Towards a food waste integrated biorefinery: Downstream valorization of apple pomace

Jacopo Paini [1], Vittoria Benedetti [1], Marco Baratieri [1], Francesco Patuzzi [1]

[1] *Faculty of Science and Technology, Free University of Bozen-Bolzano, Bolzano, 39100, Italy.*
Keywords: Biorefinery, Food waste valorization, Subcritical water, Hydrothermal Carbonization
Presenting author e-mail: jacopo.paini@natec.unibz.it, Tel: +39 0471 017250

Global population is expected to increase steadily, showing a growth trend reaching over 9 billion people by 2050 (Henry et al. 2018). Due to this, the demand for food is expected to increase, particularly for food with high protein content. Food value chain contributes to environmental degradation and greenhouse gases emissions in all its stages: production, processing, consumption and waste. Food waste has been defined by the European Parliament as: 'food intended for human consumption, either in edible or inedible status, removed from the production or supply chain to be discarded, including at primary production, processing, manufacturing, transportation, storage, retail and consumer levels, with the exception of primary production losses' (Banks et al. 2018; European Parliament 2017). Just in Europe, food waste has been estimated to be 173 kg ca. per person yearly (Banks et al. 2018; European Parliament 2017) and therefore, innovative strategies are necessary for its valorization.

Food waste is characterized by a high moisture content as well as seasonal variability, which can influence the selection of the most suitable applications (Trabold and Babbitt 2018). Currently, biochemical conversion technologies (i.e. anaerobic digestion and fermentation) are preferred to handle wet substrates while thermochemical conversion technologies (i.e. gasification and pyrolysis) are applied to feedstocks with low moisture content(Trabold and Babbitt 2018). Wet substrates could be treated also through, hydrothermal carbonization (HTC), a process operating under subcritical water temperatures between 150 °C to 250 °C. These conditions promote hydrolysis reactions to disentangle complex substrates, considering that under critical and subcritical conditions water acquires properties interesting for the extraction of valuable compounds (Ibrahim, Santos, and Bowra 2018; Hoshino et al. 2009). Specifically, this work aims at valorizing wet food waste from apple juice industry by integrating, in the same reactor, subcritical water extraction with downstream HTC. In this framework, waste streams from food processing industries can be implemented for the extraction and fractionation of raw materials and, in a biorefinery perspective, spent material can be further employed.

Materials and Methods

The substrate selected for this study is pomace from apple juice production. The material was provided by a local company, producing apple juice from the Golden Delicious cultivar. The process firstly involves washing and selecting apples. Then fruits are crushed and pressed using an industrial belt filter press. Finally, the juice obtained is initially decanted, bottled and pasteurized. Currently, apple pomace is used as cattle feeding.

To process the collected material, a 250 mL stainless steel reactor is employed. The first extraction step is performed in a temperature range from 100 to 125°C. To maintain the solvent in a liquid state, pressure is kept above saturation (around 6 bar) using N_2. Hence, acid hydrolysis is improved due to the higher ionization constant of water (Kw) (Bandura and Lvov 2006; Eric W. Lemmon 2019). Then, spent material is characterized by moisture and ash content according to UNI EN ISO 18134-2:2015 and UNI EN 14775:2010, respectively. Elemental composition is determined by elemental analyzer (Vario MACRO cube, Elementar). Higher heating value of the samples is measured by an isoperibolic calorimeter (IKA C200). In addition, thermal analysis of solid spent material is performed using a Simultaneous Thermogravimetric Analyser (Jupiter STA 449F3, Netzsch) coupled with a Fourier Transform Infrared Spectrometer (FT-IR, Tensor 27, Bruker) for the analysis of evolved gases. Folin-Ciocalteu antioxidant capacity assay and galacturonic acid content are used to respectively quantify phenolic and pectin content in the liquid phase. Afterwards, HTC of spent material was performed at 220 °C for 3 hours. The solid material and the liquid phase obtained were collected, separated and characterized with the same methodologies previously described.

Results and discussion

Before testing, a thorough characterization of apple pomace was necessary. Three different procedures to stabilize the feedstock have been adopted and assessed according to the literature (Zhang et al. 2018). Preliminary results are reported in Table 1. Apart from the moisture content, stabilization methodologies do not affect the composition of the samples.

Table 1 Ultimate and calorimetric analyses of apple pomace (* oxygen calculated by difference)

		105 °C 24 hours	**60 °C 48 hours**	**40 °C 96 hours**
Ash	$\%wt_{db}$	1.42 ± 0.10	1.20 ± 0.10	1.54 ± 0.2
Moisture	%	0	4.51 ± 0.20	7.11 ± 0.02
Carbon	$\%wt_{db}$	46.98 ± 0.36	46.63 ± 0.77	46.83 ± 0.77
Hydrogen	$\%wt_{db}$	6.93 ± 0.10	6.46 ± 0.13	6.42 ± 0.04
Nitrogen	$\%wt_{db}$	0.55 ± 0.03	0.58 ± 0.03	0.64 ± 0.04
Oxygen*	$\%wt_{db}$	43.68	44.80	44.28
Sulphur	$\%wt_{db}$	0.44 ± 0.12	0.35 ± 0.01	0.30 ± 0.01
HHV	MJ/kg	18.06 ± 0.18	17.51 ± 0.23	17.69 ± 0.21
Volatile Matter	%	74.35		
Fixed Carbon	%	24.23		

Our preliminary results demonstrate that it is possible to valorize food waste using water at subcritical conditions. Such pre-treatment step is an effective approach to sequentially recover thermolabile compounds, hydrolyzed proteins and polysaccharides, ranging from 10 to 60% of recoverable products at increasing reaction temperatures (Ibrahim, Santos, and Bowra 2018; Hoshino et al. 2009). Temperatures also influence apple pomace total phenolic content extraction in the order from 6 mg GAE / g dw to 46 mg GAE / g dw. With this process it is possible to employ food waste and residues from food processing industries by recovering green chemicals before their thermochemical treatment. So, the amount of material to dispose of would be considerably reduced.

References

Bandura, Andrei V., and Serguei N. Lvov. 2006. 'The Ionization Constant of Water over Wide Ranges of Temperature and Density'. *Journal of Physical and Chemical Reference Data* 35 (1): 15–30. https://doi.org/10.1063/1.1928231.

Citation Banks, C J, S Heaven, Y Zhang, and U Baier. 2018. *Food Waste Digestion: Anaerobic Digestion of Food Waste for a Circular Economy*. *IEA Bioenergy Task*. Vol. 37.

Eric W. Lemmon, Mark O. McLinden and Daniel G. Friend. 2019. 'Thermophysical Properties of Fluid Systems'. NIST Chemistry WebBook, NIST Standard Reference Database Number 69, Eds. P.J. Linstrom and W.G. Mallard. 2019. https://doi.org/https://doi.org/10.18434/T4D303.

European Parliament. 2017. 'European Parliament Resolution of 16 May 2017 on Initiative on Resource Efficiency: Reducing Food Waste, Improving Food Safety (2016/2223(INI)'. https://www.europarl.europa.eu/doceo/document/TA-8-2017-0207_EN.pdf.

Henry, R. C., K. Engström, S. Olin, P. Alexander, A. Arneth, and M. D.A. Rounsevell. 2018. 'Food Supply and Bioenergy Production within the Global Cropland Planetary Boundary'. *PLoS ONE* 13 (3): 1–17. https://doi.org/10.1371/journal.pone.0194695.

Hoshino, Munehiro, Masahiro Tanaka, Akihiro Terada, Mittsuru Sasaki, and Motonobu Goto. 2009. 'Separation and Characterization of Pectin From Juice Processing Residue Extracted By Sub-Critical Water'. *The 5th ISFR (October 11-14, 2009, Chengdu, China)*, 223–28.

Ibrahim, Salis, Regina Santos, and Steve Bowra. 2018. 'Optimization of Subcritical Water Mediated Extraction of Apple Pomace Polyphenolics and Their Antioxidant Activity'. *Journal of Chromatography & Separation Techniques* 09 (05). https://doi.org/10.4172/2157-7064.1000410.

Trabold, Thomas A., and Callie W. Babbitt. 2018. *Sustainable Food Waste-To-Energy Systems*. *Sustainable Food Waste-To-Energy Systems*. Elsevier. https://doi.org/10.1016/C2016-0-00715-5.

Zhang, Bide, Mohammad Heidari, Bharat Regmi, Shakirudeen Salaudeen, Precious Arku, Mahendra Thimmannagari, and Animesh Dutta. 2018. 'Hydrothermal Carbonization of Fruit Wastes: A Promising Technique for Generating Hydrochar'. *Energies*. https://doi.org/10.3390/en11082022.