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Review on extraction and micro-encapsulation of beta carotene from sweet potato peel

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Abstract
Food production rises as a result of globalization and greater industrialization. Nonetheless, poor management and infrastructure have resulted in enormous losses and waste of completed goods, raw resources, and byproducts. Food waste is presently one of the most severe concerns facing the planet. According to FAO figures approximately 40% of the food produced in the globe is still wasted. Food waste happens at all stages of the supply chain, including harvesting, transportation to packing houses or markets, grading, storage, marketing, processing, and residences before or after cooking. According to the 2016 food loss index, 13.8 percent of food is lost globally from harvest to distribution. Because of their perishable nature, fruits and vegetables incur the highest losses. A huge quantity of world's fruit and vegetables are grown is wasted following. Furthermore, harvesting vegetables and fruits regenerates considerable amounts of leftovers such as non-edible components such as peels, cores, and pomace, as well as unripe or damaged vegetables and fruits, which continue to be a source of biologically active substances. Carotenoids are a wide category of pigments whose colours vary from yellow to red. They are typically preserved in the skins of vegetables and fruits that are commonly rejected, such as tomatoes, oranges, grapes, sweet potatoes, and carrots. The trash created in the form of peels and byproducts contains several key active components that are frequently employed in various sectors to develop or make medicinal capsules. These components have antioxidant qualities and can be employed in the food and pharmaceutical sectors. Some of these bioactive chemicals are utilised to treat cancer and other heart problems. Consumers are becoming more interested in food bioactives that benefit people benefiting by and illness disease prevention. This review mainly concentrates on the many methods of extracting beta carotene derived from food wastes, specifically sweet potato peel waste utilising microwave aided extraction followed by encapsulating techniques.

Keyword: Micro-encapsulation, beta carotene, sweet potato peel

Introduction
It is also known as the sweet potato and is rapidly gaining popularity as a health food due to the presence of many phytochemicals that lessen the risk of age-related and chronic disease-related degenerative disorders. It is the world's seventh-largest food crop and is cultivated in over a hundred countries. Many people are concerned about the massive quantity of food and agricultural waste produced worldwide. Because of their composition with a range of useful components, this trash can be recycled various manufacturing procedures as supplies of dietary fibre, perfumes, natural colours, and antioxidants. Sweet potato peels, on the other hand, are considered substantial wastes created during the sweet potato manufacturing process. Sweet potato peels include several polyphenols and carotenoids with health-promoting properties, making them excellent for transformation into beneficial components in foods. Typically, agricultural waste might be recycled into high-value goods utilising a number of green extraction processes. Carotenoids are easily oxidised and destroyed by external elements such as oxygen, heat, and light. Some form of distribution or processing mechanism is essential to assure their efficacy and intended aims. Encapsulation is a simple approach for increasing phytochemical stability by encasing the core component in a coating material.

Fruits and vegetables are the most commonly eaten foods when it comes to horticulture crops. Because of changing dietary habits and population expansion, the production and processing of horticultural products has expanded dramatically. Peel waste is a substantial byproduct of the fruit and vegetable industry as well as domestic kitchens, and it has negative economic, environmental, and nutritional consequences. Just in fruit and vegetable preparation, 25-30% of the final product is wasted. Pomace, peels, skins, and seeds are all exceptionally abundant in key bioactive compounds such as carotenoids, enzymes, polyphenols, lipids, vitamins, and a variety of other components.

These bioactive components interacts well with proteins, DNA and other biological components to accomplish desired effects, which may then be used to create natural medical treatments. India anticipated a loss of 12 million tonnes of produce, or around 4.4 and 10.6 billion dollars in lost food and food value, respectively. It is critical to extract beta carotene since it has been shown to have various medicinal properties, including the capacity to treat a number of ailments. Because of the possible economic and environmental benefits, an increasing number of individuals are getting interested in using plant by-product extract as a functional component. These physiologically active chemicals have since found many uses in food, pharmaceutical cosmetic, and textile industries. The primary purpose of this review paper is to extract beta carotene, a beneficial component, from residual sweet potato peel during cooking or food processing.

Sweet potato peels as sources of functional compounds

Potato peels provide a number of health advantages that are not well understood. The potato skin, which contains vitamins, minerals, fibre, and antitoxins, is commonly peeled and discarded. Peels can help to boost immune function. They are nutrient-dense and inexpensive to grow. One of the primary areas of focus is the recycling of waste from the food processing sector. Papers and research studies summarise the importance of powdered sweet potato and potato peel in improving sustainability in the food industrial sector. Following processing, a huge amount of sweet potato skin is generated, which has little value (Nida Taiyeba *et al*., 2020) [2]. Many review studies and research publications summarise the valuable components retained in sweet potato peels and their powder in improving sustainability in the food processing industry. SPP is a waste product that is produced in large quantities after processing. The utilisation of SPP acquired following processing is crucial for the company since it has a high level of nutritious fibre.

Beta carotene sources and its importance

Beta-carotene is a reddish-orange pigment present in many fresh fruits and vegetables. Vitamin A is an important nutrient derived from beta carotene. Beta carotene is a carotenoid and antioxidant. Squash, onions, carrots, peas, and spinach are examples of vitamin A-rich foods. The carotenoid molecule beta-carotene is abundant in the human diet and, as a result, is found in all human tissues, including the blood. The primary function of beta carotene in the body is to give provitamin A, which influences eye health, appropriate growth, and embryonic development. It possesses antioxidant and anti-cancer properties, and it is considered to suppress some genes (Harasym and Oledzki, 2014; Zhang *et al*., 2016) [4, 5]. Vitamin an activity is exhibited by Carotenoids are molecules with the same structure as retinol molecules. As a precursor to vitamin A, beta carotene has the highest bioactivity. There are two -ionic rings in the -carotene molecule. In principle, the chain break at -C15 = C15′ yields two retinol molecules. By passive diffusion, the small intestine mucosa transforms beta-carotene to retinol. Because the conversion of beta-carotene to vitamin A is incomplete, it has only one-sixth the activity of retinol, making 1 mg of retinol equal to 6 mg of beta-carotene. Because carotenoids are lipophilic and tend to concentrate in cell membranes and lipoproteins, beta-carotene derived from food is dissolved in the lipid phase. Carotenoids have an impact on a number of biological functions because to their capacity to dissolve in fat, including photosynthesis, the process of seeing, and the free radical and singlet oxygen removal (Odriozola-Serrano *et al*., 2009) [6]. One study found that smokers who ingest a lot of beta-carotene may be more prone to get lung cancer. According to some research, beta carotene may help to prevent cognitive decline. Some drugs, such as mineral oil and statins, may be affected by beta-carotene supplements. Beta carotene may help reduce age-related lung strength decrease in elderly people. Aside from "carotenodermia," a skin darkening caused by excessive quantities of carotenoids, no potential negative effects of -carotene consumption have been observed. -carotene did not appear to be mutagenic, carcinogenic, or teratogenic in any of the studies performed (Milani *et al*. 2017) [7]. In fact, even after long-term -carotene supplementation in individuals with adequate vitamin A levels, there was no increase in blood retinol levels. It must be combined with dietary lipids for prolonged -carotene serum and tissue accumulation. However, high dosages of -carotene supplements should be avoided in smokers since they may raise their chance of getting lung cancer as well as other malignancies (Bohn *et al*. 2019) [9]. There are several methods for extracting beta-carotene, depending on the source. Much research is being conducted to optimise pigment extraction and encapsulation. Mechanical extraction, enzymatic extraction, and organic solvent-based extraction are the three broad categories of extraction procedures. There are also some collaborative extraction approaches that mix some existing strategies with some new ones (Chen *et al*. 2021) [10]. There are several methods for extracting beta-carotene, depending on the source.

Sweet potatoes, for example, are high in fibre. However, as the peeling is removed, the fibre content decreases. According to (Low *et al*. 2016 [70], orange-fleshed sweet potatoes (contain up to 276.98 lg of provitamin A beta-carotene per. A 125 g serving of boiling can satisfy preschoolers' daily vitamin A needs and avoid night blindness. Orange fleshed sweet potato includes substantial amounts of protein, fat, carbohydrate, dietary fibre, and other minerals, and some phytonutrients in addition to beta-carotene. As a result, orange-fleshed sweet potatoes are a basic meal that may provide vitamin A and energy to people in developing countries with limited resources, such as Bangladesh. Because antioxidants are concentrated in and under the skin of sweet potatoes, eating the peels can help you get more of them. Sweet potato peel contains antioxidants, vitamins A, C, and E, as well as minerals like potassium and manganese. Sweet potato peels are appropriate for processing into value-added components in functional meals because they include a variety of polyphenols and carotenoids with special health beneficial qualities. Sweet potato peel is a good source of beta carotene. Typically, the beta carotene that gives sweet potato skins their unique orange colour is to fault.

Extraction

Extraction is the process of removing medicinally valuable components from inert plant or animal tissues using solvents and traditional extraction procedures. During the extraction process, one or more compounds are chosen to be dissolved in a suitable solvent, yielding an extract. For quantitative and qualitative study on bioactive components derived from plant matrices, the appropriate extraction process is critical (Sasidharan *et al*., 2011) [14]. The initial stage in every plant study is extraction, which has an influence on the result. "Sample preparation techniques" is another term for extraction methods. Despite the fact that the study is overlooked and carried out by untrained research staff, despite the fact that sample preparation processes account for analytical chemists work. The extraction methods, input factors, and specific characteristics of the plant components remain important to the efficacy of bioactive component analyses. True, the introduction of contemporary chromatographic and spectrometric technologies has simplified the procedure. The matrix qualities of the plant portion, the solvent, the temperature, the pressure, and the duration are the most prevalent elements influencing the extraction process (Hernández *et al*., 2009) [6]. Because of our improved understanding of the dynamic chemical nature of numerous bioactive compounds, an insoluble matrix can be removed from it in the form of a solution or association. This separation technique consists of two steps: liquid extraction and solid extraction. Consider the solubility, characteristics, cost, and safety of a solvent. Alcohol (EtOH and MeOH) is a common solvent used in solvent extraction for phytochemical investigations. As the extraction outcome improves, the particle size falls. The extraction potency will rise due to increased matter dispersion and solvent penetration caused by the reduced particle size. However, too-small particle sizes may cause excessive matter absorption inside the solid and subsequent filtering issues. Solubility and Adsorption When it gets heated, the square measure expands. Too high temperatures, on the other hand, may cause solvent evaporation, leading in the extraction of unwanted contaminants and the subsequent annihilation of unstable components. Because the extraction time was spread out over a set period of time, the extraction potency increased. Extending the extraction duration will have no effect after the material has reached equilibrium both within and outside of the solid substance.

Organic solvents are commonly utilized in earlier methods of extraction like maceration, reflux and percolation which need huge volumes of solvent and lengthy extraction durations. In the extraction of natural components, it is common practice to employ cutting-edge or environmentally friendly extraction techniques such as SFC, PLE, and MAE, which have the advantages of using less organic solvent, working faster, and producing better results. a description of the numerous methods used to extract natural components Extraction is used in many businesses, including those that produce food, prescription medications, essential oils, and perfumes. Plant components can be extracted using a variety of ways. Over the last 50 years, innovative procedures have been developed that are more ecologically friendly since they utilize less synthetic and organic chemicals, work faster, and provide greater yield and quality extracts. Various techniques, including ultrasound; PEF, enzyme assisted; extrusion; MAE; and ohmic heating, have been studied as non-conventional methods to increase overall yield and selectivity of bioactive compounds from plant matrices. At the same time, traditional extraction techniques like Soxhlet are still used as a benchmark to assess the efficacy of freshly created methodologies. There are various scientific papers, book chapters, and monograms that go into detail into unconventional ways. These articles focus the extraction methods are used in the manufacturing of nutraceuticals, food additives, and a number of other products and goods.

Conventional methods for the extraction of betacarotene

Extraction via soxhlet

Soxhlet extraction an extraction method that extracts molecules in tiny amounts using solvents at ambient pressure and boiling temperatures. The classic soxhlet extraction technique generates the most carotenoids. As a result, it is commonly used to evaluate the performance of other approaches. Nonetheless, it takes long period of time and any solvents, which boosts the extraction cost. The high temperature and long duration enhance the likelihood of degradation due to high thermal loss. In comparison to percolation, (Cardenas-Toro *et al*., 2015) [17] discovered that Soxhlet extraction produced the highest yield of lipophilic extract t from crushed palm fiber in six hours. (35 °C, 2.4 g/min) and ASE (55 °C, 40 bar, 2.4 g/min ethanol flow rate) at optimal circumstances.

Maceration

Many solvents have traditionally been carotenoids are extracted from their natural sources using this method. A cell must be disturbed physically, chemically, or mechanically in order for intracellular carotenoids to be extracted effectively. Cell wall breakdown allows solvents to more easily solubilize intracellular carotenoids inside the cell. Cell wall rupture boosts carotenoid production by 8-10 times (Uquiche, Antilaf, & Millao, 2016) [18]. At 20 °C for 40 minutes, an acetone/n-hexane (1:3, v/v) solvent mixture, and a solvent volume of 40 ml/g, the highest recovery of total lycopene (94.7%) and purity of all-E-lycopene (98.3%) were obtained from tomato pulp waste (Poojary & Passamonti, 2015) [19]. When different extraction procedures were evaluated, acetone maceration produced the best yield of total carotenoids from pink prawns (*P. brasiliensis* and *P. paulensis*), followed by Soxhlet extraction with hexane/isopropanol (Mezzomo *et al*., 2011) [20]. The absence of a heating system during extraction, which minimises thermal destruction of carotenoids, and the reduction in the length of time a solvent is in contact with a raw material, according to the authors, make maceration superior to other approaches. Soxhlet's presentation of a sufficient carotenoids yield could be attributed to boiling temperatures' less viscosity and surface tension, which increase carotenoids diffusion and solubilization.

Non-conventional methods of extraction of beta carotene

Ultrasound assisted extraction

A green, reasonable cost, and straightforward method for extracting carotenoids various types of oils was employed as solvent substitute in this green ultrasound-assisted extraction (UAE) technology, which adheres to the concepts of green extraction and bio-refinery. Traditional procedures are often used to extract colour pigments and other bioactive substances. Novel extraction processes developed due to the increased demand for these bioactive chemicals in a variety of food items. The ultrasonic-assisted extraction approach yields a high yield with faster extraction rates, less solvent consumption, and more products in less time. When compared to traditional extraction methods, UAE consumes less fossil energy and requires less wastewater treatment when the extraction process is completed. Several colours, chemical and inorganic contaminants, and antioxidants may be effectively removed from a wide range of food matrixes using UAE (Awad *et al*., 2012) [21]. Because more implosions result in substantial pressure, heat, and turbulence, increasing ultrasonic power allows for more efficient recovery of bioactive compounds from food and plants (Sanwal, Mishra, Sahu, & Naik, 2022) [22]. Non-thermal extraction techniques have been studied extensively, including PLE (Oliveira *et al*, 2022) [23] and ultrasound (Yusoff, Taher, Rahmat, and Chua, 2022) [24]. Pulsed electric fields (Naliyadhara *et al*., 2022) [59] and supercritical fluid extraction are two further non-thermal approaches. The UAE approach has been used successfully in a number of research studies to find the ideal conditions for pigment recovery from various plant and food matrices (Liu *et al*., 2018) [26]. Ultrasonic power, temperature, solid to solvent ratio and extraction time plays an important role in extracting high yield. Several studies have shown that the UAE technique has a great deal of potential for extracting pigments from plants or plant-based materials. The ultrasound causes agitation, which destroys the cell walls. Solvent penetration caused by cell wall distortion results in rising mass transfer. UAE is a methodical extraction with a lower time requirement and a higher output capacity. Variables on the extraction of bioactive compounds. Several research investigates the various ways of the UAE for extracting bioactive components from a variety of sources. As a result, many bioactive compounds are recovered from various food matrixes utilising ultrasonic aided extraction method with great options to the food sector extraction (Kumar, Srivastav, & Sharanagat, 2021 [28] Ultrasonic-assisted extraction method providing excellent suggestions for the chemical and food sectors.

Table 1: Carotenoids extraction utilizing an ultrasound-assisted extraction approach.

Material	Parameters	Findings of the work	References
Carrot	temp range: 20 - 60 °C; duration range: 10 to 35 minutes; range: 10 to 30 W/cm2; carrot/sunflower oil ratio: 1:15 to 2:10	A 20-minute A 40 °C treatment with a carrot and oil as solvent of 2:10 and an ultrasonic intensity of 22.5 W/cm2 produced more -carotene- 33.48 mg/100 ml.	Li *et al*. (2013) [29]
GAC peel	Temp: 25-50 °C; power: 150-280 W; frequency: 43.2 kHz; time: 60-100 min.	At 20 °C, the concentration of 263 mg/100 g DW was obtained using ultrasonic power of 250 W and frequency of 43.2 kHz.	Chuyen *et al*. (2018) [30]
Mandarin epicarp	Temperature: 40-60 °C; time: 40-60 minutes; solid-to-liquid ratio: 0.0004-0.0012 g/mL	The highest concentration of carotenoids (140.70 2.66 mg/100 g) was achieved at 60 °C w with an optimal extraction period of 60 minutes and a solid-liquid ratio of 0.0004 g/mL.	Ordóñez-Santos *et al*. (2021) [64]
Peel of orange	Temperature: 40–70 °C; time: 20–50 minutes; solid-liquid ratio: 10–15 g/mL	A higher carotenoids concentration (1.85 mg/100 g) was achieved at 42 °C with a solid-liquid ratio of 15 g/mL time for 35 minutes.	Savic Gajic *et al*. (2021) [65]
Mango	Temperature: 5 to 10 degrees Celsius; time: 20 to 40 minutes; duty cycle: 0.5 to 0.8; amplitude: 25 to 35%.	B-cryptoxanthin concentration of (359 mg/100 g) was found in the ultra-sonication experiment at 5 °C, 30 minutes with 30% amplitude 30% and 0.8 period cycle.	Mercado-Mercado *et al*. (2018) [31]

Pressurized fluid extraction

To decrease extraction time and solvent use, the pressure fluid extraction technique employs high pressure and temperature regulation. The high pressure permits the solvent, which would otherwise boil in the environment, to be utilised, as well as making the extraction more effective by generating mechanical force which allows the solvent into the matrix. Because of the small amount of solvent required, this will be the most environmentally friendly alternative. This approach involves heating and expanding the solvent as it enters the extraction cell. After the apparatuses reach a predefined set value, the solvent is driven into the sample to be extracted for a specific length and number of cycles, during which the solvent is replenished by new solvent. Traditional carotenoid extraction processes necessitate use of solvents, which are expensive and dangerous to the environment. PLE employs common solvents at high pressures and temperatures, consumes less solvent, and takes less time to extract (Arwa Mustafa *et al*., 2012) [60]. PLE to extract chlorophyll pigment and carotenoids from the green microalga Chlorella vulgaris. The temperatures (50, 105, and 160 degrees C) and times (8, 19, and 30 minutes), were assisted for extraction which are important factors for PLE, were optimized with a high extraction efficiency. The functional components of *C. vulgaris* were effectively recovered using the extraction solvent. PLE outperformed MAC, SOX, and UAE in terms of extraction efficiency.

Supercritical fluid extraction

Supercritical CO_2 (SC-CO_2), according to (Servaes, K *et al*., 2015) [61], is a cost-effective, nature friendly, yet sustainable solvents that allows you to adapt the process of extraction by adjusting the polarity or pressure while using minimum amounts of organic solvents. It's great for isolating lipophilic compounds. Furthermore, the low operating temperature required to achieve the supercritical state prevents thermal damage to labile bioactive compounds, with phenolics needing a higher temperature than carotenoids. Given the increased interest in SC-CO_2 as a carotenoid extraction solvent, several matrices have been extracted using this method in recent years, including microalgae Molino, A *et al* 2020 [62] and carrot peels (de Andrade Lima, M *et al*.,2019) [63]. Nonetheless, the few scientific studies on mango as the principal source of biologically active substances. Investigated supercritical CO_2 (SC-CO_2) extraction of bioactive chemicals from mango byproducts. Furthermore, the co-extraction of phenolic acids, flavonoids, and xanthonoids under various circumstances was investigated. Finally, the bioactive components recovered from the pulp and peel fractions of two Ecuadorian cultivars were compared using SC-CO_2 and a two-step organic solvent extraction. The ideal parameters for extraction were shown to be a greater temperature for other than carotenoids.

Microwave Assisted Extraction

Microwave aided extraction is a strategy for reducing the amount of solvent required as well as the amount of time, temperature, and energy utilised, and recovery of molecules of interest. (Rombaut *et al*., 2014) [66]. The MAE idea is totally based on the concept of interaction of microwaves with molecules via ion conduction or dipole rotation, with both processes acting simultaneously. When microwave incidence rises, molecules, such as water, have positive and negative partial charges at opposite ends and spin to align with the created electric field. The electromagnetic wave energy is converted into heat energy through molecular mobility and molecule friction raising the temperature of the matrix and facilitating compound extraction (Aspé and Fernández, 2011)

[67] and increasing the mass diffusion constants of the solutes in the solvent, hence increasing extraction yield. The MAE procedure may be used to extract bioactive compounds from natural sources due to its heating properties. Carotenoids and antioxidant capacity from the peel may be successfully extracted using organic solvents, according to studies on the traditional extraction of bioactive compounds from Gac peel. Traditional extraction methods, on the other hand, need massive amounts of solvent, significant energy usage, and extensive extraction durations to extract bioactive compounds efficiently. Many novel techniques to bioactive chemical extraction have recently been researched in order to increase extraction efficiency and overcome the disadvantages of traditional extraction methods. Because of the availability of equipment, microwave aided extraction and ultrasound assisted extraction have been recognised as two of the most practicable industrial processes. The extraction yields obtained by MAE are usually lower than those produced through classical solvent extraction. MAE provides various benefits for extracting bioactive chemicals from matrices, including a better extract yield, smaller equipment, less temperature gradients, and quicker heating. MAE removes bioactive compounds faster than standard extraction methods. MAE, a breakthrough green extraction approach with an effective and speedy process, appears to have eliminated the problems of traditional extraction procedures, such are the large amounts of solvents utilised, the high temperatures employed, or the extended extraction periods necessary. The use of microwave radiation that is intermittent at different values of the intermittency ratio (= 1/2, 1/3, and 1/4), in order to enable for prolonged MAE without severe heat destruction of carotenoids from carrot peels. In comparison to the similar continuous MAE to produced more extractable beta carotene and total carotenoids. The effects of microwave power (400-800 W), liquid-to-solid ratio (10-50 mL/g), and extraction duration (60-120 s) on process yield, phenolic content, and antioxidant capacity were investigated using a Box-Behnken design. A 60% aqueous ethanol solution was used as an extraction solvent. The most influencing parameters on the response variables were found to be microwave power and liquid-to-solid ratio. In his study on establishing a successful alternative and "green" approach for extracting phenolics from pomegranate peels. When compared to traditional extraction procedures, the microwave-assisted approach boosted extraction yield while reducing treatment time by more than 60 times. The best operating parameters were determined to be: The solvent is 50% aqueous ethanol; the solvent/solid ratio is 60/1 mL/g; and the power is 600 W. The effectiveness of the suggested extraction strategy was compared to that of ultrasound-assisted extraction. When compared to ultrasound-assisted extraction (10 minutes), the microwave method yielded more in a shorter time period (4 minutes).

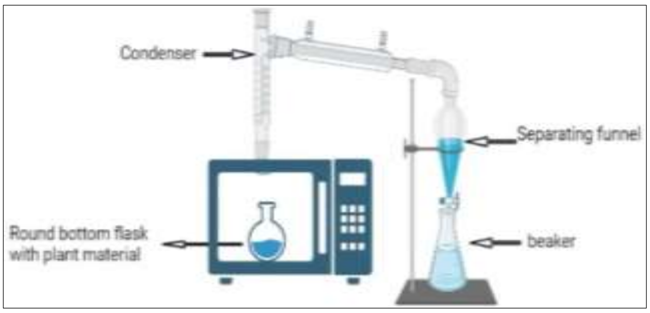

Fig 1: Microwave-assisted extraction

Table 2: Microwave Assisted Extraction

Parameters involved	Advantages	Disadvantages	References
Moisture content, particle size, textural complexity, and dielectric loss factor of plant materials PH, volume, dielectric characteristics, solid: liquid ratio, and density are all solvent parameters. Process variables (microwave power, temperature, pressure, extraction time)	Heating is uniform. There is no temperature differential between the solid and liquid systems. Reduced the amount of solvent used. Lower time of extraction and cost enhanced extraction yield Minimal work is required for operation. There is no danger of oxidation. Thermodynamic heating Volatile substances can be eliminated without causing any damage.	Solvent solutions can induce wear on several types of equipment. Thermo sensitive chemicals should not be used. Fat oxidation happens on occasion. The vessel must be chilled in order to collect the volatile component. The temperature of the solution is low.	(Al-Dhabi and Ponmurugan 2020; Arrutia *et al*. 2020; Okolie *et al*. 2019; Upadhyay *et al*. 2012) [71, 72, 73, 74]

Microencapsulation

Encasing tiny solid particles or droplets of liquids or gases in a biopolymer to generate miniscule spheres with dimensions ranging from 1 to 1000 m known as microcapsules or microparticles is referred to as microencapsulation. This technology might reduce manufacturing costs by streamlining food production, processing, and storage. Furthermore, because microencapsulated bioactives are insulated from external conditions, their stability improves. One among the most popular recognised utilisations of encapsulation technology is in the food industries. A variety of food-grade encapsulating chemicals are used to coat or entrap solid, liquid, or gaseous particles into thin films. Microencapsulation involves surrounding or immobilising one or more substances such as a core substance, an active material, or a distinct phase in a mixture with one or more materials such as a shell, polymer matrix, support, or wall material to keep them safe from biotic and abiotic factors. It is an effective method of avoiding oxidative fatty acid and vitamin degradation. The shell and core properties are critical, that influence encapsulation efficacy, core stability, and other physicochemical features of microencapsulation. Natural biologically active compounds' stability, i.e., their ability to retain their predicted functional qualities that might be enhanced by using encapsulating Spray drying, spray cooling, coacervation, extrusion, fluidized bed coating, and polymerization are all examples of procedures. Among the various methods of microencapsulation are spray-drying and freeze-drying, physicochemical methods such as complex coacervation, ionic gelation, and electrostatic layer-by-layer deposition, and chemical procedures such as interfacial polymerization and *in situ* polymerization. The enclosed structures consist of two components: the core (bioactive chemicals) and the protective matrix material. The core components are dispersed in a polymer solution (wall material) and subsequently atomized into a heated chamber, resulting in rapid water removal. The type of wall material used, as well as spray drying operating conditions such as inlet and outlet temperatures, feed flow rate, inlet air flow rate, and atomization speed or pressure, can all influence powdered particle properties (such as particle size and distribution, moisture content, and thermal stability). This article addresses numerous methods for generating microencapsulated carotenoids, including freeze-drying and spray-drying, as well as physicochemical methods like complicated coacervation and ionic gelation and chemical techniques like interfacial polymerization. This article also goes through the principles, parameters, advantages, disadvantages, and applications of various techniques. The basic goals of the encapsulation process in the food business are as follows:

1. Reducing the rate at which core materials are transferred to neighbouring materials.
2. Keeping the essential elements safe from potentially hazardous environmental conditions.
3. Keeping compounds incompatible and reactive.
4. Modifying the physical qualities of the original materials to make them more manageable.
5. Covering up an undesirable taste or odour of the primary ingredients.
6. When desired, diluting the core components to lower the amount of compound. Controlling the distribution of key commodities.
7. Improving storage conditions through the prevention of degradative processes such as dehydration and oxidation.

Coating Material Properties

1. Protects the active material.
2. Particularly releases under certain circumstances.
3. Film-forming, malleable, flavourless, and stable.
4. Non-hygroscopic, low viscosity, and low cost.
5. Soluble in aqueous fluids, solvents, or melt.
6. The coating might be flexible, brittle, rigid, thin, or any combination of the above.

Examples of Coating Materials

- Gelatine, Carboxymethylcellulose, Gum Arabic, Starch, Polyvinylpyrrolidone, Hydroxyethyl cellulose, Arabinogalactan, polyvinyl alcohol, and polyacrylic acid are all constituents of methylcellulose.
- Ethyl cellulose, Polyethylene, Polymethacrylate, and Polyamide are examples of polymers. (Nylon), Poly (Ethylene- Vinyl acetate), cellulose nitrate, Silicones, Poly (lactides- glycoside), cellulosen, Carnauba, Spermaceti, Beeswax, Stearic acid, Stearyl alcohol, Glyceryl stearates.
- Shellac, cellulose acetate phthalate, and zein are all ingredients are examples of enteric resins.

Microencapsulation methods

Spray drying

Due to its flexibility, low cost, and high efficiency, traditional spray-drying is one of the most used drying processes in the food and pharmaceutical industries. A good way to minimise major oil quality degradation is to spray-dry fish oil before encasing it in wall materials made of milk. Spray-drying flaxseed oil at various input temperatures resulted in the microencapsulation of the oil. Looked at how walnut oil microcapsules' physicochemical characteristics were impacted by the wall material composition and spray-drying conditions. By spray-drying modified starch as a wall material created microencapsulated beta-carotene. In contact with the hot air, the water evaporates rapidly, and the matrix encloses the core substance. The first step in encapsulating any bioactive substances is to prepare a stable emulsion. An emulsion is a combination of two or more typically immiscible liquids. Emulsifiers are needed to help the process along by stabilising the emulsion by lowering the interfacial tension between the two phases and creating a stiff interfacial film that acts as a mechanical barrier to coalescence. Once the material for the wall or coating has been chosen to contain the active substance, it needs to be hydrated. The active ingredient to be encapsulated, such as flavours, vitamins, minerals, oil, etc., is added to the wall material solution after the wall material has been solubilized. The mixture is then homogenised to produce tiny droplets of the active component within the wall material. The in feed is atomized. Core-wall material mixture or emulsion: This substance is fed into a spray drier and atomized there using a nozzle or spinning wheel. The air heater, atomizer, main spray chamber, blower or fan, cyclone, and product collector are the key parts of a typical spray drier. Dehydration of the atomized particle: The water in the particle evaporates when it comes into touch with hot air travelling in either a contemporaneous or countercurrent direction, leaving behind a dried, encapsulated product. Spray drying produces microencapsulated products with matrix-type morphology and particle sizes between 10 and 400 m. Despite recent improvements in the spray drying process, the procedure is still far from being fully under control for the microencapsulation of active food components. For the food and pharmaceutical industries to make encapsulated substances, spray drying technology has not yet established itself as a standard technique. A major obstacle to producing effective encapsulated goods is choosing the right covering material. This can be overcome by using a multidisciplinary research strategy and considering industry needs and restrictions.

Spray Freeze Drying

In this process the emulsions are sprayed with liquid nitrogen or extremely cold air to form frozen droplets, which are then placed in a vacuum freeze dryer to sublimate the ice and produce the dried powders. Because it combines the advantages of spray-drying and freeze-drying while avoiding their drawbacks, spray freeze-drying is particularly well suited in the case of sensitive materials to oxidation and deterioration. When compared to freeze-drying, spray freeze-drying uses less energy and takes less time to dry. Moreover, the spray freeze-drying powder has good granulation and fluidity. Spray freeze-drying, as opposed to spray-drying, maintains nutrients and does not alter the biological activity of the target material, which improves shelf life. Parthasarathi and discovered that spray freeze-drying using whey protein isolate as the encapsulating agent produced efficient vitamin E microcapsules with outstanding solubility and encapsulation efficiency.

Coating

The purpose of coating is to bind powder particles, such as starch, to the surface of particles sprayed from a nozzle by suspending them in an air stream that is kept at a specified temperature. As a result, a second wall will be created to safeguard the core substance. This technique could be employed for -carotene powders and offers additional protection for microencapsulated powders above the primary microencapsulation approach.

Fluidised bed coating

The technique of fluidized bed coating involves spraying an encapsulating chemical onto a fluidized powder bed to create coated particles. Processing factors in fluid bed coating, such as the Humidity, coating feed rate, and temperature, as well as solid circulation rate and nozzle atomization pressure, crucial because they affect how well the particles aggregate and form films, which affects coating effectiveness. This is why analysing the impact of processing variables is essential for optimising coating operations employing fluidized bed technology. Several coating materials, including proteins, starches, and gums, among others, can provide an effective barrier protection and maintain their stability over an extended period.

Air Suspension Coating

One microencapsulation technique that has potential in the food and medication delivery systems is air suspension. The particles are partially dispersed from wall and core material in a solvent and suspended in a continuous air stream during the operation. Solvent has a usually good ability to evaporate. A layer of wall material is created around the core material once the solvent has evaporated. Depending on the goal of the micro-coating, the cyclic process is repeated with typically large particle sizes in this approach. Depending on the type and thickness of the wall, this technology enables one to encapsulate foods or medications quickly and easily and then release the components in a regulated manner.

Complex Coacervation

Microencapsulation by complex coacervation typically done in three processes performed under Continuous agitation is used in the following processes: (a) the formation of three immiscible chemical phases, (b) coating deposition, and (c) coating rigidification. (M. N. Singh *et al*., 2010) [68]. There are two types of coacervation-phase separation: simple coacervation and complex coacervation. The former entails adding a very hydrophilic material to a colloid solution. This additional material induces the formation of two stages. The complicated coacervation process is mostly a pH dependent process. To create microcapsules, the system's acidic or basic composition is altered. Depending on whether the solution is acidic or basic, microcapsules may develop above a specified threshold pH value. They will not form below that pH level. Typically, complicated coacervation is concerned with the system. In a study review he attempted to explain about Complex coacervation which is an old technique that has been employed in a variety of industrial applications. It is critical for protecting and controlling the nature of a product's active agent Complex Coacervation by introducing it and discussing the principles of manufacturing Complex Coacervation and also discussed its application in the food business and nutrition, namely in the encapsulation of oils and essential oils and the encapsulation of probiotic bacteria.

Centrifugal Extrusion

Another encapsulating method that has been researched and employed by some manufacturers is centrifugal extrusion. Products including flavorings, spices, and vitamins have been encapsulated using a variety of coating techniques that have been authorised for use in food. Lipids, fatty acids, waxes, and polyethylene glycol are some of the wall components used. A liquid coextrusion technology called centrifugal extrusion uses nozzles with concentric orifices on the head. The coating and core materials are pushed separately to the numerous nozzles located on the device's outer surface through a concentric feed tube in the encapsulating cylinder or head. Coating material goes through the outer tube as the core material travels through the centre tube. The head of the gadget spins around its vertical axis thanks to its attachment to a rotating shaft. The core and coating materials co-extrude via the nozzles' concentric orifices as the head rotates, forming a fluid rod of the core that is sheathed in coating material. The rod is propelled outward by centrifugal force, breaking into small pieces. Surface tension causes the covering layer to enclose the core material, achieving encapsulation. The microcapsules are gathered on a moving bed of fine-grained starch, which softens their impact and soaks up extra moisture from the coating. The diameter of the particles created with this technique ranges from 150 to 2000 mm. Liquids can be enclosed using a spinning extrusion head with concentric nozzels. In this technique, a wall solution sheath is placed over a jet core. Due to rayleigh instability, as the jet travels through the air, it splits into droplets of core that are all coated in the wall solution. The droplets arrive in a tight ring with a mean diameter that is within +-10%. This method works effectively for creating particles with a diameter of 400–2000 micrometres. This method only works with liquids or slurries. The output rate is high and can reach 22.5kg (50lb) of microcapsules per head and nozzle each hour. Table 3 displays centrifugal extrusion-prepared compositions.

Ionic gelation microencapsulation using sodium alginate

The external ionic gelation phenomenon is caused by the extrusion method, which involves dripping the emulsification process. The bioactive loaded lipid droplets were formed by employed as standalone delivery methods or combined by injecting them and an alginate combination into a gelling solution ($Ca2+$), they were transformed into hydrogel beads. This method produces alginate beads, which are widely used in various sectors to encapsulate and preserve bioactive substances. When a zone of union between the acid -L-guluronic (G) blocks of one alginate molecule is physically attached to another acid -L-guluronic (G) block from another alginate molecule by calcium ions, this is when gelation takes place. Extrusion is the method used to achieve the external ionic gelation. (YEO *et al*., 2001) [69] Demonstrated this method which involves adding the sample or the material to be encapsulated to an alginate solution and immediately incorporating them as droplets in a calcium chloride solution to harden the material. An insoluble gel is created when certain ions, such as $Ca2+$, interact with the carboxyl groups of the polymer chains of alginate. The size of the particles created via extrusion is determined by the needle diameter, the alginate solution's viscosity and concentration. Typically, extruded particles have diameters between 500 m and 3 mm Extrusion is the method used to achieve the external ionic gelation. The sodium alginate microencapsulation method for creating oospore microcapsules has been developed. It has been proven that alginate encasement creates a strong barrier to protect the oospores inside of it. The oospore is shielded from physical harm as well as direct contact with outside elements, especially pathogens and other microorganisms that might prevent germination and restrict the formation of protonemal and primary rhizoidal cells.

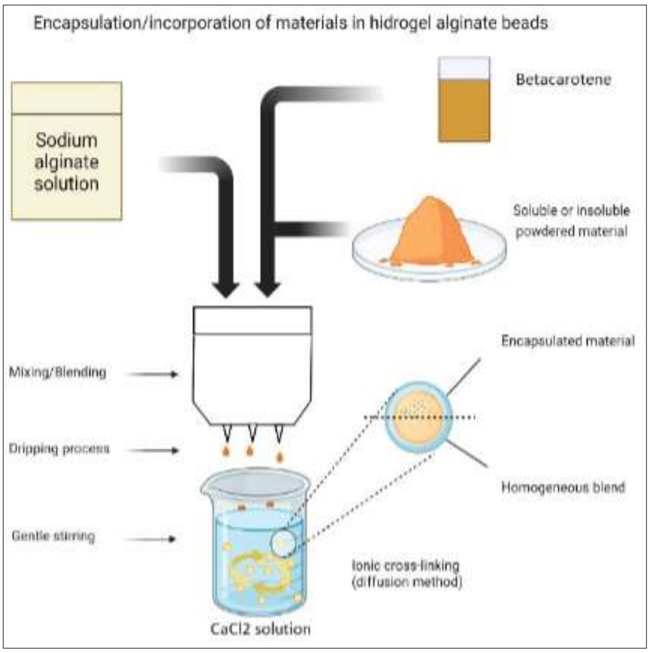

Fig 2: Microencapsulation

Conclusion

In conclusion, a viable approach to resolving nutritional and environmental issues is the extraction and microencapsulation of beta carotene from sweet potato peel waste. The importance of beta carotene, their health advantages, and the abundance of sweet potato peel waste as an underutilized source have all been emphasized in this paper. A variety of extraction techniques, including solvent extraction, enzymatic extraction, and supercritical fluid extraction, provide effective means of recovering beta carotene. The desired beta carotenoid components, the circumstances of the extraction, and the choice of solvent all need to be taken into consideration while customizing these procedures.These precious molecules are shielded by microencapsulation technologies, which improves their stability, bioavailability, and use in a variety of culinary and medicinal items. The possibility for maintaining beta carotenoids during processing and storage has been demonstrated by methods such as spray drying, coacervation, and nanoencapsulation. Nonetheless, there are still issues to be resolved, such as the requirement for microencapsulation and extraction process optimization, as well as cost- and profit-effectiveness. To bridge these gaps, cooperation between academics, business leaders, and legislators is crucial.With the increasing need for natural antioxidants and sustainable solutions, the extraction and microencapsulation of beta carotenoids from sweet potato peel waste has great potential to reduce food waste, improve health, and advance the field of nutraceuticals and functional foods. In addition to outlining the promise for a better, healthier, and more sustainable future, this review paper offers a thorough summary of the status of research in this field.

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