Waste to Wealth: Transforming Food Waste to Slash Methane in Landfills

By. Ruben Ignatius

Problem:

When food waste is left in landfills it eventually turns into methane gas. Methane gas is 28 times more potent than carbon dioxide and after a decade it turns into carbon dioxide. This project looks at food waste from various industries, analyzes the important bioactive compounds found in them and the potential of extracting them using various techniques.

So with this considered, I will be trying to answer the question:

- What would be an effective way of keeping food waste from landfills other than composting?

Method:

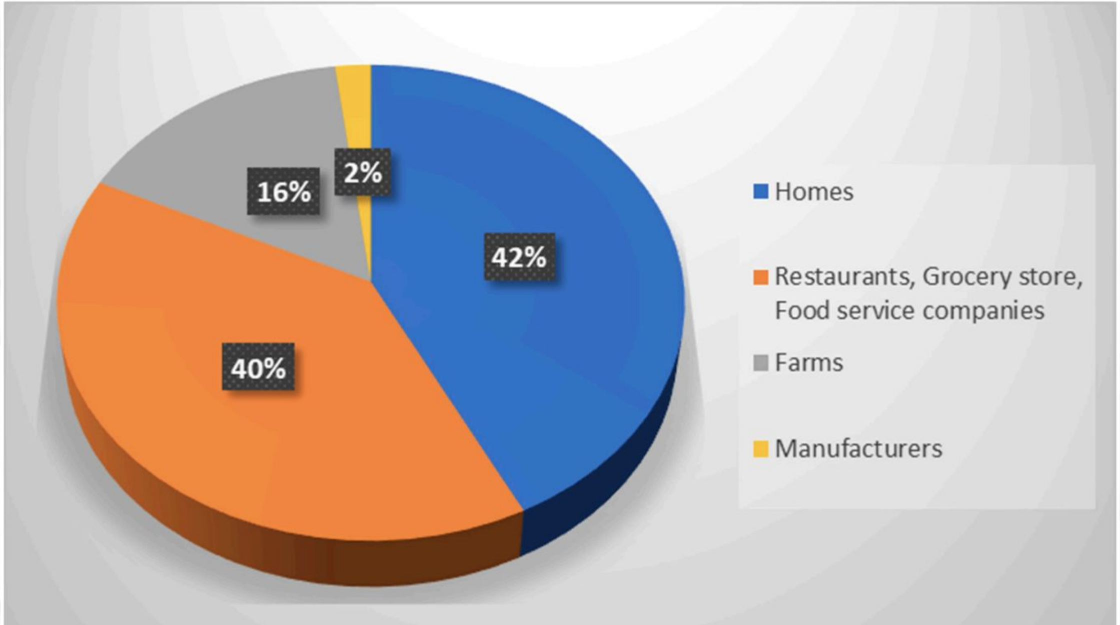
1. Research food waste decay rate in landfills and efficiency of gas collection systems in capturing the methane emissions from food waste.

2. Analyse different sources of food waste from major food industries.

3. Examine the different food valorization techniques in converting food waste into useful bioactive compounds.

Background Research

- 30 to 40% of the food produced by farmers globally, is never consumed.
- At the manufacturing level, more than 10% of food is wasted due to human errors.
- About 30% of food is thrown away by grocery stores
- The annual value of food wasted worldwide is one trillion dollars



Percentage of food waste generated at various levels of food supply chain in America

Landfill systems

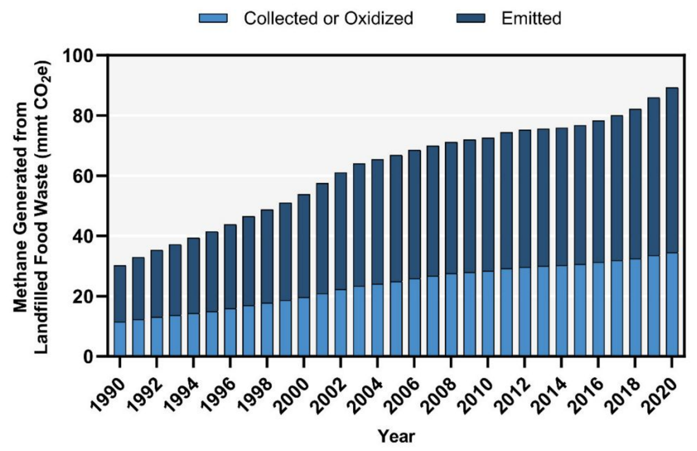
It is mandatory for landfills to install gas collection systems within five years to capture methane gas being produced in landfills. Most food wastes produced are not composted rather they are taken in landfills where they turn into methane gas.

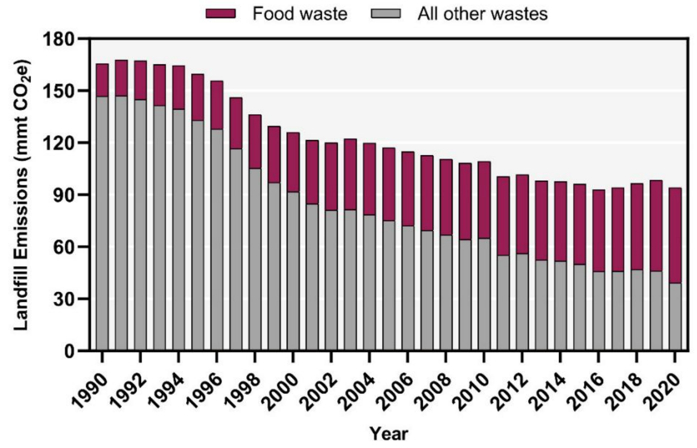
Material	Decay rate (yr^{-1})	Number of years over which ½ of the carbon has been degraded to methane
Branches (Yard)	0.02	34.6
Cardboard	0.03	23.1
Copy paper	0.04	17.3
Dimensional lumber	0.11	6.3
Food waste	0.19	3.6
Leaves (Yard)	0.22	3.2
Grass (Yard)	0.39	1.8

Decay rate of various organic materials

The decay rate is a first order reaction – the higher the rate, the faster the decay. For example, food waste has a decay rate of 0.19 means that half of the carbon has been degraded to methane in 3.6 years.

Efficiency of collection systems

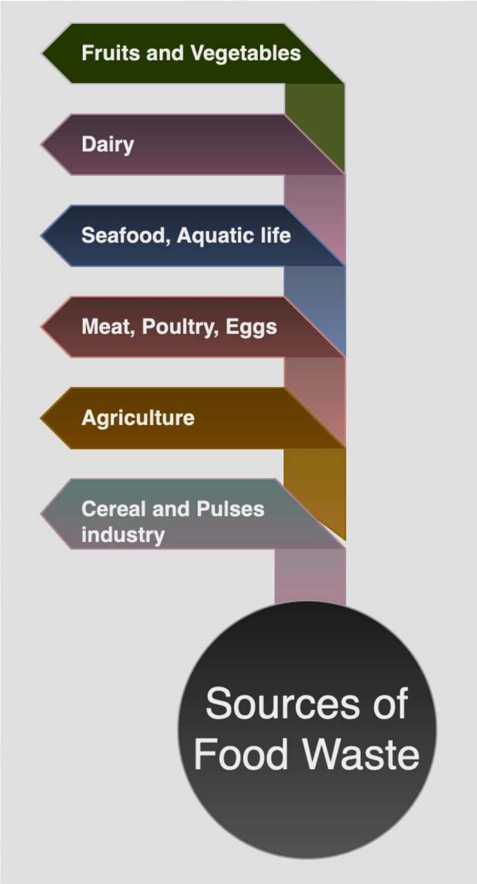




- An estimated 61 percent of methane generated by food waste avoids collection by landfill gas collection systems. They become fugitive emissions (i.e., is released to the atmosphere)

- The increase in the amount of methane emitted from food waste is due to:
    - Food waste emissions occur earlier and landfill operators are collecting more gas later in the landfills lifetime than earlier.
    - Thus, for materials like biodegradable textiles, paper products, and wood, which degrade more slowly, more of the landfill gas is collected.

Sources of food waste



Waste from different industries

Fruits and Vegetables

- Changes in colour, infected with microbes, breakage or frostbite, subjected to heat treatment, reaching levels of ripeness that make them unacceptable to consumers are often considered waste.
- Harvesting, transportation, sales, and processing, nearly 30% of the fruits and vegetables produced were wasted during these processes.
- Fruits and vegetables are abundant in essential nutrients and contain high levels of water, soluble carbohydrates, fiber, minerals, vitamins, polyphenols, and other bioactive compounds.

Dairy

- In the total milk production worldwide, approximately one-sixth is lost or wasted which amounts to an annual wastage of around 128 million tons of milk
- Microbial spoilage, inadequate handling and processing are factors that generate waste in the dairy industry.
- The complex organic composition of dairy products includes proteins, fats, sugars, and a small quantity of food additives.

Waste from different industries cont'd…

Seafood and Aquatic life	Meat, Poultry, Eggs
• Around 50–70% of raw seafood is wasted annually. • The seafood waste includes inedible fractions such as shrimp shells, crab shells, prawn waste, fish scales, and endoskeleton shells of crustaceans • The shells and scales are rich in valuable chemicals such as proteins, chitin, and calcium carbonate.	• Livestock industry generates large quantities of slaughterhouse waste, and wastewater with 49% originating from cattle, 47% sheep and lambs, 44% pigs, and 37% chickens. • The most typical industrial waste materials are feathers, hair, skin, horns, hooves, soft tissue, deboning remnants, and bones. • These waste contain blood residue, animal fat, protein, and a substantial quantity of organic matter

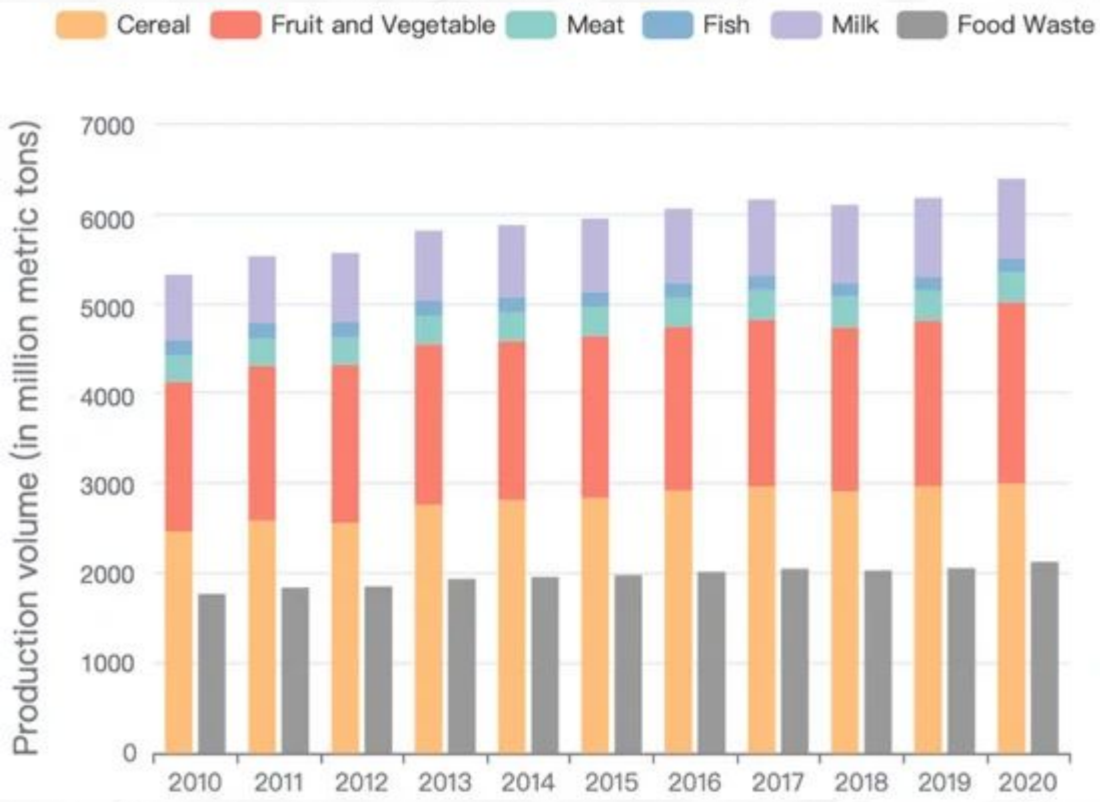
Waste from different industries cont'd…

Agriculture

- Agricultural waste encompasses a variety of materials, such as straw, bagasse, molasses, spent grains, husks, nut shells, fruit skins, and plant debris.
- Approximately 250 million tons of inedible plant waste from different crop processing methods are generated as agricultural waste.
- Agricultural wastes contains various nutrients such as polysaccharides (starch, cellulose, hemicellulose), proteins, lignin, fiber, minerals, and vitamins.

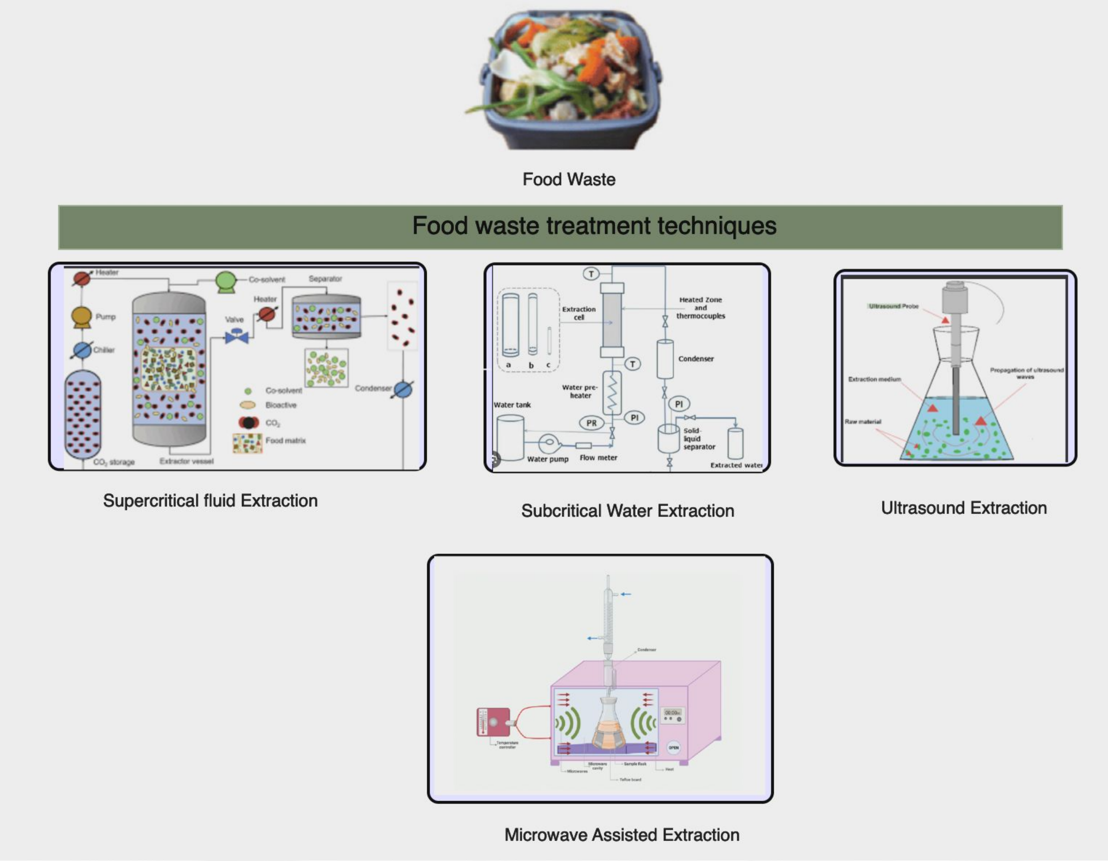
Cereals and Pulses

- Residue from this industry is often considered waste
- These wastes are a rich source of various bioactive compounds, including phytates, phenolics, and insoluble dietary fiber, Vitamin E.



Cereal
Fruit and Vegetable
Meat
Fish
Milk
Food Waste
Production volume (in million metric tons)
7000
6000
5000
4000
3000
2000
1000
0
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020

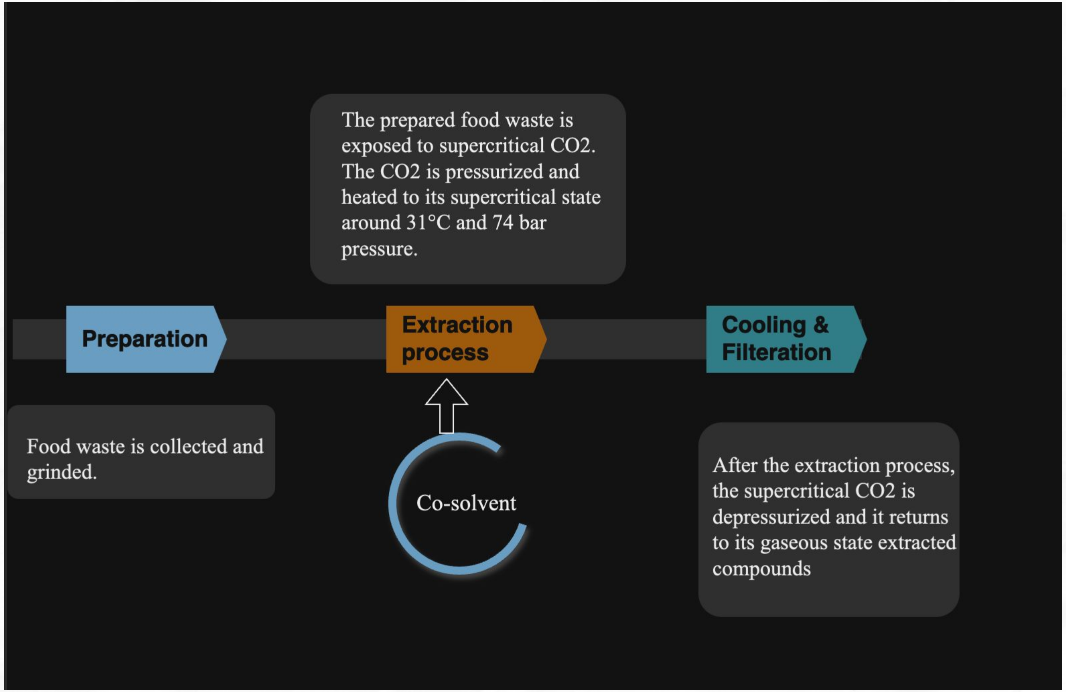
Food valorization techniques

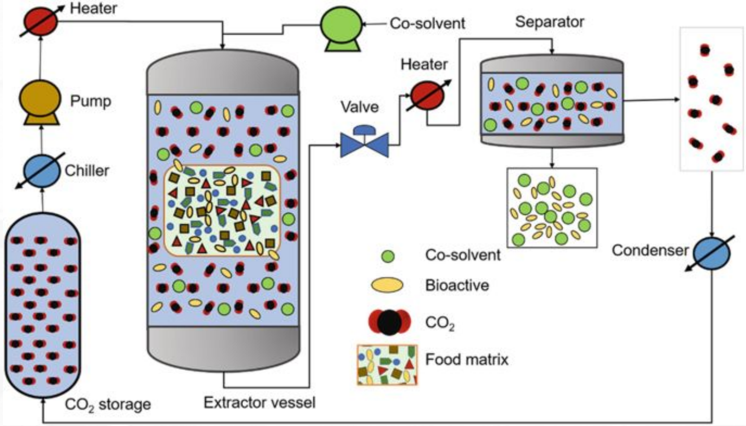


Novel approaches to circulate waste by producing bio-active compounds

Supercritical fluid extraction

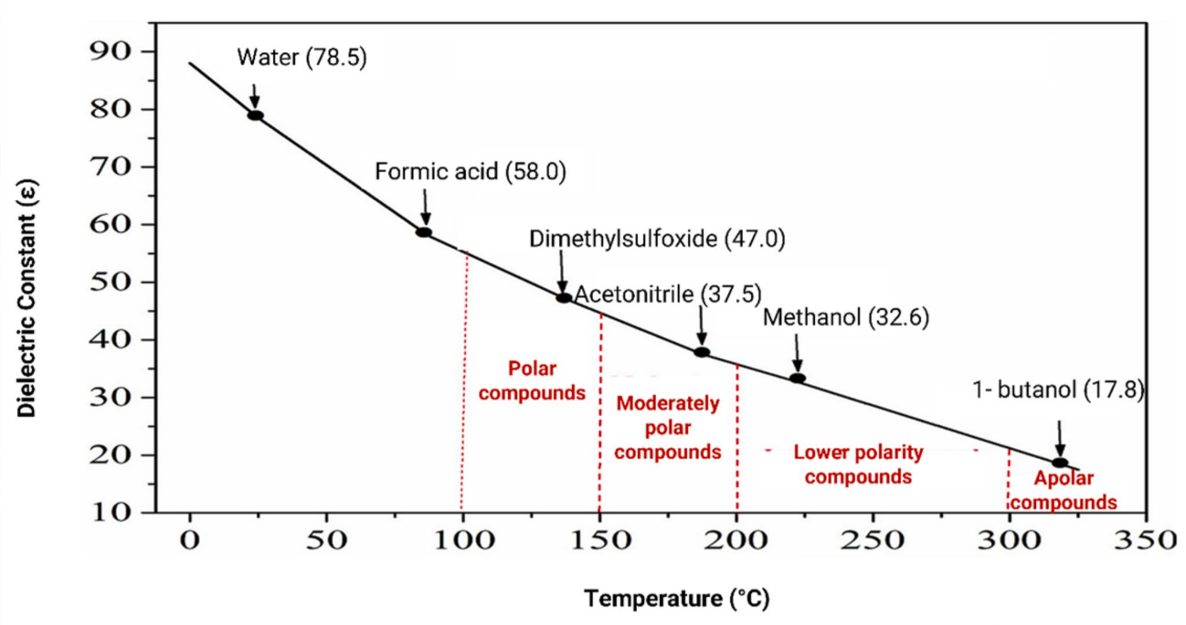
Supercritical fluid extraction (SFE) is a process that uses supercritical fluids, such as carbon dioxide (CO2), to extract desirable compounds from various substances. In the context of food waste, SFE with CO2 can be a valuable technique for extracting valuable compounds from food waste streams, thereby reducing waste and potentially obtaining useful products.



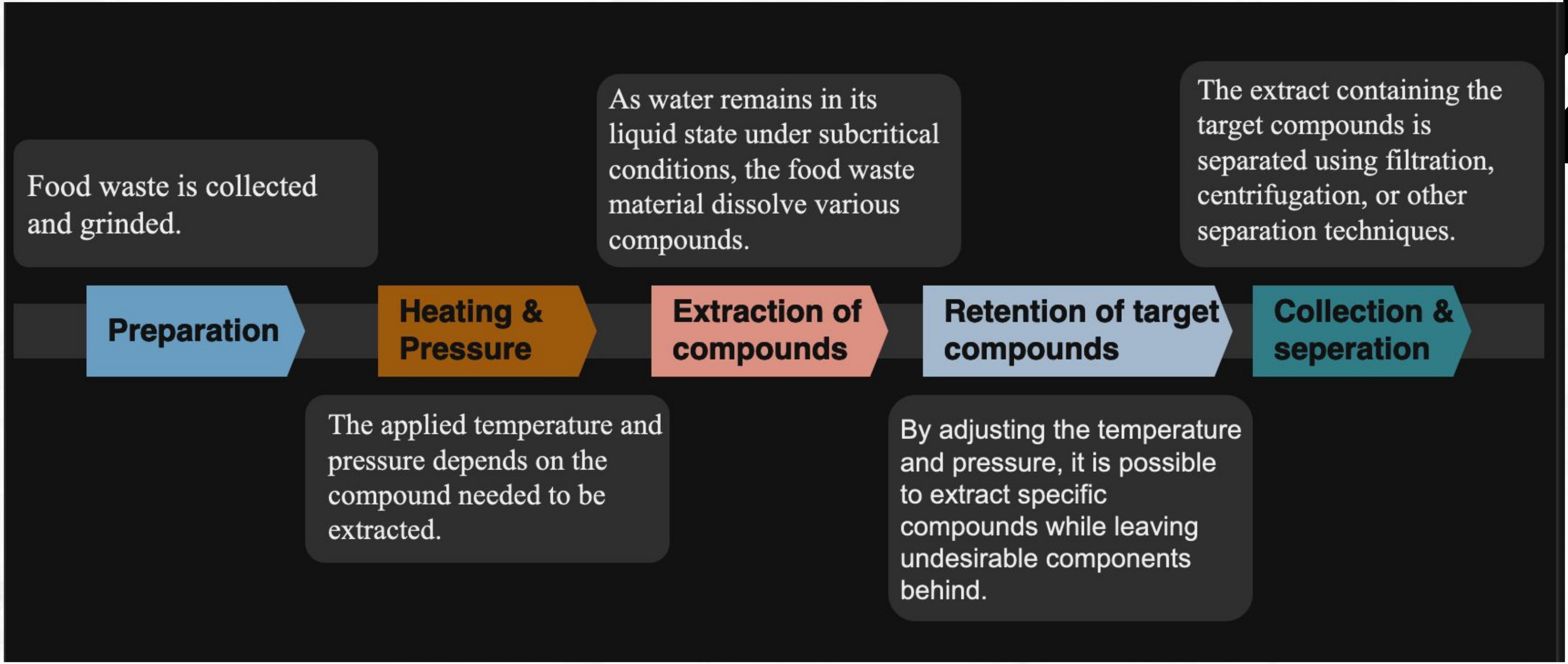


Raw material	Extraction Conditions	Compound
Apricot, sweet potato, red tomato, pumpkin and peach peels; green, yellow and red bell peppers and their waste residues (seeds and stems) Grape peel Banana peel Yarrow and rosehip herbal dust, and their mixture	59 C; 350 bar; 15.5% of ethanol; 30 min; flow rate of 15 g min1 37–46 C; 137–167 bar; 5%–8% of ethanol; 30 min; flow rate of 2 mL min1 40–50 C; 100–300 bar; 220 min; flow rate of 5 g min1 40 and 60 C; 100–300 bar; 5 h; flow rate of 0.194 kg h1	Carotenoids
Orange peel	35.86–64.14 C; 82.7–333.7 bar; 90 min	Terpenes
Broccoli stem and leaves	443 bar, 40 °C, 31 g/min	β-carotene, chlorophylls, phytosterols, and phenolic compounds
Tomato waste, seeds and skins	150 bar, 20 °C, and 5 mL/min	Lycopene 205 mg per 100 g and β-carotene 75 mg per 100 g of extracted oleoresin

Subcritical water extraction



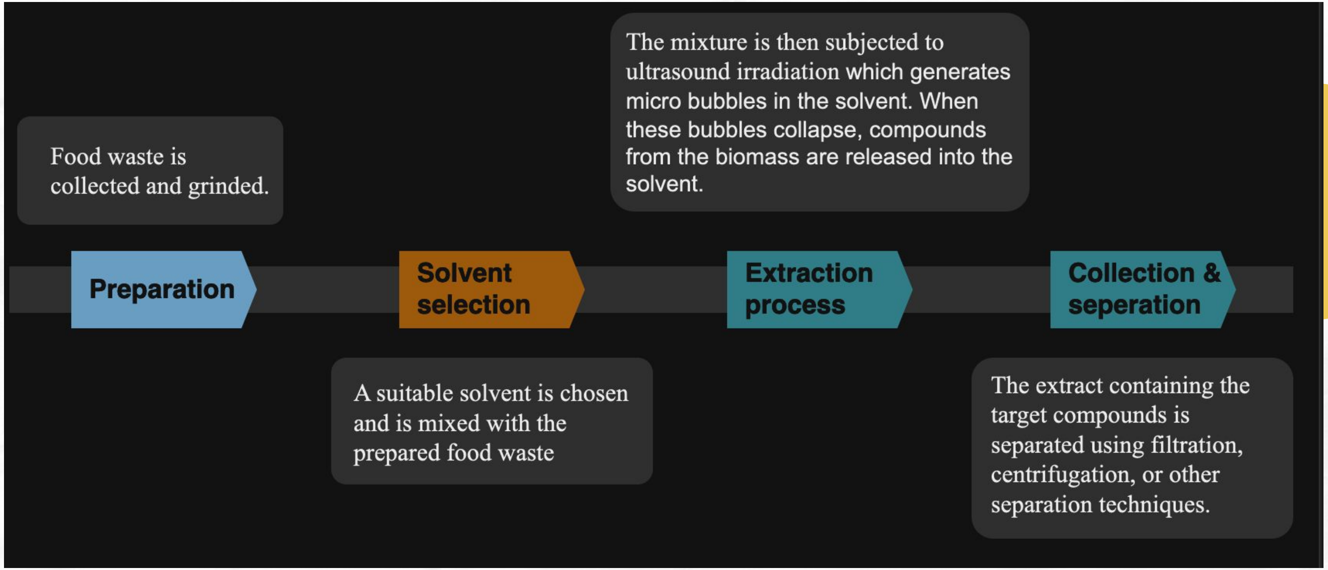
Referred to as high-temperature and high-pressure water is subcritical water. Useful and unique characteristics of subcritical water, its polarity can be dramatically decreased with increasing temperature. Meaning subcritical water can behave similar to methanol or ethanol. Making subcritical water a green extraction fluid used for a variety of organic species.

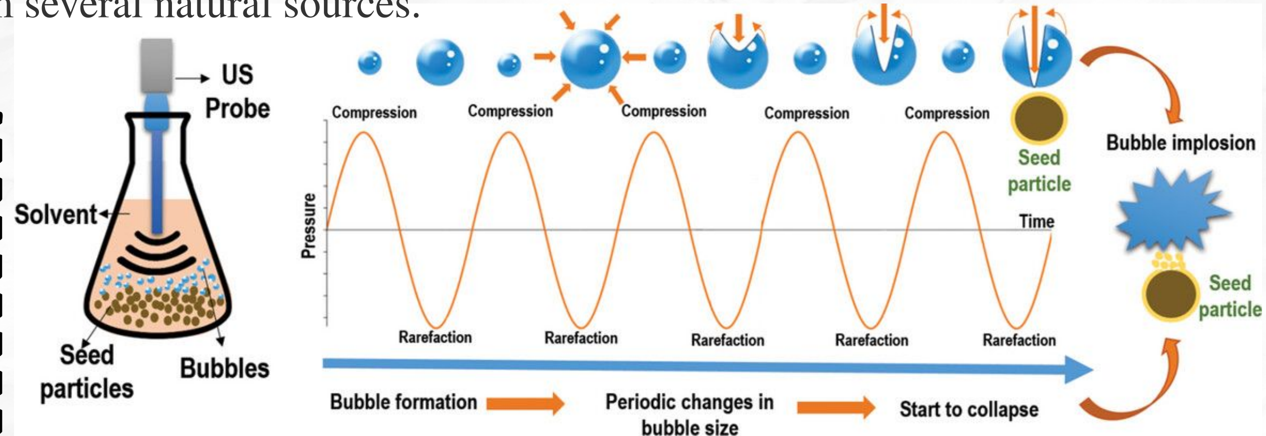

Food waste is collected and grinded.
Preparation
Heating & Pressure
The applied temperature and pressure depends on the compound needed to be extracted.
As water remains in its liquid state under subcritical conditions, the food waste material dissolve various compounds.
Extraction of compounds
Retention of target compounds
By adjusting the temperature and pressure, it is possible to extract specific compounds while leaving undesirable components behind.
Collection & seperation
The extract containing the target compounds is separated using filtration, centrifugation, or other separation techniques.

Compound	Raw material	Extraction condition
Polyphenols	Potato peel	100–240 C; 60 bar; 30–120 min
	Grape skin	100–160 C; 100 bar; 40 s
	Red grape pomace	40–140 C; 68 bar
	Pumpkin leaves	100–220 C; 10–50 min
	Spent coffee grounds	160–180 C; 35–55 min
	Apple by-products	25–200 C; 103 bar; 3–17 min
	Onion skin	170–230 C; 30 bar; 30 min
	Wheat straw	130–270 C; 1.7–54 bar; 10 and 30 min
Carbohydrates	Spent coffee ground	150–210 C; 20–60 bar; 5–15 min
	Citrus peel and apple pomace	100–140 C (citrus peel) and 130–170 C (apple pomace); 5 min
		110–130 C; 80–120 bar; 20–40 min
	Sugar beet pulp	40–80 C; 10–80 min;
	Peach pomace	99.8–319.8 C; 5 min
	Onion bulbs and skins	180–240 C; 60–480 s
	Peanut shell	280–390 C; 25–40 s
	Corn stalks	
Proteins and amino acids	Shrimp cephalothorax by-products	230–280 C; 27.8–201.8 bar; 5–30 min
	Waste fish entrails	19.8–449.8 C; 350 bar; 90 min; flow rate of 40 cm3/min
	Okara	70–260 C; 2–120 min
	Deoiled rice bran	100–220 C; 1.03–39.7 bar; 0–30 min
	Mackerel liquid waste	90–190 C; 50 bar; 1 or 2.5 h
Oils and fatty acids	Squid by-product entrails	169.8–379.8 C; 7.92–300 bar; 1–40 min
	Olive pomace	160–200 C; 5–25 bar; 260–350 s
	Rice bran	120 and 240 C; 10 and 20 min

Ultrasound extraction

Ultrasound-assisted extraction produces a phenomenon known as cavitation, which entails the production, growth and collapse of bubbles, leading to improved release of the target compounds from several natural sources.

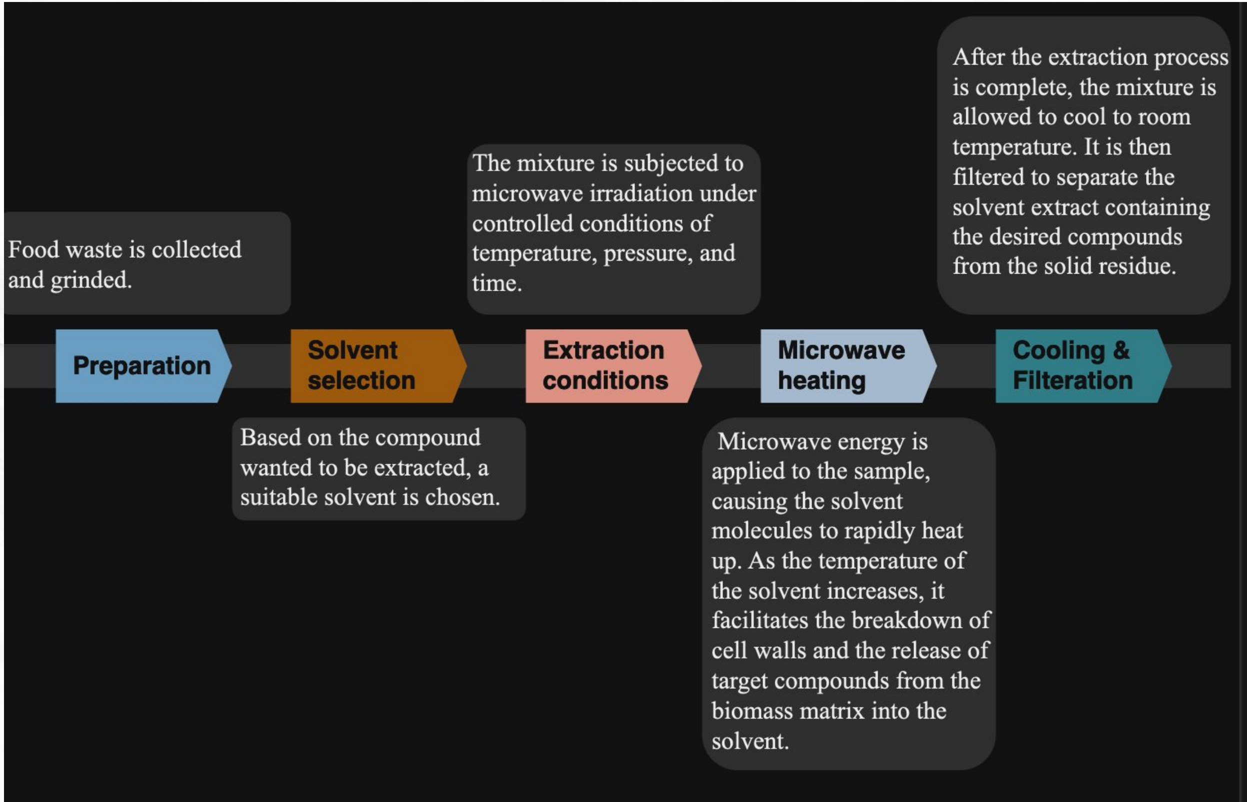


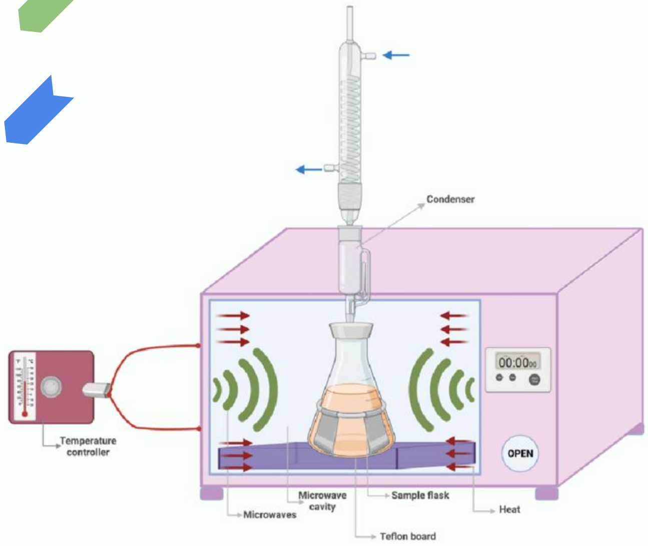


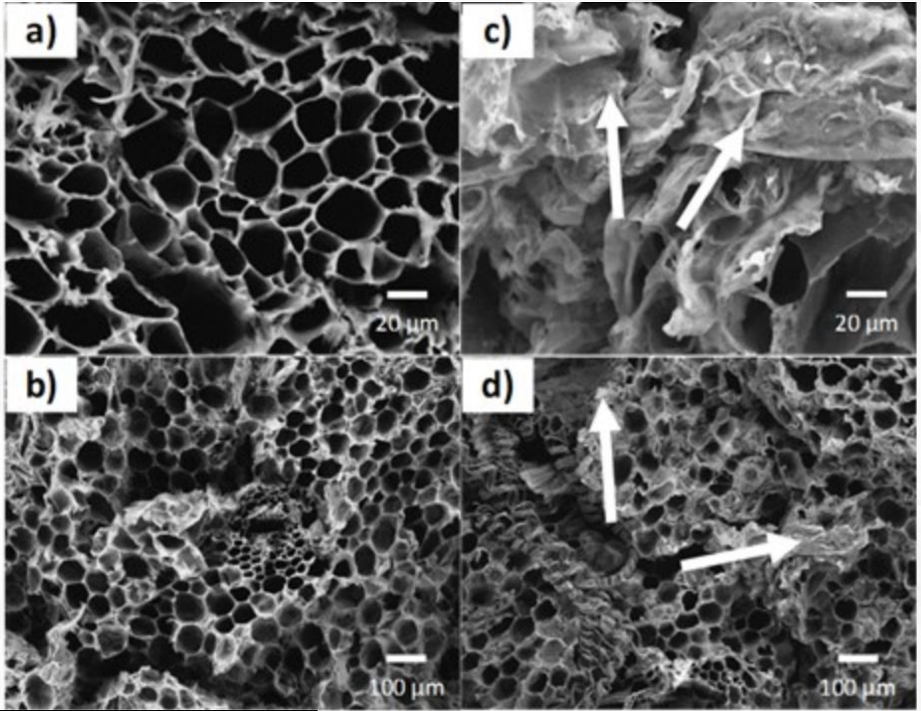
Fruit source:	Target compounds:	Extraction conditions:
Grape pomace	Phenolics	20–60 °C, Amplitude 20–60 %, LS 8–24 mL/g, 240 min
Sichuan red orange peel	Tangeretin & nobiletin	Ethanol 85 %, LS 20:1 mL/g, 40 min, 50 °C, 150 W, 20 kHz
Mandarin peel	Phenolic content	48 °C, 56.71 W, 40 min, 38.5 kHz
Mandarin peels	Pectin	80 °C, 37 kHz, 30 min
Orange peel	Carotenoids	35 min, 42 °C, LS 15 mL/g
Orange peels	Antioxidants	30 min, 60 °C, 15 mL/g

Microwave assisted extraction

This method uses microwave energy, heating the solvent within the sample, which accelerates the extraction process by the release of target compounds from the biomass matrix.







Sources:	Compounds:	Temperature:	Solvent/Co-solvent
Vine prune residues	Total phenolic content	120	Ethanol -water
Ocimum basilicum	Polyphenols	-/442	Ethanol
Mangifera indica leaves	Mangiferin	-/272	Water
Red grape pomace	Phenolics	50/200	Water-ethanol
Cabbage leaves	Phenolic content	~50/100	Ethanol

Conclusion

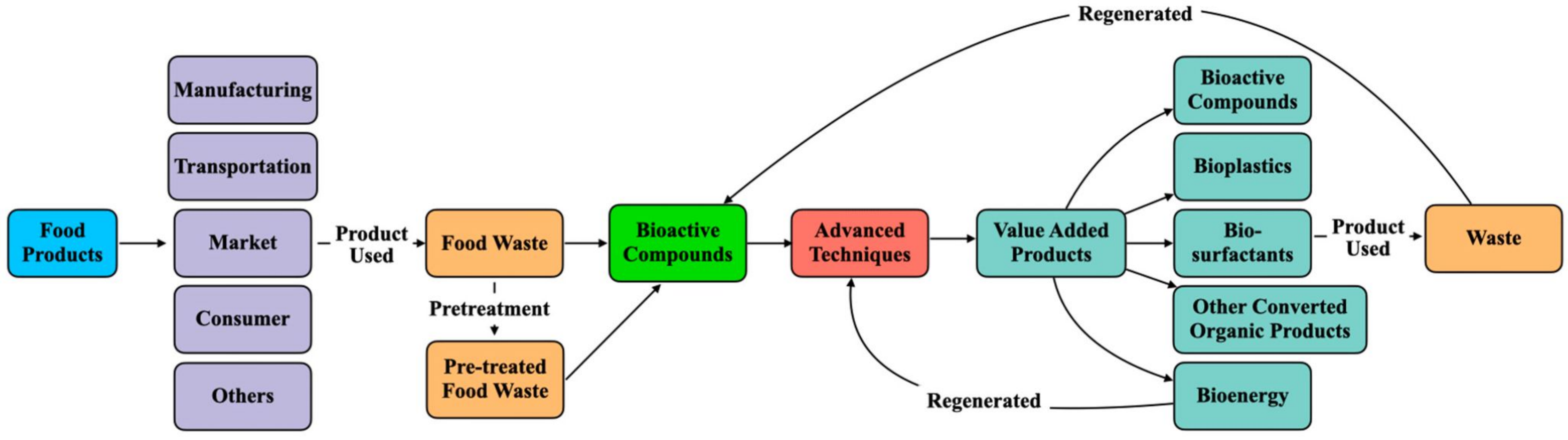
- My research has shown that numerous bioactive compounds can be derived from food waste.

- Various advantages are provided by these methods
  - Reducing waste
  - Create new economic prospects and promote a circular economy
  - Develop functional food ingredients, cosmetics, and dietary supplements.

- Limitations of these techniques:
  - Most techniques are in their early stages of development
  - Excessive extraction costs due to expensive equipment, solvents, and energy being a significant obstacle.
  - Undesirable extraction rates,

- Advancements needed in this technology:
  - Improve the efficiency of the extraction processes
  - Develop new methods that are more environmentally friendly
  - Use of more green solvents

Ultimately, the goal of the project is to find alternate ways other than compositing and breathe new life into waste with the background of the urgent problem of global FW production as a driving force. Going forth from this, the next steps of this project would be to advance and expand on this topic, channeling food waste to factories where food waste is utilized to make new products.



Acknowledgement

I would like to acknowledge my parents who were my coordinators and advised me through this process.

Question & Conclusion:
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