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Sustainable production of next generation biofuels from waste streams

Key external stakeholders:

Food processors, Policy makers, Carbohydrate-based food product manufacturers, Bio-fuels manufacturers, Nutraceutical manufacturers

Practical implications for stakeholders:

EU faces a challenge of ensuring clean, secure and efficient energy system in the coming decades. Sustainable biofuels manufacturing without negative impact on land use and biodiversity is a direction to solve the challenge. Selection of good sources for fermentation to product biofuels is necessary. Each year millions tons of agri-food wastes is produced, many of which contain considerable amount of carbohydrate suitable for biofuel fermentation. The agri-food waste, such as is hence valorized by biofuel production, and also by extraction of high valuable bio-compounds there. The project established the methods and confirm the feasibility of making use of agri-food waste to produce bio-butanol, and of extraction of bio-compounds, such as polyphenols, pectin, amnio acid, lipids from the wastes. Novel green extraction methods were established to extract the bioactive compounds, employing ultrasound, microwave and enzyme, to avoid traditional employment of organic solvent which could introduce environmental friendly approaches for high value compounds.

Main results:

1. Suitable enzyme and catalytic routes were selected for production of bio-butanol from popular agri-food wastes (coffee silver skin, potato peels, apple pomace, and BSG).
2. Novel green extraction methods, combining power ultrasound, microwave, and enzyme, using water other than organic solvent as solvent were established to avoid solvent-caused environmental shock, which can be employed in many other extraction processing in lab or industry.
3. High value bioactive compounds were extracted from some of the wastes using the novel green extraction technologies:

    BSG could be a good source for protein/AA, its extract shows antimicrobial activity to some bacteria, like Staphylococcus aureus, such pectin, high-antioxidant polyphenols, amino acids, lipid, were extracted from the wastes,

    Apple pomace is a good source of polyphenolic compounds, containing many well-known bioactives; pectin yield could reach as high as appro. 50% under optimal extraction conditions, using novel extraction technologies, and the pectin is LM pectin, suitable for gelling agent and stabilizer in food and cosmetic industry.

Opportunity / Benefit:

Further developments in the area of novel extraction technologies and an increase in the awareness of the potentials values of the agri-food wastes, in which much more bioactive compounds can be extracted and exploited in future.

Collaborating Institutions:

Contact Brijesh Tiwari Email: Brijesh.Tiwari@teagasc.ie.

Teagasc project team: Prof Brijesh K Tiwari (PI)
Dr Dilip Rai, Dr Zhihang Zhang
External collaborators: Dr. Mirta Pinilla Rodriguez, IRIS (Coordinator) and 45 European Researchers

1. Project background:

WASTE2FUELS developed next generation biofuel technologies capable of converting agrofood waste (AFW) streams into high quality biobutanol and value added products. The partners of the project were active in: i) the development of novel pre-treatment methods for converting AFWs to an appropriate feedstock for biobutanol production; ii) in genetically modification of microorganisms for enhancing conversion efficiencies of the biobutanol fermentation process; iii) the development of integrated recovery-fermentation system coupling inline the solvent recovery and biofilm reactor systems for enhancing conversion efficiencies of Acetone-Butanol-Ethanol (ABE) fermentation; iv) the development of new routes for biobutanol production via ethanol catalytic conversion; v) the valorisation of the process by-products; vi) the development of an integrated model to optimize the waste-to-biofuel conversion and facilitate the industrial scale-up; vii) the process fingerprint analysis by environmental and techno-economic assessment; viii) the biomass supply chain study and design of a waste management strategy for rural development. Teagasc developed strategies for valorisation of AFWs by recovering added value by-product, apple pomace, coffee silver skin, potato peels, and brewer's spent grain for bioactives, proteins and amino acids. The WASTE2FUELS project contribute to advance the state-of-the-art in the biorefinery concept of the biobutanol production from waste by performing a complete analysis of the possible valorisation routes along the whole biobutanol production value chain, including initial AFW matrices and wastes from pretreatments, fermentation and catalytic routes. Energy valorisation and extraction of high-value compounds were performed.

2. Questions addressed by the project:

How AFWs can be valorized for value added compounds, which are currently considered as waste. Can these waste processing streams can be converted to high value ingredients by employing clean and green extraction techniques.

3. The experimental studies:

A complete characterization of target AFW wastes (apple pomace, silverskin, potato peels and BSG) was made in order to evaluate the feasibility of the proposed AFW matrix for valorisaion routes. Various novel extraction techniques including ultrasonics, microwave, enzyme assisted processes alone or in combination were employed. The use of clean and green solvents compared to conventional solvents and techniques were investigated. Extrinsic and intrinsic process control parameters to obtain value added compounds from AFWs were determined.

4. Main results:

• Development of novel pretreatment methods for converting AFW to an appropriate feedstock for the production of value added compounds thus dramatically enlarging current available biomass for biofuels production.
• Genetically modified microorganisms for enhancing conversion efficiencies of the biobutanol fermentation process.
• Coupled recovery and biofilm reactor systems for enhancing conversion efficiencies of Acetone-Butanol-Ethanol fermentation
• Development of new routes for biobutanol production via ethanol catalytic conversion.
• Biobutanol engine tests and ecotoxicological assessment of the produced biobutanol.
• Valorisation of the process by-products for high value food ingredients including bioactives, proteins and fibres.
• Development of an integrated model to optimise the waste-to-biofuel conversion and facilitate the industrial scale-up
• Process fingerprint analysis by environmental and techno-economic assessment
• Biomass supply chain study and design of a waste management strategy for rural development.

Contact Brijesh Tiwari Email: Brijesh.Tiwari@teagasc.ie.

5. Opportunity/Benefit:

State-of-the art novel ultrasound, microwave and enzyme assisted extraction technologies were developed for bioactives.
A green extraction concept was developed involving energy efficient extraction technologies green solvents used to reduce environmental shock, and less energy consumption for post-processing, to achieve a sustainable extraction processing.
Technologies to valorise apple pomace waste for bioactives, pectins, amino acids and proteins was developed.
Technologies to valorise coffee silver skin for dietary fibre, caffeine, proteins and other bioactives was developed for food applications.
Valorisation routes for potato peels and Brewers spent grains for proteins, bioactives and dietary fibre were developed.
The application of pre-treatment, extraction and biotransformation approaches for selected biomasses investigated in this project can be translated to other biomass of interest.

6. Dissemination:

Main publications:

Wen, L., Álvarez, C., Zhang, Z., Poojary, M. M., Lund, M. N., Sun, D.-W., & Tiwari, B. K. (2020). Optimisation and characterisation of protein extraction from coffee silverskin assisted by ultrasound or microwave techniques. Biomass Conversion and Biorefinery, 1-11.
Wen, L., Zhang, Z., Rai, D., Sun, D. W., & Tiwari, B. K. (2019). Ultrasound-assisted extraction (UAE) of bioactive compounds from coffee silverskin: Impact on phenolic content, antioxidant activity, and morphological characteristics. Journal of Food Process Engineering, 42(6), e13191.
Wen, L., Zhang, Z., Sun, D.-W., Sivagnanam, S. P., & Tiwari, B. K. (2020). Combination of emerging technologies for the extraction of bioactive compounds. Critical Reviews in Food Science and Nutrition, 60(11), 1826-1841.
Wen, L., Zhang, Z., Zhao, M., Senthamaraikannan, R., Padamati, R. B., Sun, D. W., & Tiwari, B. K. (2020). Green extraction of soluble dietary fibre from coffee silverskin: impact of ultrasound/microwave-assisted extraction. International Journal of Food Science & Technology, 55(5), 2242-2250.
Perussello, C. A., Zhang, Z., Marzocchella, A., & Tiwari, B. K. (2017). Valorization of apple pomace by extraction of valuable compounds. Comprehensive Reviews in Food Science and Food Safety, 16(5), 776-796.
Zhang, Z., Poojary, M. M., Choudhary, A., Rai, D. K., & Tiwari, B. K. (2018). Comparison of selected clean and green extraction technologies for biomolecules from apple pomace. Electrophoresis, 39(15), 1934-1945.
Hassan, S. S., Ravindran, R., Jaiswal, S., Tiwari, B. K., Williams, G. A., & Jaiswal, A. K. (2020). An evaluation of sonication pretreatment for enhancing saccharification of brewers' spent grain. Waste Management, 105, 240-247.
Hassan, S. S., Tiwari, B. K., Williams, G. A., & Jaiswal, A. K. (2020). Bioprocessing of brewers' spent grain for production of xylanopectinolytic enzymes by Mucor sp. Bioresource Technology Reports, 9, 100371.

Popular publications:

Zhang, Z. & Tiwari, B. K. (2017). Next generation biofuels, 12 (3), TResearch
Priyadarshini, A, Rajauria, G., Wen, L and Tiwari, B.K. (2019) Bio-Waste to Bio-Based 14 (3), TResearch.

7. Compiled by: Brijesh K Tiwari and Zhihang Zhang

Contact Brijesh Tiwari Email: Brijesh.Tiwari@teagasc.ie.