Natural Pigments, their Applications and Methods of Extraction: A Review

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Abstract:- Pigments have an essential role in food industry, influencing sensory aspects of food products. They significantly impact the perception of freshness, nutritional quality, safety, and overall visual appeal. These pigments, sourced from plants, insects, minerals, or microbes, encompass varieties like carotenoids, flavonoids, chlorophyll, betaines and others. They are utilized to restore or enhance the colour of processed foods. Given their perceived safety, being non-toxic, non-allergenic, non-carcinogenic, and environmentally friendly—researchers are increasingly focused on exploring natural pigments and their extraction techniques. The quest for novel natural colourants has intensified due to their presumed safety compared to synthetic counterparts. Extraction methods, classified as conventional (like maceration, Soxhlet extraction) and non-conventional (including Super-critical Fluid Extraction, Pressure-driven Liquid Extraction Method, Microwave-assisted Extraction, and Ultrasound-assisted Extraction), not only expedite pigment retrieval but also align with eco-friendly practices. Of particular interest in this review are plant-derived pigments, in high demand globally for their antioxidant properties, replacing synthetic alternatives. This article primarily delves into the diverse extraction techniques employed to derive these natural pigments from plants.

Keywords:- *Betalains,Carotenoids, Chlorophyll, Extraction Methods,Flavonoids, Natural Pigments.*

I. INTRODUCTION

Pigments found in plant or animal tissues, serve as the natural colouring agents imparting colour to a range of materials. Differing from dyes due to their higher molecular weight and reduced water solubility, pigments have a rich historical application. Ancient civilizations utilized natural sources like plants, insects, and minerals for dyeing textiles, painting, adorning the religious rituals, and more. The advent of synthetic pigments began in 1856 when William Henry Perkin, an English chemist, identified the first organic dye derived from distillate of coal tar, consequently leading to commercial proliferation of dyes and their applications. However, the reliance on synthetic pigments stemming from chemical reactions has resulted in significant environmental strain, associated with health risks such as toxicity, teratogenicity, and oncogenicity.[1] Pigments find applications across diverse industries, including food production, dye manufacturing, cosmetics, and pharmaceuticals.[2]

Colour stands as a primary sensory attribute in food, not only enhancing appeal to consumers but also serving as an indicator of quality, freshness, and safety. The initial impression of a food product often hinges on its colour, significantly influencing consumer purchasing decisions. Some food items lack vibrant natural colours, leading consumers to overlook them and impacting sales negatively. To address this, the food and beverage industries heavily employ colour additives to enhance the visual appeal, attractiveness, and consistency of their products.[3] Various industries show a growing interest in natural pigments, seeking them not just for colouration but also for their health benefits, responding to increased regulatory demands and evolving consumer preferences. [4]

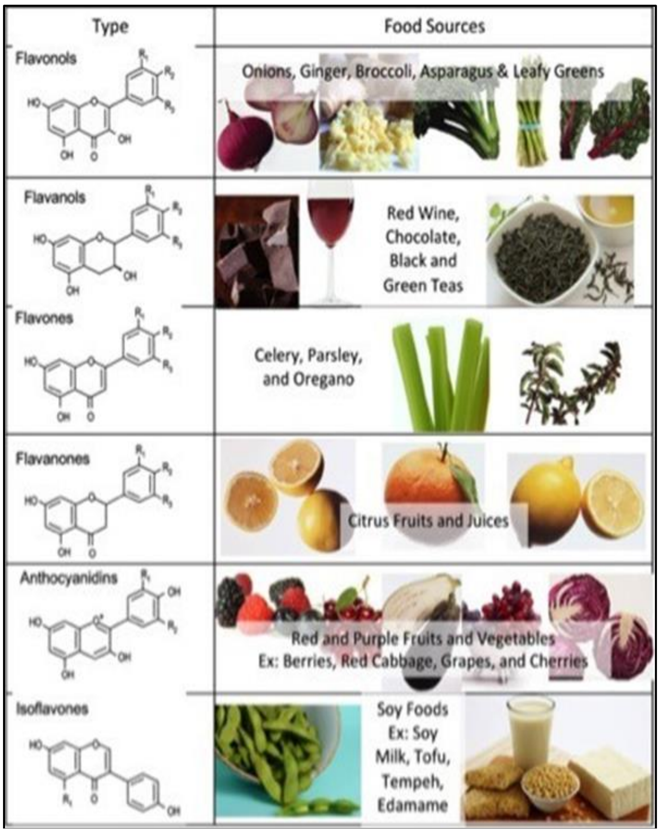

Fig 1 Flavonoids from Different Food Sources (https://images.app.goo.gl/wwEoXXLqwW91yiwU8)

Extraction, particularly in the context of plants, refers to the process of isolating pigments, the colourful compounds responsible for the vivid hues seen in leaves, flowers, and fruits. Commonpigments of plants encompass anthocyanins, chlorophylls, and carotenoids. Multiple methods exist for extracting natural pigments from plants, including maceration, super-critical fluid extraction, soxhlet-extraction, pressure-driven liquid extraction, ultrasound-assisted extraction, and microwave-assisted extraction. The success of extraction techniques relies significantly on input variables, the chemical composition of bioactiveelements, characteristics of the plant substances, and the level of scientific knowledge and skill involved.[5]

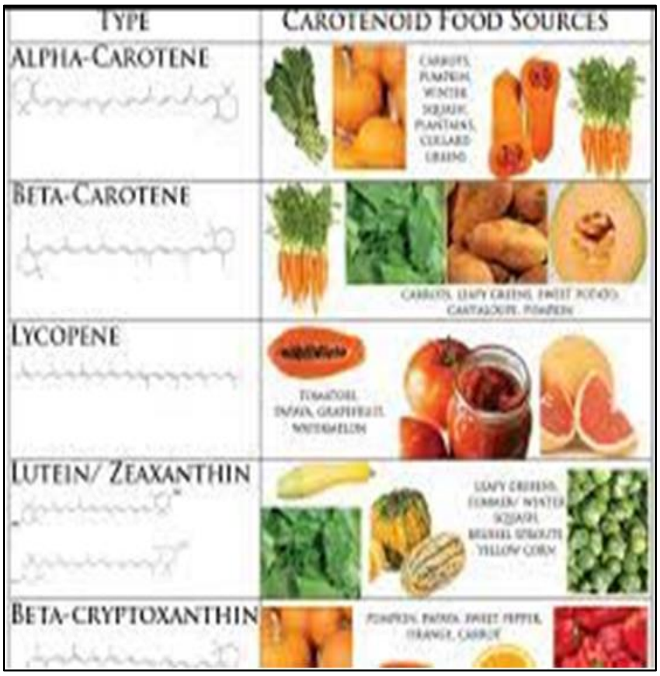

Fig 2 Carotenoid Rich Food Sources with the Pigments (https://images.app.goo.gl/YjgJibMsLpygbuHj9)


Fig 3 Betalain with some of its Sources Indicated (https://images.app.goo.gl/hQWRKitjjJNr3n8m7)


Fig 4 Chlorophyll, the Most Common Pigment found in all Green Plants (https://images.app.goo.gl/RdUzGXzEstPxTF8Z6)

II. EXTRACTION METHODS FOR NATURAL PIGMENTS

➢ *Maceration Method*

Maceration stands out as a traditional method for extracting heat-sensitive pigments, ideal for processes at room temperature. In the study reported, authors claimed that by macerating green microalgae (*Chlorella vulgaris*) at 25°C for 6 hours, they obtained a crude extract with lower pheophytin content, a marker for chlorophyll degradation, as compared to the content obtained from a 2-hour Soxhlet extraction at 100°C. This method involves grinding a plant sample and mixing it with an extraction solvent. The mixture is then placed in an extraction vessel, occasionally agitated. Once completed, the liquid is separated, and the remaining residue undergoes mechanical pressing or centrifugation. This process may need repetition with fresh solvent until it no longer carries colour. Given the reliance on room temperature, this method demands a longer extraction time and a substantial volume of solvent for repeated extractions.[6]

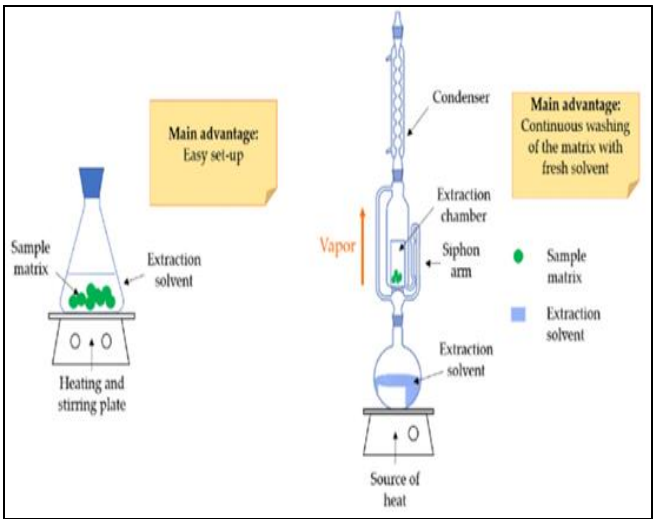

Fig 5 Experimental set up for the Process of Maceration (https://images.app.goo.gl/VeVfNCytbhonYrGf6)

In brief, maceration method was coupled with mixing and was carried out until the value of the absorbance became stable with sample taken for every two hours.[7]

- *Soxhlet Extraction Method*

Soxhlet extraction was initially developed for lipid extraction, but it has evolved into a standard method for assessing the yield in comparison to more advanced extraction techniques. In this process, a plant sample enclosed in a thimble is repetitively percolated with the condensed vapor of a solvent until the extraction is complete or until the solvent can no longer solubilize the targeted compounds in the sample. The completion of extraction is indicated by the solvent becoming colour less. Despite its simplicity and ease of use, Soxhlet extraction has some drawbacks, including the substantial requirement for solvent, an extended extraction period, and the potential for pigment degradation due to the applied heat.

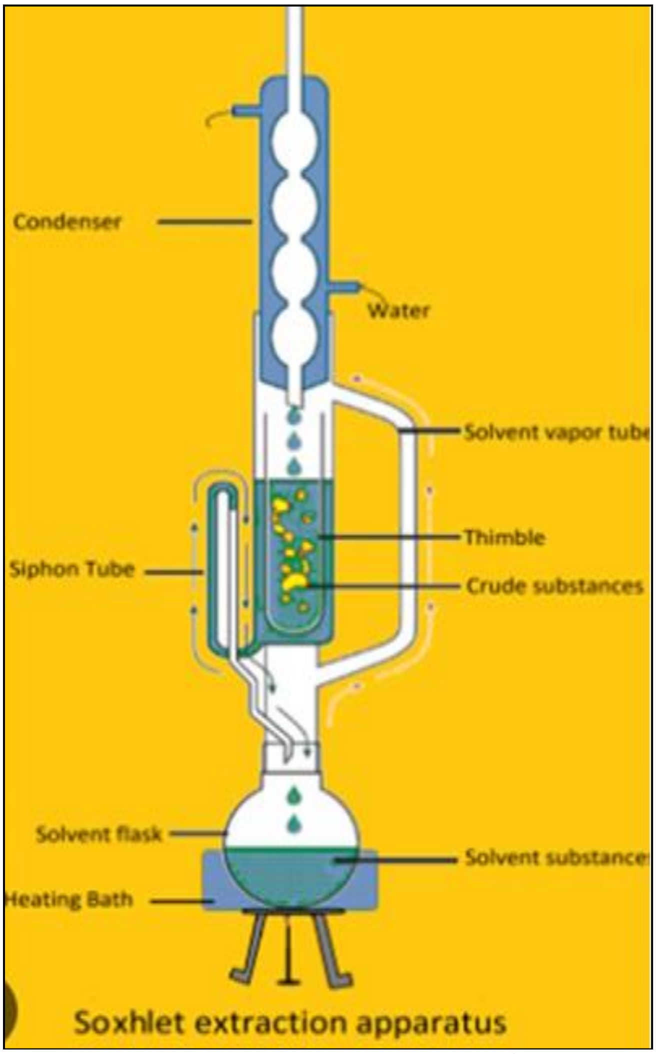

Fig 6 Soxhlet Extraction Equipment for Extraction from Liquids (https://images.app.goo.gl/M8WNan9Afa461nxn6)

- *Super-Critical Fluid Extraction Method*

Supercritical fluid extraction takes advantage of supercritical fluids, which possess characteristics of both gases and liquids, making them highly effective for extraction purposes. These fluids are achieved by subjecting a solvent to temperatures and pressures beyond their critical points, resulting in high diffusivity and low viscosity akin to gases, yet with potent solvation abilities similar to liquids [8]. This unique state enables better penetration into the sample matrix, significantly enhancing extraction efficiency.Carbon dioxide stands out as an excellent solvent for SFE due to its relatively moderate critical temperature (Tc) and critical pressure (Pc) of 31°C and 74 bars, respectively. Operating within a pressure range of 8 to 40 MPa and a temperature range of 30 to 60°C, SFE becomes applicable forextracting heat-sensitive pigments.[6] observed lower pheophytin contents in crude extracts of*Origanum Majorana* L. obtained via SFE at 40, 50, and 60°C compared to Soxhlet extraction at 70 and 80°C.

Primarily suited for low-polar pigments like carotenoids and chlorophylls due to the non-polar nature of most SFE solvents, this method isn't optimal for high-polar pigments such as betaines and anthocyanins. However, SFE's speed and selectivity over ultrasound-assisted maceration when extracting carotenoids and chlorophylls from *Nannochloropsis Guadiana*. The optimal conditions for achieving the highest extraction yields of carotenoids and chlorophyll a through SFE were observed at a temperature of 60 degrees Celsius and a pressure of 400 bar. although yields were lower compared to ultrasound-assisted maceration using methanol as a solvent.

Efforts to enhance carotenoid and chlorophyll extraction involve combining carbon dioxide with organic solvents like ethanol or methanol. Adding ethanol to supercritical carbon dioxide led to increased b-carotene extraction yields in carrots. Similarly, using ethanol as a co-solvent raised the extraction yield of chlorophylls a and b significantly. Despite its efficiency, minimal solvent usage, and potential for automation, SFE's drawbacks include high capital and operating costs due to the necessary high pressure for operation. However, its ability to extract heat-sensitive pigments without or with minimal use of toxic solvents makes it an appealing option.

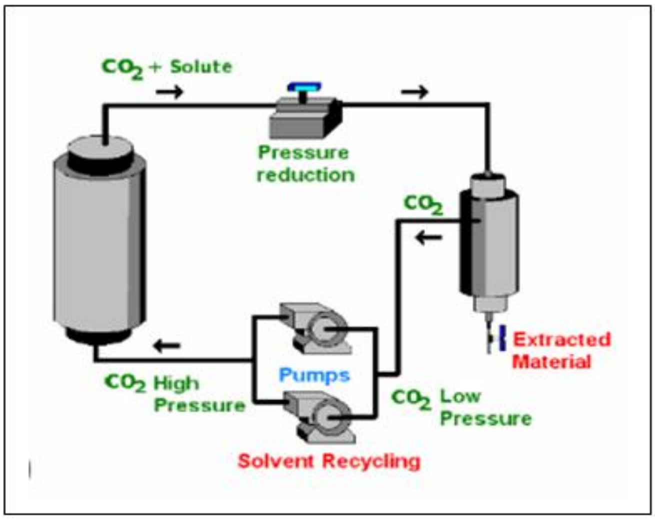

Fig 7 Depiction of Steps in Super Critical Fluid Extraction (https://images.app.goo.gl/Bt77L6kiPYDkB8Rk8)

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➢ *Pressure-Driven Liquid Extraction Method*

Pressurized liquid extraction is a technique utilizing elevated pressure and temperature with a liquid solvent to efficiently extract compounds. By employing heightened temperature, the method enhances solvent penetration into thesample and disrupts plant cells, facilitating pigment release. The increased pressure aids inforcing thesolvent into matrix pores, improving contact between the compounds and solvent for extraction. This process reduces time and solvent usage compared to other methods. Pressure-driven liquid extraction demonstrate versatility in extracting both water- and oil- based pigments, contingent upon the chosen extraction solvent. So high temperature requirements limits its use for heat-sensitive pigments. Thus, it's commonly employed for extracting more robust pigments like anthocyanins, carotenoids, and chlorophylls. Studies have shown its efficiency in extracting these pigments compared to traditional methods like Soxhlet extraction or maceration. For example, in extracting monomeric anthocyanins,

PLE (100°C) outperformed maceration at 25°C or Soxhlet-extraction at 80°C, and significantly reduced extraction time. Similarly, for carotenoids and chlorophylls, PLE at 160°C and up to 120 minutes provided greater yields compared to maceration or Soxhlet extraction. However, the elevated temperature used in PLE can cause increased degradation, resulting in higher pheophytin content.

To mitigate pigment degradation during PLE, various pretreatment methods can be employed. Adjusting solvent pH to acidic values can slow down anthocyanin degradation by favouring the formation of a more stable form. Incorporating co-pigmentation can enhance anthocyanin stability, while converting native chlorophylls to metal-chlorophyll derivatives before extraction helps retain the green colour in chlorophyll extracts obtained via PLE. Despite its efficiency and reduced solvent usage, the use of high pressure in this method increases both capital and operating costs.

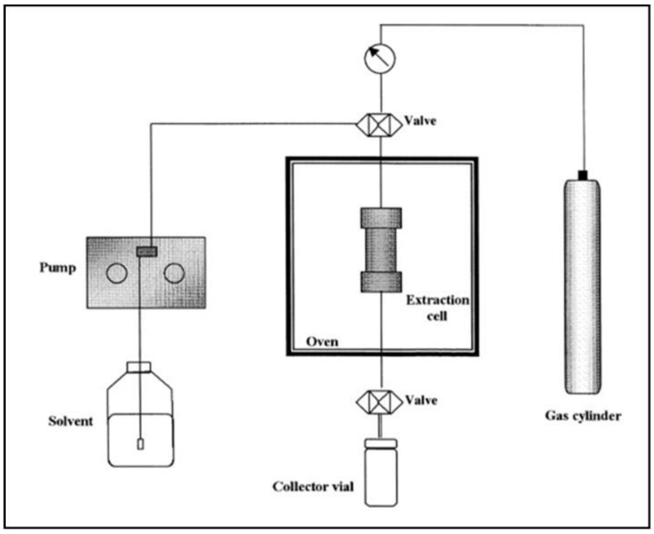

Fig 8 Experimental set up of Pressure-Driven Liquid Extraction (https://images.app.goo.gl/iYpko4gKhTBZSDbR7)

➢ *Microwave-Assisted Extraction Method*

Microwave-assisted extraction (MAE) stands out for its efficacy in extracting oil and water-based pigments of plants due to its speed and minimal menstrum usage coMPared to traditional techniques. Microwave radiation causes rapid heating that expands plant-cell structures, leading to rupture of cell wall and easier migration of compounds, including pigments, resulting in faster extraction rates. For instance, illustrated that MAE significantly reduced duration of extraction and volume of solvent needed for colorants (alizarin and purpurin) from rubiaceous plants compared to soxhlet extraction.

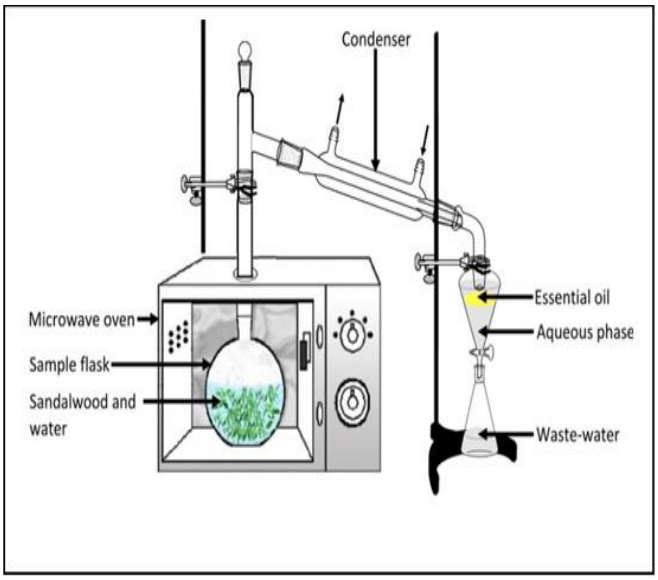

Fig 9 Micro-Wave Assisted Extraction Setup (https://images.app.goo.gl/BSdjgXXy57PEiWN49)

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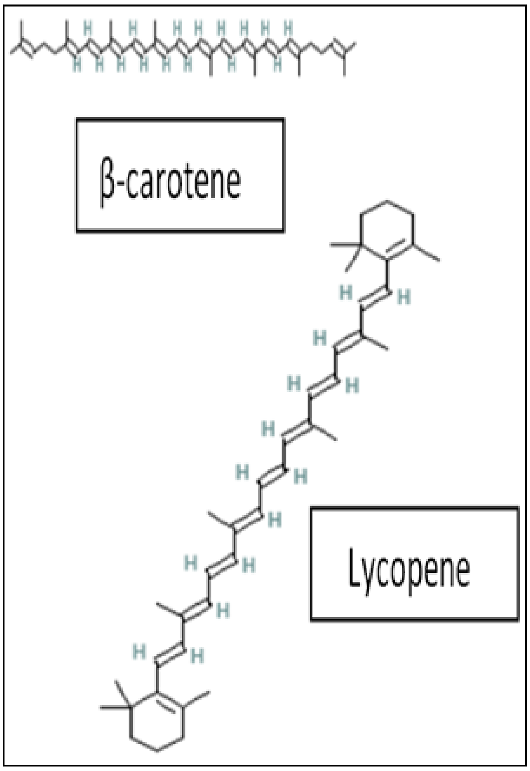
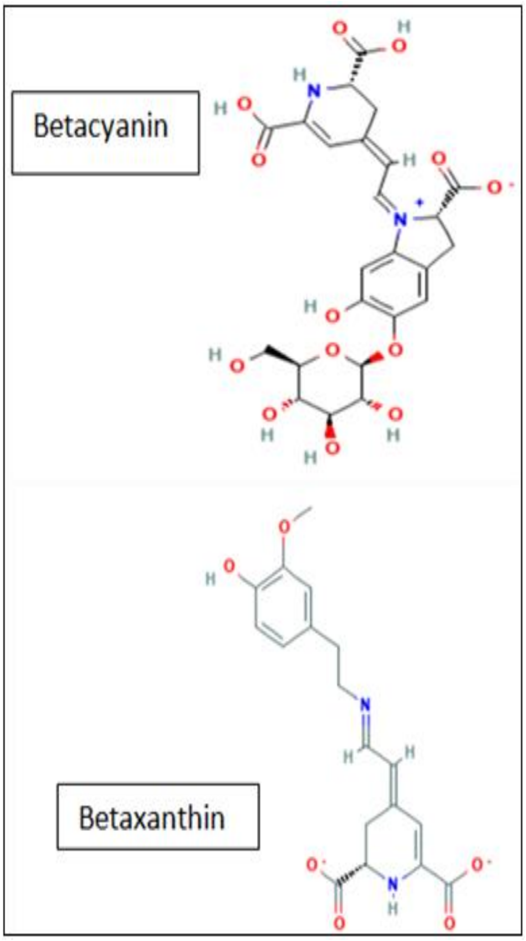
Table 1 A List of Most Often Extracted Pigment(s) / Compound (s) with Structure and Industrial Application

Compound	Pigments	Structure	Applications
Cartenoids	Beta -carotene, Lycopene		Lycopene: Natural red pigment used in food, cosmetics, and diagnostics for its antioxidant properties. Beta-Carotene: Orange pigment employed in food, supplements, and cosmetics as a natural colorant and antioxidant.
Betalains	Betacyanin, Betaxanthins		Betacyanin : Red to violet pigments used in food, cosmetics, and pharmaceuticals as natural, vibrant colorant. Betaxanthins serve as natural colorants in food and cosmetics, valued for antioxidant properties and pharmaceutical applications.

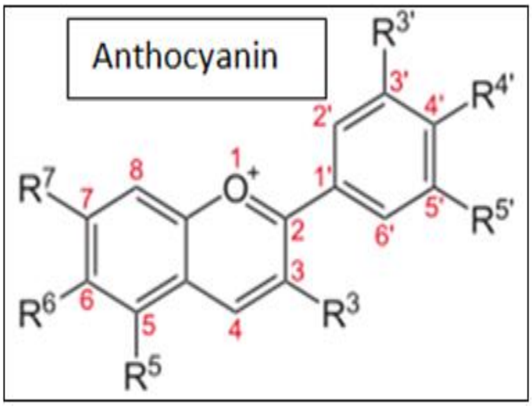
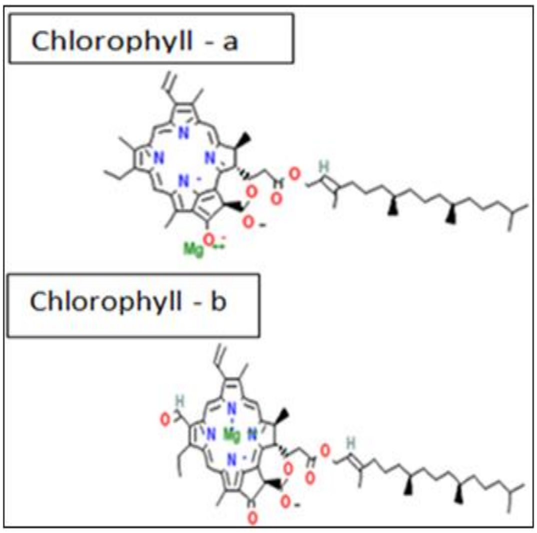
Flavonoids	Anthocyanin		Provides vibrant colours in food, cosmetics, and beverages, while also offering antioxidant benefits for nutraceutical applications.
Chlorophyll	chlorophyll-a and chlorophyll-b		Find applications in food, pharmaceuticals, and cosmetics, for their natural green colour and potential health-related applications.

Table 2 Summarized Benefits and Limitation of Techniques in Extracting Natural Pigments from Plants

Extraction method	Benefits	Limitations
Ultrasound	• Faster extraction • reduced solvent consumption • potentially higher pigment yield	• High Equipment cost • Cavitation effect • Scale-up challenge
Microwave	• Faster extraction • Reduced energy consumption.	• High Equipment cost • Uniform heating
Pulsed electric field	• Reduced processing time • lower energy consumption, • potential preservation of pigment quality	• Limited scalability • Energy consumption.
Maceration	• Simplicity • Versatility • Low cost	• Low extraction • Low Efficiency • More Time consuming
Soxhlet Extraction	• High extraction efficiency • Solvent recycling	• More Time consuming • Solvent wastage • Potential for thermal degradation
Supercritical fluid extraction	• High Selectivity • No residue • High Efficiency	• Safety concern • Complexity • Equipment cost
Pressurized fluid extraction	• High Efficiency • Automation • Solvent control	• High Cost • Operation Skill Required

Table 3 A Short Discussion on Plant Source, Extraction Method with Operating Condition and Yield of the Extracted Pigments Extracted

Source	Extraction Method	Operating condition	Extraction Yield	Pigment	Reference
Jabuticaba epicarp	Ultra-sound method	Operational parameters include a 500 W power, temperatures ranging from 25 to 30°C, a duration of 24.4 minutes, 34.5% ethanol, & a solvent/solid ratio of 20 mL/g	The extract contains 31 mg of cyanidin-3-O-glucoside Eq/g	Anthocyanin	10
Grape-pomace	Pulsed-Electric Field	The conditions involve field strength of 1.2 kV/cm, an energy input of 18 kJ/kg, a density of 1g / cm^3, temperatures from 20-50°C, a solvent consisting of 50% ethanol, and a solvent/solid ratio of 5mL/g	The proportion between overall anthocyanins and total flavan-3-ols increased from (7.1 - 9.0)	Anthocyanin	11
Saffron industry residue	Supercritical Co_2	The parameters include a flow rate of 100 mL/min, a temperature of 62°C, apressure of 16.4 MPa, a cosolvent comprising 5% ethanol(99.9%), and a duration of 47 minutes.	The content measured was 103.4 milligrams per 100 grams of dry weight.	Anthocyanin	12
Jucara-residue	Pressure-driven liquid extraction	The parameters utilized were a flow rate of 1.5 mL/min, a pressure of 10 MPa, a temperature of 40°C, an acidified water solvent with a pH of 2.0, a solvent /solid ratio of 9:1, yielding an equivalent of 9.2 mg of cyanidin-3-rutinoside per gram of dry weight of 18 blackberry (*Rubus fruticosus* L.) residues. In a different setup, a flow rate of 3.35 mL/ min, a pressure of7.5 MPa, and a temperature of 100°C were used for pressurized liquid extraction.	The equivalent amount of cyanidin-3-rutinoside in the dry weight was found to be 9.2 mg/g.	Anthocyanin	13
Fig-peel	Microwave-assisted	The conditions employed were a power of 400 watts, a duration of 5 minutes, a temperature of 62.4°C, utilizing 100% ethanol as the solvent, with a solid : solvent of 1:20.	The cyanidin 3-rutinoside content in the dry weight was measured at 4.11 mg/g.	Anthocyanin	14
Red-beet stalks	Ultra-sound assisted	The process was conducted at 53°C using 89 watts of power for 35 minutes. A solid-to-liquid ratio of 1 gram of powder per 19 milliliters of water was employed as the solvent.	The measured quantity was 1.28 mg of betacyanin per gram of the substrate	Betalains	15
Red-beet peels	Microwave-assisted	At 50°C, the process was run for 5 min utilizing a solid to solvent ratio of 1:20, and the solvent was subsequently discarded as a waste.	The dry sample had a content of 3.08 mg of betacyanin per gram of the substrate used.	Betalains	16
Prickly-pear peels	Microwave-assisted	The operation utilized 400 watts of power at 25°C for 8.8 minutes, with a solid-to-solvent ratio of 20.3 grams per litre. The solvent composition consisted of 54.8% methanol.	The extract contained 144.6 mg of betacyanins per gram of substrate used.	Betalains	17
Redpricklypear-peel	Pulse-Electric Field	For pretreatment, it involved subjecting the sample to 50 pulses at 20 kV/cm, utilizing water as the solvent with a solid toliquid ratio of 3 g of fresh sample per 30 mL of solvent.	There were 81.3 mg of colorants per 100 g fresh weight of the peels and 34.25 mg of colorants per 100 g fresh weight in the pulps.	Betalains	18
Pitaya fruits-peels	Pressure-driven hot	The process parameters were set at 56.9°C and 6.7 MPa for a duration of	The PFP registered 2.18 mg of betanin	Betalains	19

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	water extraction	9 minutes. The solid-to-liquid ratio used was 1g/6 mL.	equivalent(BE)/ gram of dry extract.		
Tomato-peels	Supercritical fluidextraction	The extraction involved a temperature range of 50 to 80°C, pressures varying from 300 to 500 bar, and flow rates between 4 and 6 g/min of CO_2 for a duration of 105 minutes.	The lycopene content measured was 1200 mg/kg of dry weight.	Carotenoids	20
Tomato-peels	Pulsed Electric Field	The PEF pretreatment utilized 5 kV/cm at 5 kJ/kg, followed by extraction using either ethyl lactate or acetone at a conc. of 1 g/ 40 ml, conducted at 25°C for 240 minutes.	The lycopene content was found to be 11,820 mg/kg of dry-weight when extracted with acetone, and approximately 6,311 mg/kg of dry-weight when using ethyl lactate as the solvent.	Carotenoids	21
Tomato-pomace	Ultra-sound assisted	The extraction utilized a mixture of ethyl lactate and ethyl acetate in a ratio of 7:3, with a volume of 100 mL/g, carried out for a duration of 20 minutes.	The lycopene content measured was 1335 mg/kg of dry weight.	Carotenoids	22
-tomato waste	Ultra-sound assisted	The oils—sunflower, corn, and rapeseed—were treated at a concentration of 50 mg/mL, subjected to ultrasonic waves at a frequency of 35 kHz, maintained at 20°C for a duration of 50 minutes.	The carotenoid content was approximately 34.8 mg/kg of dry weight for extra virgin sunflower oil, around 38.4 mg/kg for unrefined corn oil, and about 35.4 mg/kg for refined rapeseed oil, measured against the same dry weight.	Carotenoids	23
Dry-Tomato (waste)	Micro-wave-assisted	The rapeseed, sunflower and corn oils, each at a concentration of 50 mg/mL were exposed to 700 watts of power for a duration of 5 minutes.	The carotenoid content was measured to be approximately 32.2 mg/kg of dry weight for extra virgin sunflower oil, around 35.2 mg/kg for unrefined corn oil, and roughly 32.3 mg/kg for the same measure of dry weight.	Carotenoids	24
Egg-plant (peel)	Ultra-sound assisted	At a Frequency of 45 kHz, a temperature of 50 °C and for a duration of 50 min, utilizing 100% methanol as the solvent with a solvent by solid ratio of 10 mL/g.	2,275 mg/Kg of cyanidin-3-glucoside Eq	Anthocyanin	25
Cranberry-pomace	Pressure-driven Liquid Extraction	The conditions specified include a pressure of 5 MPa, a temperature range between 60 and 120ºC, using 100% ethanol as the solvent.	It appears to indicate a concentration range of 5.22-7.78 mg of cyanidin 3-glucoside equivalent per liter (mg/L).	Anthocyanin	26
Opuntia-joconostle-endocarp	Micro-wave-assisted	Initial processing involved using 297 watts for 5.5 minutes. The extraction phase was conducted at a temperature of 5°C for a duration of 10 minutes, utilizing water as the solvent.	This measurement indicates 8.47 mg of betanin per 100 gm of the substance.	Betalains	27
Beet-leaves	Ultra-sound	The process involved using 90 watts	There are 949.1	Betalians	28

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	assisted	of power, a solid : solvent is 1:20, a duration of 16 minutes, and water is the solvent.	micrograms of betaxanthin per gram of dry weight and 562.2 micrograms of betacyanin/gram of dry-weight in the substance.		
Pomogranate-wastes	Ultra-sound assisted	The sunflower and soy oils were mixed at a concentration of 4 grams per milliliter and left for 30 min.	This denotes a concentration of 3.25 milligrams of carotenoids per kilogram of dry weight in the substance.	Carotenoids	29
Dunaliela-salina	Super-critical Fluid	The extraction process involved temperatures ranging between 40 and 60 degrees Celsius, pressures spanning from 100 to 500 bar, and a flow rate of 3 liters of CO2 per minute for a duration of 90 minutes.	This represents an approximate value of 115.4 milligrams of carotenoid/Kg of dry-weight in the material.	Carotenoids	30

➢ *Pulsed-Electric Field Extraction Method*

Pulsed electric field (PEF) technology has arisen as a hopeful non-thermal option for extracting and generating natural colorants from food matrices. [30]It has emerged as a beneficial method in food production processes, including extraction. It involves using short bursts of high-voltage electric fields to create pores in plant walls of cell, improving the release of cellular components and thereby enhancing extraction efficiency.

Solvents utilized for extracting betaines and anthocyanins typically possess electrical conductivity, enabling the passage of electricity through sample cells. However, non-polar solvents present high electrical resistance and don't allow the electric field to pass through. Consequently, PEF is more effective for extracting betaines and anthocyanins than chlorophylls and carotenoids.

Numerous studies have explored PEF's application in pigment extraction. For example, a study utilized PEF (Pulsed Electric Field) at 3.4 kilovolts per centimetre and 105 milliseconds (delivered as 35 pulses of 3 milliseconds each) for the extraction anthocyanins from purple-fleshed potatoes., achieving higher yields compared to non-PEF-treated and macerated samples. Additionally, an examination explored how varying the solvent's pH impacted the PEF extraction yield of betanin's from red beetroot. The findings indicated that employing a McIlvaine buffer at pH 3.5 resulted in the highest betanin yield. This outcome is likely attributed to the potential of an acidic solvent to potentially hinder the degradation of betanin's throughout the extraction process. However, despite its potential, implementing PEF extraction, especially on an industrial scale, requires costly high-power supply equipment and treatment chambers, posing a current challenge due to their expense.[31]

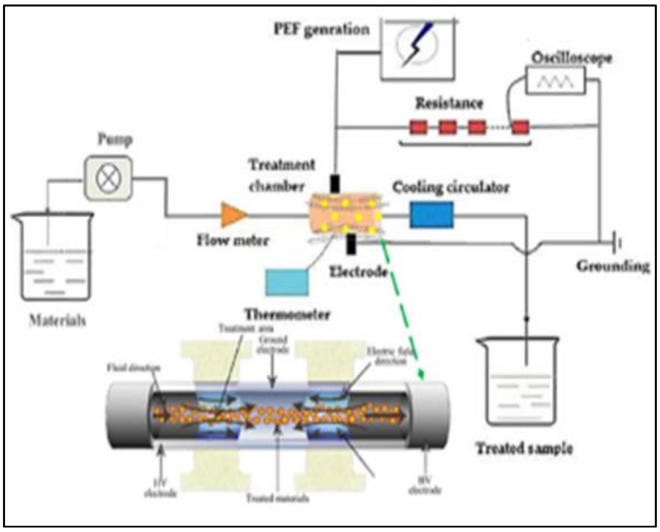

Fig 10 Experimental Setup for Pulsed Electric Field Extraction
(https://www.frontiersin.org/articles/10.3389/fnut.2022.925642/full)

➢ *Ultrasound-Assisted Extraction Method*

Ultrasound-assisted extraction (UAE) employs ultrasound waves to create cavitation bubbles, enhancing extraction efficiency by inducing cycles of compression and decompression within a medium. These bubbles, when they collapse, generate shearing forces that disrupt walls of cell, assisting in the liberation of compounds contained within cells. UAE offers advantages like operating at lower temperatures without external heating and consuming less solvent.

UAE is versatile on extracting both oil and water-based pigments, making it suitable for heat-sensitive pigments as it operates without external heat. For instance, Luxsika delved into using UAE for anthocyanin extraction from wine lees. Their comparison with maceration showed that, at identical extraction durations and temperatures (36 minutes at 60°C), ultrasound at 40 kHz yielded higher anthocyanin quantities than maceration. Furthermore, UAE has demonstrated efficacy in extracting betalains and chlorophylls. Further, the authors observed that UAE significantly enhanced the extraction rate, up to an 88.9% increase when retrieving chlorophylls from *Chlorella vulgaris*, compared to maceration.[6]

Nevertheless, UAE could potentially exhibit lower efficacy when compared to alternative non-conventional methods such as PEF, PLE, SFE& MAE Extraction. In the study, greater yields of carotenoids and chlorophylls from *Chlorella vulgaris* were noticed when employing PLE at elevated temperatures in contrast to UAE. However, it's noteworthy that PLE led to more chlorophyll breakdown, consequently concluded in greater pheophytin content.

To enhance UAE's productivity, repeated extraction is often necessary, demanding larger solvent volumes for the process. Recently, combining UAE with MAE has been proposed toboost extraction efficiency and reduce processing time. This combined method, referred to as UAE and MAE, has shown more extensive damage to plant structures, leading to higher yields of extracted compounds like lycopene from tomatoes compared to UAE alone.[21]

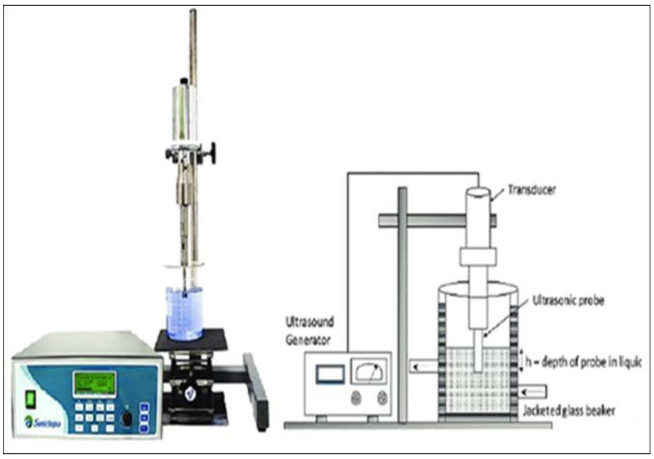

Fig 11 Components of Ultrasound-Assisted Extraction Unit (https://images.app.goo.gl/DpN17cqtj2HXKHr27)

III. CONCLUSION

In this current generation, consumers are becoming more aware of natural colorants, and this is becoming more crucial in the food industry. This trend has vigorated the role of natural pigment extraction techniques, which need to be more efficient. In this article, we discussed conventional and non-traditional extraction techniques. Non-traditional methods are more efficient extraction techniques than conventional methods, by means of minimum fossil energy consumption and need minimum post-treatment of waste water.

The non-traditional techniques offer clear advantages in terms of extraction rates, extraction time, energy consumption, and environmental impact. However, they also come with drawbacks such as the significant need for equipment and the necessity for process optimization. Among non-conventional extraction methods, efficiency varies based on factors like types of pigment, source of plant &specific goals of the extraction. Finally, for natural pigment extraction, the more efficient techniques are non-traditional methods that include ultra-sound assisted extraction method (UAE), Micro-wave assisted extraction (MAE), Super-critical fluid extraction technique(SFE), Pressure-driven liquid extraction technique (PLE)and Pulsed-electric field extraction technique (PEF).The best extraction method should be chosen for each natural pigment that needs to be extracted depending on its composition and stability.

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