PROPOSAL SUBMITTED FOR PhD ADMISSION BY OKEKE UDODINMA JUDE.

RESEARCH TITLE:
Application of Novel Techniques for Extraction and Characterization of Bioactive Compounds from by-Products of Food Processing as Sources of Ingredients for Functional Foods And Nutraceuticals Development.

KEYWORDS:
Novel Techniques, Extraction, Characterization, Bioactive compounds, Functional Foods, Nutraceuticals, Ingredients Development.

RESEARCH AREA:
Area 07-Agricultural and Veterinary Services / AGR 15- Food Science and Technology

GENERAL PRESENTATION OF THE PROJECT AND STATE OF THE ART:
The food industries have continued to generate enormous amounts of processing by-products particularly from fruit and vegetable processing as a result of higher production rate coupled with inappropriate handling technologies. These volumes of by-products have opened up important research areas aimed towards transforming them into valuable products maximizing production output on one hand and minimizing and managing industrial wastes more efficiently on the other hand through valorization to support zero wastes concept. Besides, food loss and waste reduction/management remain integral parts of the circular economy and food sustainability. Food sustainability is one of the 17 Sustainable Development Goals (SDGs) of the United Nations. But current production and distribution portends great contradictions on food sustainability. While a third of the global volume of food produced for human consumption is lost/wasted FAO (2012), over 2 billion people are exposed to different levels of food insecurity annually (FAO, et al., 2020). The amount of food wasted globally is estimated to be about 1.3 billion tons per annum (Gustavsson, et al., (2011). Higher values up to 60% are reported in horticultural produce (fruits, vegetables, and root crops) according to (Imbert, 2017; Gupta, et al., 2019). Monier, et al., (2010) quantified the amount of food wastes generated in the European Union to be approximately 180 kg of annual food loss per person while the European Commission puts it at slightly lower of approximately 160 kg of food wasted per person (StenMarck, et al., 2016). According to Kader (2004), around one-third of all fruits and vegetables produced globally are lost during postharvest processing, whereas, as much as 50% of the cultivated fruits and vegetables are wasted even before reaching the consumption stage (Sagar, et al., 2018; Elik, et al., 2019).

The food processing industry is one of the largest industrial sectors globally where there is large by-product production with large underutilization leading to piles of wastes that cause complications in environmental terms. Annually, more than 1.6 billion tons of foods are wasted around the world, which causes not only great economic losses estimated to 750 billion USD but also severe damage to natural resources (Garcia-Amezquita, et al., 2018). From the 1.6 billion tons of food wastes, approximately 1.4 billion tons come from plant sources, mainly cereals and vegetables (71%), followed by fruits (25%) and oilseed crops and legumes (4%). Approximately, 46% of these wastes are mainly due to losses during processing and distribution or the non utilization of the entire products (FAO 2013).

Fruit and vegetable wastes generated in food industrial post processing remain underutilized owing to lack of appropriate processing technologies essential for their efficient valorization (Elik, et al., 2018; Hussein, et al., 2020). These vital wastes generated are a well established source of functional ingredients and bioactive compounds. By-products from fruits and vegetable processing such as peels, seeds, and bagasses are of particular interest and the amount of wastes per year as calculated using the 2014 global fruits and vegetable production by FAO (2014) is enormous. Fruit and vegetable processing industries generate high amounts of by-products for instance, 50% from orange, Crizel et al., (2013) and Marín, et al., (2007), 59%; 54%; 33%; 30%; 23%; 20% and 7% from carrots, potatoes, kiwi, bananas, beetroots, grapes and tomatoes respectively (Schieber, et al., 2001). Furthermore, mangoes, apples and pineapples generate 60%, 36% and 32% of wastes respectively (Ajila, et al., 2008; Oreopoulou and Tzia, 2007; Tran and Mitchell, 1995). Some products generate even higher percentages of wastes such as prickly pear and passion fruit wastes represent about 37–67% of peel and 10% of seeds, Jiménez-Aguilar et al., (2015), and 67% of the fruit rind, Schieber et al., (2001), respectively. Recovering and transforming these by-products and bringing them back into the food supply chain is becoming an increasing area of research with tremendous benefits such as tackling global hunger, malnutrition, improved health outcome, reduction in green house gas emission and other hidden costs brought about by food wastes.

Solvent extraction has been use as a conventional method of derivatising phytochemicals from by-products of plants-food processing. However, solvent extraction is plagued with so many challenges such application of toxic and expensive chemicals that are harmful to the environment, inefficient extraction process as only a handful of plant bioactive compounds (anthocyanins, carotenoids, lycopenes, and polyphenols) could be extraction using conventional solvent extraction. Therefore, the overall aim of the PhD research is to develop a novel tandem process that could be used to obtain the optimum bioactive extracts from products of plant-food by-processing and utilize the extracts as functional foods and nutraceutical ingredients. The process will utilize novel technologies such as ultrasound assisted extraction technology, microwave assisted extraction technology, super critical and subcritical fluids extraction techniques, pressurized liquid extraction and enzyme assisted extraction techniques. The state of the art in this research proposal can be seen from the large number of possible combinations of different extraction and separation processes which represents an innovative way for the development of new hybrid or integrated processes, with great potential for saving energy and time and higher extraction yields. Replacing conventional technologies and solvents with non-conventional ones for the extraction of valuable compounds from plant by-products processing industries will provide many advantages both to the food industry, consumers and the environment.

Selection of the most sustainable extraction technique for plant by-products depends on the source and the bioactive compound to be extracted. The use of technologies such as ultrasound assisted extraction, microwave assisted extraction, in combination with pressurized fluid extraction techniques or DES could further enhance extraction efficiencies. The scale up and combination of potential techniques will therefore become priorities for providing sustainable solutions for the increasing food industrial processing by-products challenges.

AIMS AND OBJECTIVES:

The overall aim of the research is to develop a tandem process that could be used to obtain the optimum bioactive extracts from products of plant-food by-processing and utilize the extracts as functional foods and nutraceutical ingredients. The objectives of the research therefore are to:

i. Evaluate the combination of different novel technologies: super- and sub- critical fluids extraction (SFE), Microwave assisted extraction (MAE), Ultrasound assisted extraction (UAE), Pressurized liquid extraction (PLE), Enzyme assisted extraction (EAE) and optimization of the technological and physicochemical parameters for an innovative approach to increase the extraction of the bioactives;

ii. Evaluate the use of natural and acidic deep eutectic solvents (DES) in lieu of toxic chemicals employed during solvent extraction process;

iii. Optimize the number of experiments using various design of experiment (DOE) at screening, such as full or fractional factorial, and at response optimization, using central composite design and/or Box-Behnken design for extraction, purification and characterization of the bioactives.

METHODOLOGY AND EXPECTED RESULTS:

Plant-foods processing generates vast quantities of by-products containing different bioactive compounds depending on the botanical origin and/or part. Bioactive compounds such as flavan-3-ols, procyanidins, flavanols, phenolic acids, anthocyanins, β-carotene, lycopene, alcohols, stilbenes, flavonol glycosides, resveratrol, oleurepein, dietary fibers, alkaloids, saponins, etc are important bioactive compounds that could be obtained from plant-food by-product of processing for use as nutraceutical and functional food ingredients. The study will be designed so that applying combination of novel technology and deep eutectic solvents (DES) will lead to extraction of more and purified bioactives with enhanced functional capabilities, reduction of extraction time and energy, reduction of solvent and enhanced environmental friendliness. Depending on the constituents of by-product(s) the combined technology will take the following extraction techniques and extracts into consideration:

1. Solvent Extraction-Anthocyanins, Carotenoids, Lycopene, Polyphenols;
2. Supercritical Fluid Extraction-Catechins, Epicatechins, Flavonoids, Polyphenols, Procyanidines, Tocopherols;
3. Subcritical Water Extraction - Caffeic acid, Chlorogenic acid, Coumaric acid, Ferulic acid, Gallic acid, Mangiferin;
4. Microwave assisted Extraction - Catechins, Mangiferin, Phenolic compounds, Polyphenols, Saponins,
5. Ultrasound assisted Extraction - Catechins, Anthocyanins, Polyphenols, Saponins, Flavonoids, Beta-glucan, Pectin;
6. Enzyme assisted Extraction - Alkaloids, Lecithin, Lycopene, Polyphenols, Terpenoids.

Recovery and stability of the extracted bioactive compounds will be studied against their antioxidant, antimicrobial and antifungal properties.
The experimental plan will provide the identification and characterization of the bioactive ingredients through HPLC-DAD-MS, GC-FID-MS and UV-VIS and their antioxidant, antimicrobial and antifungal properties investigated using DPPH and FRAP.

EXPECTED OUTCOME:

It is expected that through this research, replacing conventional technologies by non-conventional ones for the extraction of valuable compounds from plant-food by-products will be developed. This new process will have several advantages not only to the food processing industries but also to consumers and the environment at large. Some of the benefits will include reduction of processing time, reduction of energy consumption, enhanced extraction yields, extraction of purer bioactives, enhanced antioxidant activities as well as the reduced use of harmful and expensive solvents.

Bibliography

Ajila, C., Leelavathi, K., and Rao, U.P., (2008) Improvement of dietary fiber content and antioxidant properties in soft dough biscuits with the incorporation of mango peel powder. J. Cereal Sci., 48, 319–326.

Chandrasekaran M., Ali, H., and Bahkali (2013) Valorization of date palm (Phoenix dactylifera) fruit processing by- products and wastes using bioprocess Saudi J Biol Sci 20, 105.

Crizel de Moraes, T., Jablonski Rios de Oliveira, A., Rech, R., and Flores Hickmann, S., (2013) Dietary fiber from orange by-products as a potential fat replacer. LWT Food Sci. Technol., vol. 53 (1) 9-14.

Elik, A., Yanik, D.K., Istanbullu, Y., Guzelsoy, N.A., Yavuz, A., and Gogus, F. (2019) Strategies to reduce post-harvest losses for fruits and vegetables. Strategies, 5, 29–39.

FAO (2012) Food and Agricultural Organisation of the United Nations, database. https://faostat.fao.org. (Accessed 31st May 2012)

FAO (2013) Food wastage footprint Impacts on natural resources. Summary Report. Rome. doi:ISBN 978-92-5-107752-8.

FAO (2014) Definitional Framework of Food Losses and Waste; Food and Agriculture Organization FAO: Rome, Italy,. Available online: http://www.fao.org/3/a-at144e.pdf (accessed on 27 March 2020).

FAO, IFAD, UNICEF, WFP and WHO, (2020) The State of Food Security and Nutrition in the World 2020. Transforming food systems for affordable healthy diets, Rome, FAO.

Garcia-Amezquita, L.E., Tejada-Ortigoza, V., Serna-Saldivar, S.O., Welti-Chanes, J., (2018) Dietary Fiber Concentrates from Fruit and Vegetable By-products: Processing, Modification, and Application as Functional Ingredients. Food and Bioprocess Technology 11:1439–1463 https://doi.org/10.1007/s11947-018-2117-2.

Gupta, N.; Poddar, K.; Sarkar, D.; Kumari, N.; Padhan, B.; Sarkar, A. (2019) Fruit waste management by pigment production and utilization of residual as bioadsorbent. J. Environ. Manag, 244, 138–143.

Gustavsson, J.; Cederberg, C.; Sonesson, U.; Van Otterdijk, R.; Meybeck, A. (2011) Global Food Losses and Waste: Extent, Causes and Prevention. In A Study Conducted for International

Congress “Save Food” at Inter. FAO, Dusseldorf, Germany, 2011; Food and Agriculture Organization of the United Nations: Rome, Italy. Available online: http://www.fao.org/3/a-i2697e.pdf (accessed on 7 February 2020).

Hussain, S., Jõudu, I., and Bhat, R., (2020) Dietary Fiber from Underutilized Plant Resources—A Positive Approach for Valorization of Fruit and Vegetable Wastes. Sustainability, 12, 5401, 1-30. http://dx.doi.org/10.3390/su12135401.

Imbert, E. (2017) Food waste valorization options: Opportunities from the Bioeconomy. Open Agric., 2, 195–204.

Jimenez-Escrig, A., Rincon, M., Pulido, R., and Saura-Calixto, F., (2001) Guava fruit (Psidium guajava L.) as a new source of antioxidant dietary fiber. J. Agri. and Food Chem, 49, 5489-5493.

Kader, A.A. (2004) Increasing food availability by reducing postharvest losses of fresh produce. Acta Hort., 682, 2169–2176.

Marin, F.R., Frutos, M.J., Perez-Alvarez, J.A., Martinez-Sanchez, F. and Del Rio, J.A., (2002) Flavonoids as nutraceuticals: structural related antioxidant properties and their role on ascorbic acid preservation. In E. Atta-Ur-Rahman (Ed.), Studies in natural products chemistry. Amsterdam:Elsevier. 741

Monier, V.; Mudgal, S.; Escalon, V.; O’Connor, C.; Gibon, T.; Anderson, G.; Montoux, H.; Reisinger, H.; Dolley, P.; Ogilvie, S.; et al. (2010) Preparatory Study on Food Waste across EU 27. Report for the European Commission [DG ENV-Directorate C]; European Commission:Paris,France.Available:online:https://ec.europa.eu/environment/eussd/pdf/bio_foodwaste_report.pdf (accessed on 2 February 2020).

Sagar, N.A.; Pareek, S.; Sharma, S.; Yahia, E.M.; Lobo, M.G. (2018) Fruit and vegetable waste: Bioactive compounds, their extraction, and possible utilization. Compr. Rev. Food Sci.17, 512–531.

Saikia, S. and Mahanta, C. L. (2016) In vitro physicochemical, phytochemical and functional properties of fiber rich fractions derived from by-products of six fruits,” Journal of Food Science and Technology, vol. 53, no. 3, pp. 1496–1504.

Schieber, A., Stintzing, F. C.& Carle, R. (2001.)By-products of plant food processing as a source of functional compounds–recent developments. Trends in Food Science and Technology, 12, 401–413.

Stenmarck, Â.; Jensen, C.; Quested, T.; Moates, G.; Buksti, M.; Cseh, B.; Juul, S.; Parry, A.; Politano, A.; Redlingshofer, B. (2016) Estimates of European Food Waste Levels; IVL Swedish EnvironmentalResearchInstitute:Stockholm,Sweden,;Availableonline:https://www.eufusions.org/phocadownload/Publications/Estimates%20of%20European%20food%20waste%20levels.pdf (accessed on 8 October 2019).

RESEARCH FEASIBILITY AND TIMELINES:

Task Name	Duration	Start	Finish	Semester
1.Research Proposal finalization and presentation	90 days	Sun 10/10/21	Sat 8/01/22	Fall 2021
1.Refinement of Research Proposal; 2.Preparation of Samples; 3. Preliminary Screening tests.	85 days	Sun 9/01/22	Sat 9/04/22	Spring 2021
Extraction Experiments; A. Screening tests 1.UAE/MAE; 2. MAE/SFE; 3. UAE/SFE 4. Purification 5. DPPH/FRAP Antioxidant tests	121 days	Sun 10/04/22	Sat 06/08/22	Fall 2022
1. UAE/PLE; 2. MAE/PLE 3. PLE/SFE 4.purification 5.DPPH/FRAP Antioxidant tests	121 days	Sun 07/8/22	Sat 03/12/22	Spring 2022
B. Optimization of Extraction/ Characterisation: 1. HPLC-DAD-MS; 2. GC-FID-MS; 3. UV-VIS 4. DPPH/FRAP Antioxidant tests	125 days	Sun 04/12/22	Sat 08/04/23	Fall 2023
1. Finalization of Dissertation Report; 2. Dissertation Defense; 3. Submission and Graduation.	123 days	Sun 09/04/23	Tue 09/09/23	Spring 2023