor, Department of Food Processing and Preservation Technology, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore
[1,2,3,4]Scholars, Department of Food Processing and Preservation Technology, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore, India

---

Abstract - *Biosorption can be defined as the ability of biological materials to accumulate heavy metals from waste water. These are made of discarded Bio waste like Fruit and Vegetable peels. It's a metabolically passive process, meaning it does not require energy. Safe drinking water is necessary for every living organism on earth. The rapid and continuous growth of industries over the last few decades has polluted rivers, ground water and streams resulting in bad quality of potable water. This waste water contains many organic and in organic matters in the form of heavy metals, atomic compounds , dyes, pigments etc. many of them have high potential toxicity to human health . Fruit and vegetable peels waste has been chosen for the removal of different pollutants from waste water. The fruit and vegetable peel bio absorbent is eco -friendly so it can be imparted in affected ponds or lake where it does not affect living organism or microorganism. The waste peels will remove heavy metals from water through adsorption. There are several methods and different techniques are used to derived a bio absorbents.*

***Key Words*: Biosorption, fruit &vegetable peels, Heavy metals, Eco friendly, polluted water, SEM, TEM, OM..**

1.INTRODUCTION

Energy and environmental sustainability are the main concerns of contemporary environmental engineers. In light of these, researchers have developed a variety of technologies over the years to treat contaminated effluents. One popular technique is biomaterial adsorption, also known as biosorption. Over the years, a large number of biological materials have been studied, including fish scales, plant leaves, bark, agricultural waste, egg shells, vegetable peels, fruit shells and many other materials . A key feature of biosorption research is the use of different analytical techniques to evaluate various aspects of other biosorbents in order to understand the potential and applicability of the material to perform the expected work. Branueur–Emmet–Teller (BET) analysis is employed to review the particle and pore dimensional characteristics of the biosorbents. Fourier transform infra-red spectroscopy (FTIR) done to work out the functional groups and complexes present within the biosorbent that would be liable for pollutant uptake. X-ray fluorescence (XRF) is employed to analyze the main and trace elements within the biomaterials by studying the behavior of atoms once they interact with radiation. X-ray diffractometry (XRD) to used investigate the properties of the adsorbent because it relates to the crystallinity of the fabric .Microscopy is employed to review the morphological features materials. We have Optical Microscopy (OM) and microscopy (SEM). OM produce coloured images but is limited in terms of resolution [13]. Despite the grey-scale images of SEM, resolution 1000 times greater than that of OM are often achieved. Scanning microscopy (as well because the transmission electron microscopy) has been used quite while is studying the surface morphology of adsorbent materials. Transmission microscopy (TEM) is additionally wont to study particle morphology albeit to offer more detailed images at higher resolutions and ensure the presence of specific molecules on the particle surface [14]. The use of TEM isn't as common as SEM in open literature probably thanks to its high cost. In SEM, a fine probe of energised electrons (having energies up to 40 keV) is projected on a selected sample and scanned along a pattern of parallel lines [15]. Various signals are generated thanks to the incidence of the electrons on the sample surface and these are collected to make a picture [15]. These incident rays are mostly secondary electrons (the high energy electrons backscattered from the first beam). More details of the physics of the method is given by Klein et al. [16]. SEM technology is predicated on two fundamental discoveries. The first is that the observation that trajectories of charged particles in

axially symmetric electric and magnetic fields could act as particle lenses indirectly laying the foundations of geometrical electron optics in 1926 [15]. The second was the introduction of the wave electronics which was supported the concept of the corpuscule round the same time.

2. BIO ABSORBENT (Fruit and vegetable peels)

2.1 ONION PEELS

Onion (Allium cepa L.) is one of the most widely consumed vegetables, and its production is increasing every day due to the increase in consumer demand. Onions have a strong unique aroma and flavor, which makes them an important ingredient in food (Ly et al., 2005). [12] In the past 20 years, world onion production has increased by at least 25%; it is reported that the annual output is about 47 million tons, making it the second most important horticultural crop. Biologically active compounds have been shown to exist in all parts of onion bulbs (Benitez et al., 2007). 2011). [16] Onion is an effective cardiovascular and anticancer agent, with cholesterol-lowering, antioxidant, antiasthmatic, and antithrombotic activities (Moreno et al. 2006). Quercetin has been shown to have the ability to resist oxidation and scavenge free radicals and its ability to prevent cardiovascular disease (Bonaccorsi et al. 2008, Benítez et al. 2011). However, the content of quercetin aglycone in onion skin is higher than in meat (Downes et al. 2009). Onion skins are not edible and will be removed quickly prior to processing and sale, but due to their composition and smell, they represent the main waste of onion processing. [16]. During food processing, the two outer fleshy scales and the roots of the onion bulb are removed along with the peel and are considered waste. [12] At the same time, different parts of the onion produce a large amount of waste, which has different effects on the environment. The concentration of total phenols, flavonoids, flavanols and other antioxidants in onion skin is higher than in the edible part of onions. [14] The increasing market for processed onions has also led to a greater accumulation of waste: Spain, the Netherlands and the United Kingdom, the main European onion producing countries, have produced around 50,000 tonnes of waste. [16]. This residue has great prospects for one-pot synthesis of magnetic nanoparticles [14]. Phytochemical analysis of onion skin extracts using different solvents (water, ethanol and methanol) revealed the presence of various phytochemicals. Among these phytochemicals, anthraquinones, tannins and flavonoids impart and enhance the color of cotton fabrics. Onion skin water, ethanol and methanol extracts show nearly comparable phytochemical activity, which may support their traditional use to combat bacterial infections[15].Sian Hui Tan et all reported that the high porosity of powdered onion peel could serves for catalytic purpose, as a result of providing adequate morphology for the adsorption of various organic materials.

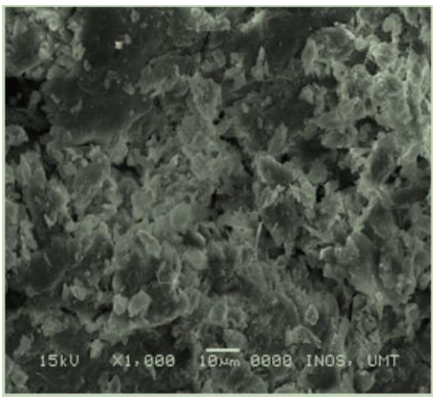

Fig 1 : Sem Image of Onion Peel
Source: Synthesis of thiazolo- and benzothiazolo [3,2-a]pyrimidine derivatives
using onion peel as natural catalyst Sian Hui Tan et all.

2.2 BANANA PEELS

The banana is a thin edible fruit, botanically a kind of berry, produced by several large flowering herbaceous plants of the genus Musa. [19] The genus Musa is native to the tropical Indian mountains of Malaya and Australia. [4] [5] They are cultivated in 135 countries / regions and are used mainly for fruits, to a lesser extent used for the production of fiber, banana wine and banana beer and as an ornamental plant. In 2017, the largest banana producing countries in the world were India and China, which together accounted for around 38% of total production. Other important producing countries are the Philippines, Colombia, Indonesia, Ecuador and Brazil. Raw bananas (excluding skin) contain 75% water, 23 sugar water, 1% protein, and negligible fat content. The physical and chemical properties of bananas are affected by many factors such as soil conditions, fertilization, cultivars, planting and harvest time.(Kitara, 2005). As one of the most used fruits in the world, banana peel is the main residue of banana fruits and represents 3.040% of the weight of the fruit. Banana peel is a common waste that contains a lot of fiber and minerals. A large quantity of banana peels has caused significant processing problems and a lot of waste of resources. Various functional groups on the surface of Banana peel, such as carboxyl, hydroxyl and amide groups, have been shown to be key features in the biosorption process. It also contains 41.37% carbon [7]. Due to its porous structure with multiple

sets of surfaces, treated pure banana peels have been used as absorbents to remove heavy metals dissolved in wastewater. However, due to its low adsorption capacity, pure banana peels still need to be chemically treated with alkali and acid. Several research groups have used raw and chemically treated banana peels and stems to remove toxic heavy metal ions from aqueous solutions and industrial wastewater. The porous banana peel biosorbent made by pretreating the banana peel precursor with KOH was found to be an effective adsorbent that can remove Fe2+ and Pb2+ ions from the aqueous phase solution.[18] Some studies also show that chemical activated carbon material developed from waste banana peels using H2SO4 is used successfully to remove heavy metal ions in industrial wastewater. [19]. The results of several experiments show that the application of low-cost biosorbents derived from banana peels to environmental treatment has great potential.[18].Harsh Kumar et all.(100) studied and concluded that banana peel is used as an effective biosorbent to remove rhodamine B, an alkaline water-soluble cationic dye. The contact time selected for the adsorption of rhodamine B in banana peel powder is 60 minutes. In another study, bioadsorbents were developed using natural banana peel, methylated banana peel, and banana peel activated carbon, and used in oil plant wastewater treatment palm.

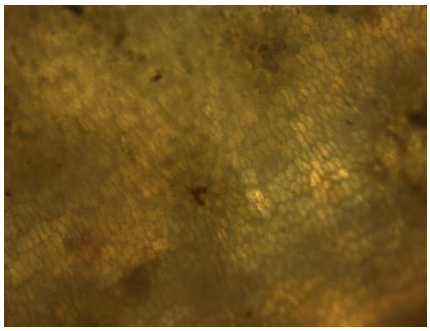

Fig NO 2: Microscopic view of banana feel
source: Morphological and Elemental study of fruit peels by Rashmi Ghosh

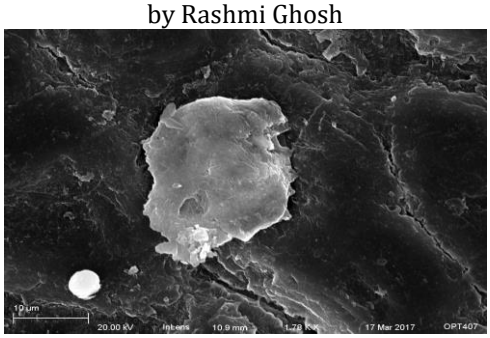

Fig NO 3: SEM Image of Banana peel
Source: Morphological and Elemental study of fruit peels by Rashmi Ghosh

2.3 GARLIC PEELS

Garlic (Allium sativum) belongs to the onion genus. Garlic has been cultivated all over the world since ancient times, especially in Asia. [23]. China produces about 80% of the world's garlic supply. [27]. Garlic is commonly used as a condiment, cooking and herbal medicine. [25]. Garlic has medicinal value and is an important ingredient in the world's major cuisines. Garlic can be used as a spice in the food industry either fresh or dehydrated. (Nourai, 1994; Matlob&Khalel,1986). Garlic contains a higher concentration of sulfur compounds than any other Allium plant. Garlic is known for its antithrombotic, antibacterial, and cholesterol-lowering activities. In current research, garlic is used as a raw material to explore its chemical composition, heavy metal content, antioxidant content, and microbial analysis. [25] Fresh or minced garlic produces the sulfur-containing compounds allicin, ajoene, diallyl polysulfide, vinyl dithiin, and talicysteine, as well as Beauty Rader enzymes, saponins, flavonoids, and reaction products, they are not sulfur compounds. Garlic peel is a very common and readily available material, generally disposed of as agricultural biological waste. In China, a large amount of garlic is consumed each year, and a large amount of garlic is discarded, causing serious problems for the community, such as decomposition in the open air and the emission of a special odor. So far, there are few reports on the effective development of garlic peel, so for the protection of the environment and the reuse of this biowaste, researchers have tried to use it as activated carbon to prepare a selective adsorbent to remove lead in garlic. Aqueous solution [24]. Activated charcoal developed from garlic peel has been used to remove Pb (II) ions from aqueous solutions. The effect of initial adsorbate concentration and pH on Pb (II) removal has been studied. Current research shows that the activated carbon in garlic peel is an effective adsorbent for removing lead (II) from aqueous solutions. The adsorption capacity increases as the pH increases from 2 to 5. [24].Hameed, B et all.(101) has studied the adsorption characteristics of garlic and concluded that garlic peels dried at 60ºC for 48 hours adsorbed 142.86 mg/g of methylene blue.

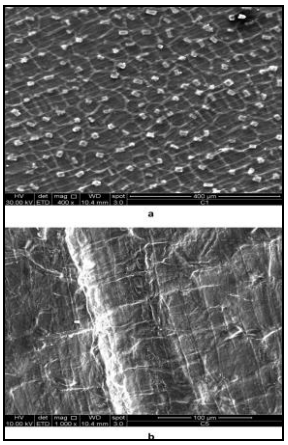

Fig NO: 4 garlic peel

2.4 ORANGE PEELS

Citrusses are high in today's agriculture and are a substantial source of producing countries. Among citrus fruits, orange is economically from the most important industry. [35] Orange is the fruit of several citrus species of the Rutaceae family. Varieties of sweet orange are produced through mutations. [38] .Fruit juice extracted from orange is a powerful natural antioxidant that accumulates the body's immune system, and also important phytochemical substances such as synephrine, polyphenols, limonoids, fabonoid, pectin, and sufcients. It is a superior source of vitamin C. [32] Nigerian production of citrus fruits requires a few to convert fruits to juice, concentrated and canned fruits, and great direct consumption for small capabilities processing industries. The worthy of converting fruits juice and concentrate has led to waste loss. [36] The food industry shows special interest in finding applications for industrial citrus products. Thousands of by-products occur during the citrus juice extraction process (Garau et al., 2007). In this sense, orange skin can be dehydrated to several products, such as dust, scales and slices (Ruizdiazet al., 2003). [34] The sudden increase in the population and the rapid increase in demand for orange demand has increased the waste of orange skin, which is anxious. Therefore, the advantage of using orange skin as adsorbent to remove cadmium ions from an aqueous solution is not only useful as a means of decontamination of contamination, but also adds values to agricultural waste that is originally perceived in land. [32] The removal of heavy metals (cobalt, cadmium and chromium) of the aqueous solution was possible with activated carbon from the orange skin. At the level of concentration where the levels of concentration were studied, the adsorption occurred between 15 and 25 minutes of adsorption. [33] The raw fiber of sweet orange skin and protein, based on the chemical composition of sweet orange skin, serve as non-calories. They can also provide a low cost nutritional supplement for livestock and humans. Sweet orange shells can be incorporated as food components and components in livestock feed. These applications promote the sustainable elimination of sweet orange skin residues. [36].Harsh Kumar et all[100] has reported that orange peel dried at 60 °C for 24 hours adsorbed 1.92, 1.37 and 1.31 mmol/g of nickel (II), cobalt (II) and copper (II) ions.

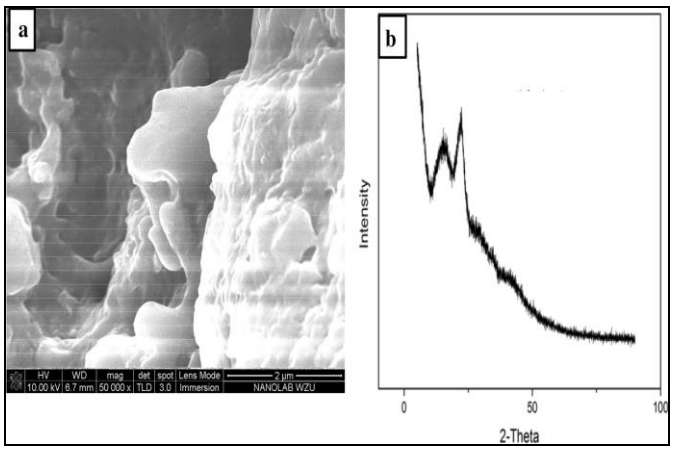

Fig NO : 5 a-SEM image and b- XRD image of orange peel absorbent

2.5 PAPAYA PEELS

The papaya is that the plant fruit tree, one in every of the 22 accepted species in the genus carica of the Caricaceae .[41] Its origin is within the tropics of land , perhaps from Central America and southern Mexico .The papaya may be a small, sparsely branched tree .Originally from southern Mexico, Central America , and northern South America , the papaya is now cultivated in most tropical countries. In 2018, global production of papayas was 13.3 million tonnes , led by India with 45% of the planet total. Global papaya production grew significantly over the first 21st century, mainly as a result of increased production in India and demand by the United States.[42] Papaya skin, pulp, and seeds contain a spread of phytochemicals , including carotenoids and polyphenols ,as well as benzyl isothiocyanates and benzyl glucosinates, with skin and pulp levels that increase during ripening. Papaya seeds also contain the cyanogenic substance prunasin .[36][40]In the varied present studies, papaya leaf has been used as a replacement low cost adsorbent to adsorb lead from water. The foremost characteristic of papaya leaf that's useful in metal removal is because of its chemical composition. As described by [22], papaya leaf consists of lignin and cellulose as major constituents and will also

contain other polar functional groups of lignin, which include alcohols, aldehydes, ketones, carboxylic, phenolic, and ether groups. These groups have ability to some extent to bind heavy metal ions by donation of an electron pair from these groups to make complexes with the metal ions in solution. Papaya leaf has high potential to use as a good adsorbent in removal of lead ions and would be useful for the look of wastewater treatment technique for removal of heavy metals.[39].This researches have shown that papaya peel may be a highly effective low-cost adsorbent. Moreover, since it's an agro -waste material, bioadsorbent from papaya peel would contribute an environmental friendly material for heavy metal removal from wastewater.[38].

2.6 POTATO PEELS

The potato may be a root vegetable local to the Americas , a starchy tuber of the plant Solanum tuberosum, and the plant itself may be a lasting in the nightshade family, Solanaceae .[50]Wild potato species , starting in modern-day Peru , can be found all through the Americas, from Canada to southern Chile .[52] The potato was initially accepted to have been domesticated by Local Americans. In 2018, world cultivation of potatoes was 368 million tonnes , driven by China with 27% of the overall (table). Other major makers were India, Russia, Ukraine and the Joined together States. It remains an fundamental trim in Europe, where per capita cultivation is still the most noteworthy within the world, but the most rapid development over the past few decades has happened in southern and eastern Asia.[8][51]. The world production of potato peels is evaluated to be 70–140 thousand tons/year . The delivered peels may well be utilized for a variety of purposes, counting generation of biogases, feedstock, and fertilizers [16].Yet, aggregation of these peels would speak to an environmental burden. Reusing of these squanders into a low cost, versatile adsorbent for the removal of HMs, dyes, drugs, etc. would be a solution to induce freed of these wastes and at the same time clean wastewater. Being rich in high-value constituents, extraordinarily polysaccharides and lignin, which can be changed over into carbonaceous fabric by burning, Potato peels would be an exquisite green adsorbent. Few studies have been reported within the writing utilizing Potato peels as an adsorbent.[49]Potato peels, which are waste and simple to get, can be utilized as a cheap adsorbent alternatively. In any case, the unmodified potato peels provide good removal productivity after a basic drying, making such low-cost waste materials more attractive in water and wastewater treatment. The low surface region of the potato peels appears that the adsorption is under the diverse impacts, in spite of the fact that the physical hold is limited. Adsorption are somewhat chemical adsorption, and there are moreover a few signs of physical adsorption in this ponder. It was concluded that boundary layer diffusion (film dissemination) and intra-particle dissemination rates are moreover partly limiting adsorption.[50] The waste potato peels utilized in this think about is low- cost, compared to other adsorbents, and its surface zone is quite low, compared to other adsorbents, since it isn't activated by any chemical pre-treatment. The use of this shape of adsorbent which has low surface area, isn't common. The characteristics (isotherm and kinetic expressions) of the adsorbent, which was not treated, are critical for understanding of usability.[50].Harsh Kumar et all[100] has reported that a dosage of 3.0 g potato peel dried at 60 °C for 48 hours adsorbed 79.32% of nickel.

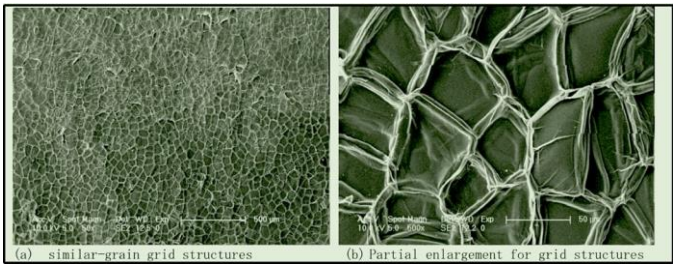

Fig NO :6 SEM micrographs of the potato peel surface. Source: Li Junwei, Ma Zichao, Wang Lidong& Yu Jiangto (2018) Mechanical properties and microstructure of potato peels

2.7 TOMATO PEELS

The tomato is that the edible berry of the plant Solanum lycopersicum,[55] commonly called a Lycopersicon esculentum. The species originated in western South America and Central America .[55][56] Numerous sorts of the tomato plant are widely grown in temperate climates across the planet, with greenhouses with the production of tomatoes throughout all seasons of the year. In 2019, world production of tomatoes was 181 million tonnes , with China accounting for 35% of the full, followed by India and Turkey as major producers (table).[57].The estimated world production of tomatoes destined for industrial processing was 28.66 million tonnes in 2005. The u. s. and Italy are the world's major tomato growers, producing 8.3 and 5.1 million tonnes each year, respectively. More than 80% of tomatoes destined for industrial processing goes into products like ingredient, purée, sauce, juice, ketchup, and canned peeled tomato. Despite scarce economic and technological means, they produce concentrates of high

added value thanks to their quality, obtained through the great lengths to which the producers head to look after their products. With the aim of standardizing their products, it's of interest to spot several physical and chemical variables that allow us to look at how the concentrates' properties evolve during their preparation.[53]Disposal of the skin and other fibrous materials (90% tomato skin) is an economic waste for many food processing industries. Developing a route to use tomato peel for water treatment solves the matter of waste disposal and serves as an alternate biotechnology for water purification. Tomato peel contains pectin, carotene and phenolic compounds with functional groups like –NH2, –OH and –COOH.25–27 These functional groups act as potential adsorption sites for various pollutants, especially for cationic pollutants. the current investigation offers complete characterization of a readily available and low cost tomato peel as a strong adsorbent, which may be used for extraction of various forms of pollutants from water.[54].

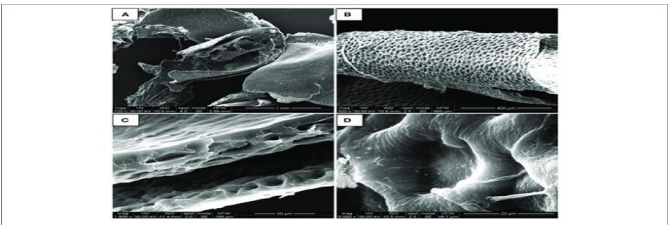

Fig NO : 7 Scanning electron microscopy (SEM) micrographs of tomato peels at 100× (A), 300× (B), 1,600× (C), and 6,000× (D) magnification.
Source: Valorization of Tomato Processing Residues Through the Production of active Bio-Composites for packaging applications by Giuliana Gorrasi et all.

3. CONCLUSION

Biosorption using FVP is a new process that has shown good promise for the removal of different organic and inorganic contaminants from aqueous effluents. As a result of many researches bio absorbent were produced from fruit and vegetable peels that replace other absorbents. This management implies the use of environmentally friendly and cost-effective processes . This paper focuses on use of FVW in batch adsorption study. The bio absorbent works on mechanism of ion exchange, physical absorption and precipitation process so it has high efficiency while it has compare with another filtration process. The heavy metals are removed by fruit and vegetable peels. . Thus, the fruits and vegetable waste is recycled and also become economical and environment friendly.

Acknowledgment

We would like to thank our University, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore for being a great moral support. Also, we would like to acknowledge and thank our Project guide Ms. M. Lavanya (Assistant Professor).

REFERENCES

[1] Adsorption of Heavy Metals on Banana Peel Bioadsorbent Rabiatul Manisah Mohamed , Norazlina Hashim, Suhaila Abdullah, Nabihah Abdullah, Amri Mohamed, Mohd Abu Asshaary Daud , Kaha Fakrul Aidil Muzakkar Journal of Physics: Conference Series,2020
[2] Application of tomato peel as an efficient adsorbent for water purification—alternative biotechnology Ramakrishna Mallampati and Suresh Valiyaveettil*
[3] Analysis of Physical and Chemical Composition of Sweet Orange (Citrus sinensis) Peels Oyebola O. Olabinjo1 *, Agboola S. Ogunlowo1, Olabode O. Ajayi2, Ayoola P. Olalusi1
[4] An Overview of Global Papaya Production, Trade, and Consumption". Electronic Data Information Source, University of Florida. Retrieved 2014
[5] Aurora Romar-Gasalla,Gustavo F. Coelho, Juan Carlos Nóvoa-Muñoz,Manuel Arias-Estévez , María J. Fernández-Sanjurjo , Esperanza Álvarez-Rodríguez and Avelino Núñez-Delgado.Wheat Straw as a Bio-Sorbent for Arsenate, Chromate,Fluoride, and Nickel.Water 2017, 9, 690; doi:10.3390/w9090690
[6] "Banana and plantain exports in 2013, Crops and livestock products/Regions/World list/Export quantity (pick lists)".UN Food and Agriculture Organization, Corporate Statistical Database (FAOSTAT). 2017. Archived from the original on May 11, 2017. Retrieved January 6, 2018.
[7] Beatrice O. T. Ifesan.Chemical Composition of Onion Peel (Allium cepa) and its Ability to Serve as a Preservative in Cooked Beef.Ijsrm.Human, 2017; Vol. 7
[8] "Biosynthesis of the flavour precursors of onion and garlic".Jones, Meriel G.; Hughes, Jill (August 2004).Journal of Experimental Botany.
[9] Blessy Baby Mathew,Monisha Jaishankar,Vinai George Biju,and Krishnamurthy Nideghatta Beeregowda.Role of Bioadsorbents in Reducing Toxic Metals Journal of Toxicology.Volume 2016, Article ID 4369604, 13 pages
[10] Cadmium removal using potato peels as adsorbent: kinetic studies
[11] Chemical and physical characteristics of 'Improved sunrise solo line 72-12' papaya fruitsLuiz Carlos Chamhum Salomão, Paulo Roberto Cecon,César Fernandes Aquino, Leila Cristina Rosa de Lins5, Luciano Ribeiro Braga
[12] Chemical And Shelflife Analysis Of Dry Garlic Powder: A Golden Herb M.Bi Bi Mariam and Dr, Usha Devi

C. International Journal of Agriculture and Food Science Technology.Volume 7, (2016)
[13] Chemical Composition Of Lemon (Citrus Limon) And Peels Its Considerations As Animal Food. Somayeh Sadat Fakoor Janati, Hamed Reza Beheshti,Javad Feizy, Niloofar Khoshbakht Fahim Research gate,2106
[14] "Citrus ×sinensis (L.) Osbeck (pro sp.) (maxima × reticulata) sweet orange". Plants.USDA.gov. Archived from the original on May 12, 2011.38.Andrés García Lor (2013). Organización de la diversidad genética de los cítricos (PDF) (Thesis). p. 79.
[15] Development of Adsorbent from Banana Peel for Wastewater Treatment Jimoh Abdulfatai, Abdulkareem Ambali Saka, Ayo Samuel Afolabi,cand Onazi Micheal Applied Mechanics and Materials Vol. 248 (2013)
[16] Effect of drying condition on the physical properties of impregnated orange peel K. Manjarres-Pinzon M. Cortes-Rodriguez and E. Rodríguez-Sandoval
[17] "EST: Banana facts". www.fao.org.Archived from the original on July 18, 2019. Retrieved May 28, 2020.
[18] Fernandes, L.; Pereira, J. A.; López Cortés, I.; Salazar, D. M.; Ramalhosa, E. C. (2015). "Physicochemical Changes and Antioxidant Activity of Juice, Skin, Pellicle and Seed of Pomegranate (cv. Mollar de Elche) at Different Stages of Ripening". Food Technology and Biotechnology. 53 (4): 397–406. doi:10.17113/ftb.53.04.15.3884. PMC 5079168. PMID 27904374.
[19] Food and Agriculture Organization of the United Nations, Statistics Division (FAOSTAT). 2019. Retrieved February 19, 2020
[20] Fruits of warm climates,JF Morton, Miami, FL. Retrieved 23 May 2015.
[21] "Garden Tomato. Solanum lycopersicum L." Encyclopedia of Life. Retrieved 1 January 2014.
[22] "Garlic production in 2018: Crops/World Regions/Production Quantity (from pick lists)". Food and Agriculture Organization of the United Nations, Statistics Division (FAOSTAT). 2019. Retrieved July 2, 2020.
[23] "Global leading producers of bananas 2017".Statista. Archived from the original on July 26, 2020. Retrieved May 28, 2020
[24] Gómez Caravaca, A. M.; Verardo, V.; Toselli, M.; Segura Carretero, A.; Fernández Gutiérrez, A.; Caboni, M. F. (2013). "Determination of the major phenolic compounds in pomegranate juices by HPLC–DAD–ESI-MS". Journal of Agricultural and Food Chemistry. 61 (22): 5328–37. doi:10.1021/jf400684n. PMID 23656584
[25] Heavy Metal Ions Adsorption from Wastewater Using Activated Carbon from Orange Peel JUAN CARLOS MORENO-PIRAJÁN and LILIANA GIRALDO
[26] H Yalcin, H Kavuncuoglu.Physical, chemical and bioactive properties of onion (Allium cepa L.) seed and seed oil.Journal of Applied Botany and Food …, 2014
[27] Jasmina Niki´c, Aleksandra Tubi´c , Malcolm Watson, Snežana Maleti´c, Marko Šoli´c,Tatjana Majki´c and Jasmina Agbaba.Arsenic Removal from Water by Green Synthesized Magnetic Nanoparticles.Water 2019
[28] Jorgensen, SuzAnne; Brennand, Charlotte (June 2005). "Pomegranates" (PDF). Utah State University, Department of Food Safety. Archived from the original (PDF) on 12 September 2014. Retrieved 17 June 2017.
[29] Joshua O. Ighalo,Adewale George Adeniyi. A mini-review of the morphological properties of biosorbents derived from plant leaves SN Applied Sciences (2020) 2:509 | https://doi.org/10.1007/s42452-020-2335-x
[30] Khairia M. Al-Qahtani.Water purification using different waste fruit cortexes for the removal of heavy metals.Journal of Taibah University for Science 10 (2016) 700–708
[31] Lead (II) Remotion in Solution Using Lemon Peel (Citrus limonum) Modified with Citric Acid Candelaria Tejada Tovar, AngelVillabonaOrtiz , Diofanor Acevedo Correa
[32] International Journal of Engineering and Technology,2018
[33] Mebrahtu Gebrezgiher and Zebene Kiflflie.Utilization of Cactus Peel as Biosorbent for the Removal of Reactive Dyes from Textile Dye Effluents
[34] Journal of Environmental and Public Health Volume 2020, Article ID 5383842, 10 pages.
[35] Neethu.P, M.A Chinnamma Natural Adsorbents for Agricultural Waste Water Treatment.International Journal of Advanced Engineering, Management and Science (IJAEMS) [Vol-3, Issue-4, Apr- 2017]ISSN: 2454-1311.
[36] Nkechi Emea Ibisi and Chizaram Anderson Asoluka. Use of agro-waste (Musa paradisiaca peels) as a sustainable biosorbent for toxic metal ions removal from contaminated water Chemistry International 4(1) (2018)
[37] Onion Peel: Turning a Food Waste into a Resource
[38] Rita Celano, Teresa Docimo , Anna Lisa Piccinelli , Patrizia Gazzerro , Marina Tucci,Rosa Di Sanzo , Sonia Carabetta , Luca Campone , Mariateresa Russo ,and Luca Rastrelli Antioxidants 2021
[39] Orange peel as low-cost adsorbent in the elimination of Cd(II) ion: kinetics, isotherm, thermodynamic and optimization evaluations Temilade Fola Akinhanmi, Edwin Andrew Ofudje , Abideen Idowu Adeogun, Peter Aina1and Ilo Mayowa Joseph
[40] Physical Attributes of Garlic (Allium sativum L.)A.A. Masoumi, A. Rajabipoor, L. G. Tabil and A. A. Akram J. Agric. Sci. Technol. (2006) Vol. 8
[41] Physical, Chemical And Morphological Characteristics Of Banana Cultivars Depending On Maturation Stages.César Fernandes Aquino, Luiz Carlos Chamhum Salomão, Paulo Roberto Cecon, Dalmo Lopes De Siqueira, Sônia Machado Rocha Ribeiro Rev. Caatinga, Mossoró, v. 30,, 2017
[42] Physical and Chemical Properties of Pomegranate (Punica granatum L.) Fruit in Maturation Stage
[43] Phytochemical screening of onion skin (Allium cepa) dye extract Mona Verma, Saroj S Jeet Singh and Neelam M RoseJournal of Pharmacognosy and Phytochemistry 2018

[44] Pomegranate Peels as Biosorbent Material to Remove Heavy Metal Ions from Industerial Wastewater
[45] Potato Peels as an Adsorbent for Heavy Metals from Aqueous solutions: Eco-Structuring of a Green Adsorbent Operating Plackett–Burman Design
[46] "Potato production in 2018; Region/World/Production Quantity/Crops from pick lists".UN Food and Agriculture Organization, Statistics Division (FAOSTAT). 2019. Retrieved 24 February 2020.
[47] Pranav D. Pathak, Sachin A. Mandavgane and Bhaskar D. Kulkarni Characterizing fruit and vegetable peels as bioadsorbents.
[48] Pranav D. Pathak, Sachin A. Mandavgane and Bhaskar D. Kulkarni.Fruit peel waste as a novel low-cost bio adsorbent.Rev Chem Eng 2015; 31(4): 361–381
[49] Removal of Pb (II) from Aqueous Solutions using Activated Carbon Prepared from Garlic Waste R. Mary Nancy Flora, Ashok, Ramanathan International Journal of Trend in Scientific Research and Development Volume – 3 Mar-Apr 2019
[50] Removal of pb(II) from aqeuous solution using Papaya peel Sahar abbaszadeh, shref rafaidh
[51] Royal Horticultural Society. July 2017.p.20. Retrieved January 24, 2018
[52] "Seed & Ware Potatoes". www.sasa.gov.uk. Science & Advice for Scottish Agriculture.Retrieved 27 February 2018.
[53] Some physical properties of orange (var. Tompson) M. Sharifi, S. Rafiee*, A. Keyhani, A. Jafari, H. Mobli, A. Rajabipour, and A. Akram Department of Agricultural Machinery, Faculty of Bio-Systems Engineering, University of Tehran, Karaj, Iran Received May 8, 2007; accepted October 8, 2007
[54] Sonia Bharat and Divya Manchanda.Efficient bio adsorbents for removal of heavy metals from water.International Journal of Chemical Studies.P-ISSN: 2349–8528
[55] E-ISSN: 2321–4902 IJCS 2017; 5(4): 1691-1694,2017 IJCS
[56] Sorption of lead(II) ions from wastewater using carica papaya leaf powder D.Sai Seetha Rama Raju*,V.Nageswara Rao, P.Rajendra Prasad, N.Chitti Babu
[57] "Tomato". Encyclopaedia Britannica.4 January 2018. Retrieved 15 January 2018.
[58] "Tomato production in 2019, Crops/Regions/World list/Production Quantity (pick lists)". UN Food and Agriculture Organization,Corporate Statistical Database (FAOSTAT). 2020. Retrieved 3 March 2021.
[59] "Tomatoes:Safe Methods to Store, Preserve, and Enjoy".Parnell, Tracy L.; Suslow, Trevor V.; Harris, Linda J. (March 2004).ANR Catalog. University of California: Division of Agriculture and Natural Resources. Retrieved 18 February 2013.
[60] Use of Physical and Chemical Properties of Commercial Tomato (Lycopersicon esculentum Mill.) Products for Monitoring Their Quality
[61] Z Dollah, A R C AbdullahN M Hashim, A Albar, S Badrealam and Z Z Mohd Zaki.Citrus fruit peel waste as a source of natural coagulant for water turbidity removal.Journal of Physics: Conference Series 1349 (2019) 012011 doi:10.1088/1742-6596/1349/1/012011
[62] Fruit and Vegetable Peels: Utilization of High Value Horticultural Waste in Novel Industrial Applications Harsh Kumar 1,†, Kanchan Bhardwaj 2,†, Ruchi Sharma 1, Eugenie Nepovimova 3, Kamil Kuča 3,*,Daljeet Singh Dhanjal 4, Rachna Verma 2, Prerna Bhardwaj 2, Somesh Sharma 1 and Dinesh Kumar 1,*
[63] Synthesis of thiazolo- and benzothiazolo[3,2-a]pyrimidine derivatives using onion peel as natural catalyst
Sian Hui Tan, Ban Soon Lim, Fu Siong Julius Yong, Mahamad Nasir Abdullah, Hafiza Mohamed Zuki, Seng-Chee Poh, Su-Yin Kan4, and Poh Wai Chia.
[64].Orange peel as low-cost adsorbent in the elimination of Cd(II) ion: kinetics, isotherm, thermodynamic and optimization evaluations Temilade Fola Akinhanmi, Edwin Andrew Ofudje, Abideen Idowu Adeogun, Peter Aina & Ilo Mayowa Joseph
[65] Li Junwei, Ma Yunhai, Tong Jin, Ma Zichao, Wang Lidong & Yu Jiangtao(2018). Mechanical properties and microstructure of potato peels, International Journal of Food.
[66] Valorization of Tomato Processing Residues Through the Production of Active Bio-Composites for Packaging Applications Giuliana Gorrasi,Paola Brachi, Valeria Bugatti, Gianluca Viscusi.2019.