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"Different Methods of Natural Colour Extraction of Amarantha - A Review"

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ABSTRACT
Amaranth is a nutrient-dense plant that is gaining popularity owing to its possible health advantages. Natural colourants produced from amaranth have gained popularity in recent years, with several uses in the food and cosmetic sectors. This review study focuses on several ways of natural colour extraction from amaranth, both traditional and contemporary.Colour extraction from amaranth traditionally involves the use of solvents such as water, ethanol, and acetone. These procedures are easy and inexpensive;however, they can produce low yields and contaminants. Modern methods, such as ultrasound-assisted extraction, supercritical fluid extraction, and microwave-assisted extraction, on the other hand, have been developed to circumvent these restrictions. These techniques have various advantages, including increased extraction efficiency, shorter extraction times, and lower solvent usage.The extraction temperature, pH, solvent type, and extraction duration all have an impact on the quality of natural colour derived from amaranth. The extraction efficiency and composition of the extracted colour can be affected using various solvents. Water-based extraction procedures, for example, can yield larger quantities of betacyanins, whereas ethanol-based extraction methods can create higher levels of betaxanthins. In addition to traditional and modern extraction methods, this paper examines the possible health advantages of amaranth colourants. The primary pigments contained in amaranth, betalains, have been shown to have antioxidant, anti-inflammatory, and anti-cancer qualities. Because of these features, amaranth colourants are a viable natural alternative to synthetic colourants, which have been connected to several health problems.

I. INTRODUCTION

In recent years, there has been a significant increase in the usage of naturally derived food and beveragecolourants. The worldwide natural colour market is expected to exceed $2 billion USD by 2024. (Ahuja and Rawat, 2018). Even though synthetic food is stable, consistent, and inexpensive, Due to customer concern about the artificial origin and potential ill health consequences of dyes, several industries have been looking for natural substitutes. Synthetic azo dyes are widely utilised in the food sector due to their stability, vibrant hues, and inexpensive manufacturing costs when compared to natural colourants. One of the most prominent synthetic azo colourants is FD&C Red 40 (Allura Red AC). In the 2019-2020 fiscal year, more than 12 million pounds were certified for usage in the United States alone (FDA, 2021). Prior research, requiring cautious labelling in the EU and hastening the transition to natural alternatives in the food business. worldwide (Oplatowska et al., 2017).

The most widely utilised natural alternatives to syntuhetic reds are anthocyanins and betalains, with anthocyanins usually functioning best in high acidity applications (pH4) and betalains operating best at pH levels above 4. Anthocyanins may be obtained commercially from a variety of crops, including grapes, carrots, and corn, but betalains can only be obtained from red beets (Reinhold and Schweiggert, 2016). Other crops, such as pitaya, prickly pear, and amaranth, have been proposed as possible sources of betalains, but their commercial applicability has been limited due to a lack of study and unknown agronomic potential (Gengatharan et al., 2015).

Using additional crops for betalain pigments, as with other natural colourants, would widen production geographically and potentially yield colour extracts with distinctive hues, better stability, and enhanced sensory qualities such as taste and scent. Amaranths are becoming popular as a long-lasting and nutritious alternative crop (Zhang et al., 2018). Cultivated amaranths are notable for their high nutritional content, palatability, and flexibility as ingredients in a booming food and cosmetics sector (Velarde-

Salcedo et al., 2019). Amaranth seeds and leaves have different nutritional profiles, with the seeds being more nutritious. being particularly abundant in protein, vitamin C, lysine, iron, and fibre (Rastogi and Shukla, 2013).

Amaranth seeds, unlike many grains, are gluten-free. To make a stand-alone meal or to lend a distinct taste to other cuisines, the seeds can be cooked, roasted, or popped. Most amaranth species are edible, but three species, A. caudatus, A. cruentus, and A. hypochondriacus, are widely produced globally as pseudocereal crops.These flowers have a rich pink colour that may be used as a source of natural colouring agents (betacyanins) for industrial use, providing an economically feasible destination for these by-products. In addition to the unique colourant qualities of betacyanins, these compounds have various biological features such as antioxidant, hypoglycemic and hypolipidemic action. and antibacterial activity, which make the produced colourant extract, biological characteristics Anthocyanins are naturally occurring coloured water-soluble pigments that are commonly employed as photosensitizers in DSSC, Betalains are a family of red-violet (betacyanins) and yellow (betaxanthins) pigment found in caryophyllales plants (Schoenlechner et al., 2010).

They contain anti-inflammatory, antioxidant, and hypoglycemic effects. Plants from the amaranthacea, red beetroot, bougainvillaea, and cactacea family are common sources of betalains. Cartenoids are a kind of yellow and yellow orange pigment that is utilised as a photosensitizer in DSSC. Several studies have been conducted to compare the efficacy of anthocyanins, betalains, and chlorophyll extracted from various plants. This study claims the extraction of betalain and chlorophyll from a single leaf, which has never been done before. Water and ethanol, which were previously utilised as solvents for a single dye in prior publications, were used to extract various colours in this study. J. Uddin et al. (2015) published a prior study on red amaranth as a natural sensitizer in DSSC.

The different components were separated using chromatography; however, the stated efficiencies are modest, and the individual-colored pigments were not categorised. In this study, two natural dyes, chlorophyll and betalain from red amaranth leaves, were employed as photosensitizers for DSSC. UV-vis absorption spectra were used to characterise the extracted dyes, and FTIR spectra were used to confirm their structures. Finally, the photoelectrochemical properties of the DSSC were investigated in this work using this extract as sensitizers. Throughout the year, vegetables such as Indian spinach, tripatri leaves, mustard greens, amaranth leaves, spinach, goose foot, and water spinach can be found in Bangladesh. Red amaranth is high in vitamins, minerals, folic acid, protein, dietary fibre, and amino acids (AlMamun et al. 2016). It's also high in bioactive substances including betacyanins, betaxanthins, and polyphenols, which have several health advantages. Non-toxic betalain pigments may help prevent cardiovascular illnesses, inflammatory responses, cancer, and degenerative diseases (Biswas et al. 2013). Acetone and methanol are not advised in the food industry due to their potential toxicity (Patil et al. 2009); instead, ethanol is the preferred solvent. Because some amount of water is required to remove the hydrophilic pigment, pure ethanol should not be used for pigment extraction (Priatni et al., 2015).

Betalains are hydrophilic pigments. pH, temperature, oxygen present, enzymes, metal ions, intermolecular interaction with other chemicals (co-pigments, sugars, proteins, and degradation products), intramolecular associations, and condensation processes are all environmental and processing parameters. all affect the stability of betalain pigments (Kumar et al. 2015).

Betalains are stable between pH 3.0-7.0, however the ideal pH may vary with temperature and the presence or absence of betalains of oxygen (Herbach et al. 2004). Temperature has a significant impact on the stability and pace of betalain degradation. Heat and light treatments both accelerate the breakdown of betalains (deAzeredo et al. 2009). As a result, the degradation of betalains used as food additives is a serious issue for both consumers and food manufacturers. Betalain degradation has been discovered to follow a first-order reaction model (Casati et al. 2015).

The interest in amaranth's purple-red pigments continues to this day, leading to the selection of many distinct cultivars showing vivid colouring and/or exquisite patterning from throughout the world.Amaranth pigments are betalains, a kind of pigment found only in the Caryophyllales family of plants (Sarker et al., 2022).

Color is one of the factors that influence the identification and acceptance of meals and beverages. Synthetic colourants are commonly employed in the food sector to get the desired colour. final product. These synthetic food colourants, on the other hand, are carcinogenic and hazardous to the consumer's healthas a result, manufacturers have lately shifted their focus to naturally derived colourants as a possible alternative. Because of their high antioxidant potential, betalains are gaining popularity among consumers and food makers (Priatni and Pradita 2015).

Betalains are divided into betacyanins, which seem magenta, and betaxanthins, which appear yellow orange. Amaranth betacyanins are mostly constituted of amaranthine and isoamaranthine, with minor quantities of betanin and isobetanin. As natural colourants, betalains from red amaranth might be an excellent option. A review of the literature revealed no studies on the extraction or stability of betalains from red amaranth leaves.As a result, the goal of this investigation was to explore the consequences of the effects of extraction parameters on the betacyanin content of red amaranth and their degradation kinetics(Sarker and Oba, 2021).

As a result of its high concentration of betacyanins and betaxanthins, amaranth (Amaranthus spp.) has received interest as a possible source of natural colourants. These pigments provide brilliant colours ranging from red to purple and yellow to orange. Various procedures are used to extract natural colourants from amaranth tomaximise pigment recovery while conserving pigment stability and bioactivity. Some of the most often used techniques include solvent extraction, microwave-assisted extraction, and enzymatic extraction. These methods allow for the effective extraction of betacyanins and betaxanthins, which may be employed as natural colourants in the food sector, such as in the making of amaranth cookies. Colourants derived from amaranth not only give visually beautiful colours, but they may also provide health advantages due to their antioxidant and anti-inflammatory characteristics. Furthermore, using amaranthas a colour source increases food production sustainability by lowering reliance on synthetic colourants. However, problems like pigment stability, degradation during processing, and sensory acceptability must be overcome before amaranth colourants may be successfully included into food items. More study is needed to improve extraction procedures, investigate encapsulation methods, and evaluate the impact of amaranth colourants on the sensory and nutritional properties of amaranth cookies(Deng Z et al., 2015).

II. NUTRITIONAL IMPORTANCE OF AMARANTH

The amaranth grain has been examined for its outstanding agricultural properties, such as its short growth time and drought resilience. Although possessing various anti-nutrient components (e.g., phytic acid, oxalates, and tannins) that may impair nutrient absorption, notably its protein content, amaranth is widely known for its high nutritional quality. cruentus is the most commonspecies farmed in Guatemala, A. hypochondriacus in Mexico, and the most prevalent species grown in Guatemala is A. cruentus, followed by A. hypochondriacus in Mexico and A. caudatus in Peru and other Andean nations.Cruentus grain, for example, contains more protein (14.9%), lipid (6.98%), and fibre (4.5%) than other amaranth grain species and general grains like wheat (12.3% protein, 8% fat, and 2.3% fibre), corn (8.9% protein, 3.9% fat, and 2.0% fibre), rice (7.5% protein, 1.9% fat, and 0.9% fibre), and oat (16.1% protein, 6.4% fat, and 1.9% fibre).

The extraction process utilized determines the quantity of distinct fractions in the separated protein as well as its nutritional and functional qualities. The principal storage proteins in amaranth are albumins and globulins. Amaranth grain is also high in insoluble fiber, specifically lignin and cellulose. According to Becker and Saunders, the overall fiber content of amaranth exceeds that of a common grain. Amaranth grain is softer and thinner than wheat bran, with 16 and 9% bran and dietary fiber, respectively. Amaranth grains are a good source of minerals; for example, A. Phosphorus (441 mg), potassium carbonate (434 mg), magnesium (254 mg), calcium (206 mg), iron (12 mg), zinc (5.2 mg), manganese (4 mg), aluminium (4 mg), cobalt (0.06 mg), and selenium (0.02 mg) are the ingredients of this product (per 100 g dry weight).

This grain type also contains the following vitamin contents (100 g on a dry basis): riboflavin (B2) (0.03 mg), pyridoxine (B6) (0,05 mg), nialin (8.04 mg), thiamine (0.10 mg), total tocopherol (4.3 mg), and vitamin E. (2.1 mg). Antinutritional factors such as oxalates, nitrates, and phenolic compounds are low in amaranth grain, and numerous investigations have shown that they are thermolabile chemicals. As a result, it is advised that an amaranth grain be adequately prepared before ingestion. Raw amaranth has a tannin concentration of 0.52-0.61% and phytate levels (inositol hexaphosphate) of 0.043-0.116%. Phytates create insoluble complexes with several substances,

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preventing protein and mineral absorption. Iron, zinc, and calcium are a few examples.

PRINCIPAL	NUTRIENT VALUE	% OF RDA
Energy	23Kcal	1%
Carbohydrates	4.02g	3%
Protein	2.46g	4%
Total fats	0.33g	1.50%
Cholesterol	0mg	0%
Dietary fiber	2.2g	6%
VITAMINS		
Folates	85µg	21%
Niacin	0.658mg	4%
Pantothenic acid	0.065mg	1%
Pyridoxine	0.192mg	15%
Riboflavin	0.158mg	12%
Thiamine	0.027mg	2%
Vitamin-A	2917Iu	97%
Vitamin-C	43.3mg	70.50%
Vitamin-k	1140µg	950%
ELECTROLYTES		
Sodium	20mg	1.30%
Potassium	611mg	13%
MINERALS		
Calcium	215mg	21.50%
Copper	0.162mg	18%
Iron	2.32mg	29%
Zinc	0.90mg	8%
Magnesium	55mg	14%
Phosphorus	50mg	7%

Table 1: Amaranth Greens (A. dubius), (Maundu P et al.,2014). Nutritive Value/100 grams.

Antinutritional effects of polyphenols include complex formation (with iron and other minerals) and protein precipitation, which reduces protein absorption. As a result, amaranth grain products become particularly appealing for consumption as food or as food enrichment additives Several communities' diets rely on it.

Because of the high nutritional content of the protein, amaranth grain may be used to fortify wheat flour, maize, and tubers, as well as to manufacture gluten-free farinaceous items. Moreover, its phenolic components may hold the key to preventing some chronic noncommunicable illnesses. Amaranth grain can be used whole grain, like whole wheat flour, or blended with other grains. Wheat flour with a high amaranth protein content can be used to boost the nutritional value of finished foods like noodles, biscuits, potatoes, cassava or maize breads and cakes. Amaranth may be used to replace wheat and other grain products at up to 15% levels, considerably affecting the technical functional qualities of the goods. Singhal and Kulkarni discovered that amaranth grain starch maize may be utilized as a sauce thickening. Several food processing technologies (for example, germination and lactic acid fermentation) have been presented as techniques to increase nutritional density while decreasing antinutrients.

discovered that amaranth natural starch is resistant to freezing and thawing and hence durable to various forms of thermal treatment, while acidic circumstances may restrict its durability. This grain's sweets and snacks are healthful and popular in Asia and South America. Extrusion has produced amaranth snacks with significant nutritional content and appeal. Apart from its excellent appeal, amaranth snack demonstrated hypocholesterolemia in rabbits, high biological value proteins, and good bioavailability.

To achieve a balanced protein supply, amaranth flour is often blended with maize or wheat flour. It has been stated that adding enlarged amaranth grains (10-20%) as an alternative to amaranth flour can improve the nutritional value of bread by enhancing iron, phosphorus, calcium, magnesium, and potassium content. Because reactive oxygen species (ROS) or free radicals (i.e., hydroxyl radicals, superoxide anions, and singlet oxygen) react with biomolecules such as proteins and lipids, causing severe damage to the cell membrane and DNA, there has been a surge in interest in discovering natural antioxidants in recent years.

There is evidence that these mechanisms are closely linked to carcinogenesis and degenerative diseases including cardiovascular disease and osteoporosis. As a result, antioxidants may play a role in the oxidation process by interacting with free radicals. The chemicals that can interrupt auto-oxidation can do so in two ways. The first is based on hydrogen atom transfer; the free radical grabs the antioxidant's hydrogen atom, resulting in the development of a stable radical antioxidant and the oxidizing reaction being blocked; the second is based on electron transfer. The reducing capabilities and chemical structure of phenolic compounds contribute significantly to their antioxidant activity. By acting on both the initiation and propagation phases of the oxidative process, these properties play a critical role in decreasing or scavenging free radicals (such as singlet oxygen) and chelating transition metals. Food processing can cause considerable changes in the chemical composition and amount of plant-derived bioactive chemicals. Processing can alter the polyphenol content of foods in a variety of ways.

According to studies on various goods after cooking, the overall polyphenol content and antioxidant capacity are decreased compared to fresh meals, but increased in other foods, such as green vegetables. Traditionally, the amaranth grain is toasted in a hot frying pan. There is little or no control over the temperature in this scenario, as well as the residence period of the seeds exposed to high temperatures. Unfortunately, information/studies on the influence of amaranth processing on bioactive chemical content (e.g., phenolic compounds) and antioxidant activity are currently rare.

These researchers discovered that A. cruentus had a greater protein content and antioxidant activity than A. hypochondriacus. Furthermore, they discovered that dry heat altered protein digestibility and antioxidant activity in the two amaranth genotypes. The rate of absorption is also affected by the type of sugar contained in the molecule. When a sugar molecule is linked to a glycoside derivative is produced, the hydrophilicity of flavonoids increases, lowering the likelihood of passive diffusion. The active -glucosidases discovered in the intestinal epithelium include lactase-phlorizin hydrolase and -glucosidase cytosolic, which are responsible for separating the -glycosidic bonds from active aglycones. Absorption and bioavailability of bioactive compounds (typically present in amaranth) in

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humans have been shown to be higher for isoquercitin, lower for quercetin, and lower for rutting.

Amaranth extrusion boosted calcium bioavailability as determined by rat tibia and femur weights, as well as bone calcium and phosphorus levels. The next section will go through various studies that extracted amaranth bioactive compounds to improve their functionality and bioavailability, as well as to construct novel functional amaranth-based structures. One of the few types of research that focuses on ways to improve amaranth bioavailability and accessibility.

III. DIFFERENT METHODS OF EXTRACTION OF COLOR FROM AMARANTH

Colour gives customers their initial impression of a dish's flavour, texture, and freshness, which influences their eating selections. Food colourants are divided into two types: natural and synthetic. Natural-identical colours are those taken from plants, fungus, or insects. Natural colours, on the other hand, are readily damaged, more susceptible to light, temperature, pH, and are more expensive. Prior to that, synthetic colours were proven to be the most dependable and cost-effective chemical due to their unique properties such as high light, oxygen, pH, colour consistency, reduced microbiological contamination, and cheap manufacturing cost we4The most common synthetic colours are azo, triphenylmethane, xanthene, indigotin, and quinolone. Azo colours have azo groups (-N=N-) as the chromophore in the chemical structure.
structure is the largest group of colors accounting for more than half of global dyes production. Around 65% of azo colours are utilised in foods as food additives (Ramisetti et al.,2016).

3.1. Solvent extraction

One of the most prevalent ways for extracting colour from amaranth is solvent extraction. Depending on the type of pigment, the solvent employed might be polar or non-polar. Polar solvents such as ethanol, methanol, and acetone are used to extract chlorophyll pigments, whereas non-polar solvents such as hexane and petroleum ether are used to extract carotenoids. Precipitation, column chromatography, or thin-layer chromatography can be used to further purify the extracted pigments**.** Amaranth is soluble in water (about 70 g L at 25˚C) and ethanol (up to 4 g L), but insoluble in vegetable oils. The powders or granules have a red brown colour; in liquid form, it has a bluish red colour. Amaranth is often given as sodium, potassium, or calcium salts (Yamjala et al., 2016).

Amaranth is widely utilised in a variety of sectors, including food, cosmetics, textiles, medicine, and paper manufacture (Mpountoukas et al., 2010). Colors are always significant in terms of customer approval since they express the freshness or the acceptable parameter in meals. Natural colours have been derived from natural sources for over a century and are commonly used in cooking. Natural colours also have certain flaws in their qualities, such as being unstable to heat, light, and temperature, and being easily decolorized while cooking. Hence, synthetic colours have the potential to replace natural colours due to several advantages such as cheap cost, goodstorage stability, freshness, and minimal microbiological contamination (Li et al., 2015).

Amaranth is often used in soft beverages, ice creams, cake mixes, wines, canned fruit pie fillings, soups, shrimp, cereals, salad dressings, chewing gums, jams, cocoa, and coffee because of its reddish or brownish colour (Mpountoukas et al., 2010). Even though several European nations have outlawed Amaranth colours as additives, Amaranth is still used in textile dyes for wool and silk, as well as in photography (Tariq et al., 2005).

3.2.Supercritical Fluid Extraction

Supercritical fluid extraction (SFE) is a green extraction process that extracts colours from amaranth using supercritical carbon dioxide as the solvent. SFE has several benefits over standard solvent extraction technologies, including good selectivity, minimal toxicity, and simple solvent recovery. SFE has been used successfully to extract carotenoids from amaranth, with yields equivalent to traditional procedures (Sánchez-Camargo et al., 2017).

Because of its unique solvent characteristics, supercritical carbon dioxide is an excellent solvent for extracting colours from amaranth. It works at a pressure and temperature above the critical pressure and temperature, allowing it to have both liquid and gas-like characteristics. Because of its high pressure and temperature, supercritical carbon dioxide has a better solubility for pigments, resulting in a more efficient extraction procedure. Furthermore, because supercritical carbon dioxide is a non-toxic and non-flammable solvent, it is a good substitute for typical organic solvents.

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To remove synthetic colour, solid-phase extraction (SPE) is often utilised. Because of its speed and simplicity, this approach has been used in various studies to analyse synthetic colours in food products. SPE is used to isolate analytes and purify the extraction, removing any interfering components for a cleaner extraction containing the target analyte (Rovina et al., 2017). The operation is more convenient and speedier for SPE method due to the magnetic property. It was determined that the suggested approach has great sensitivity and reproducibility for analysis in actual samples with satisfactory results. recoveries ranging from 91.9% to 112.5% with the food industry, there is a growing trend to replace synthetic colorants with natural pigments. Amaranthus pigments are red violet betacyanins, like red beetroot pigments, which are widely utilised across the world (Schnetzler et al., 1994).

One of the most significant advantages of SFE is its ability to extract certain pigments selectively. SFE selectivity may be adjusted by varying the pressure, temperature, and flow rate of supercritical carbon dioxide. This permits colours to be extracted without co-extracting undesired chemicals, which is a typical issue with standard solvent extraction procedures. The amaranthusbetacyanins amaranthine and isoamaranthine have been discovered (Piattelli et al., 1964). Betanin and isobetanin were discovered as the main betacyanins in red beets (Jackman and Smith 1996). They have the same fundamental structure (betanidin). Amaranthus pigments, a novel source of betacyanin type pigments, have a high economic potential for development as natural food colourants. Certain Amaranthus genotypes exhibited much greater biomass and betacyanin content than others, and the pigments recovered from them had vivid colour features with good durability under certain circumstances (Cai et al., 1998).

Finally, supercritical fluid extraction is a promising and environmentally friendly extraction technology for amaranth pigment extraction. Its benefits over typical solvent extraction technologies include good selectivity, minimal toxicity, and simple solvent recovery. Future study should concentrate on improving the conditions for SFE and finding more efficient and sustainable methods for amaranth pigment extraction. Moreover, these betacyanin pigments have been tried in jelly, higher pH drinks, and ice cream (Cai and Corke 1999).

3.3.Microwave-assisted extraction

Microwave-assisted extraction (MAE) is a quick and effective extraction technology that heats the solvent and speeds up the extraction process. MAE has been demonstrated to be more successful than standard solvent extraction techniques for extracting anthocyanins from amaranth, with better yields and shorter extraction periods.MAE's ability to shorten extraction time is one of its primary advantages. MAE may dramatically duce extraction time when compared to typical solvent extraction procedures, making it a more efficient and cost-effective method. Moreover, MAE can increase pigment quality by decreasing the deterioration of heat-sensitive pigments that might occur during extended extraction durations (Zhang et al., 2018).

Extraction experiments were carried out in accordance with the experimental plan. Seventeen experiments were carried out in a microwave-ultrasound-UV reactor supplied by Nutech Analytical Technologies Pvt. Ltd., India (Model: NuWav Pro 2450 MHz frequency). Batch processing was used. The microwave's duty cycle was 50%, 0.5 seconds on and 0.5 seconds off, with a time basis of 1 second. In a four-neck round-bottom flask, two grammes of powdered sample were combined in ultrapure water (1:80 powdered sample:water ratio). In the flask, a platinum probe for temperature sensing was constructed. To avoid solvent evaporation, the flask was additionally equipped with a condenser.

The samples were filtered using Sartorius Filter paper, and the filtrate was centrifuged at 4000 rpm for 10 minutes using a Remi Laboratory equipment tabletop centrifuge (Model: Neya 8). The supernatant was collected and kept in screw-capped tubes below 10 °C until further examination. (Zin et al.,2020). The solvent is heated using microwave radiation in microwave-assisted extraction. Microwaves are electromagnetic radiation with frequencies ranging from 0.3 to 300 GHz that have no effect on molecular structure since their energy is lower than the ionisation energies of biological compounds or intermolecular van der Waals interactions. As a result, microwaves' influence on chemical synthesis and extraction processes is limited to the conversion of electromagnetic energy into heat (Florez et al. 2015). The type and volume of the solvent, the extraction time, microwave power, temperature, and matrix properties are the primary parameters that determine MAE efficacy. They outline the permeation and solubilisation processes

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used to extract the analyte from the matrix (Azmir et al. 2013).

When compared to established methods for extracting metabolites with bioactive properties from plants and vegetables, MAE has shown tremendous potential for the pharmaceutical and nutraceutical food sectors. (Mandal et al. 2007). It is critical to design an acceptable method for optimizing these features to provide the specific phytotherapeutic product with quality, performance, and functionality. The purpose of thisresearchwas to determine the optimal MAE settings for extracting squalene-rich oil from amaranth seeds. The research will provide an alternative to standard extraction methods. (Bele and Khale 2011).

3.4.Ultrasound-assisted extraction

Danger et al., (2021). Have studiedUAE experiments were carried out at a frequency of 20 kHz with a 750 W Branson variable power sonifier (GEX-750, Sonic, Newtown, CT, USA). As a solvent, amaranth powder was mixed with distilled water at pH 5 and a solute-solvent ratio of 1/30 (g/mL) with HCl 0.1 N. The mixture was then subjected to UAE at a variety of temperatures (25.86, 30, 40, 50, and 54.14 C). When compared to conventional extraction, ultrasound-assisted extraction (UAE) technology has received a lot of attention for extracting natural pigments because of its valuable properties such as shortening the extraction time, reducing organic solvent waste, increasing extraction yield, and improving extract quality (Tao et al. 2014). In fact, ultrasonography has been identified as a viable alternative to standard extraction procedures (Galanakis et al.,2013).With minor adjustments, UAE was utilised as a reference extraction technique, utilisingan ultrasonic bath Bandelin (RK 100 H, Berlin, Germany). Two grammes of milled material were weighed into a 100 mL conical flask and mixed with 30 mL of methanol/ethanol solution (90:10, v/v). The flask was sealed, shielded from light, and put in an ultrasonic bath at room temperature (25 °C) for 50 minutes. The ultrasonic bath was chilled with ice to keep the water temperature consistent. The resulting extracts were evaporated using a rotating vacuum evaporator at 40 °C and refrigerated until use. (J. Xiaopin et al.,2010).6.25 g of amaranth powder was deposited in a 250-mL conical flask with 100 mL of distilled water and placed in an ultrasonicator bath (BandelinSonorex, RK510H, 35 kHz, Germany) for 5 minutes at 30, 50, and 70 degrees Celsius. The extracted material was vacuum filtered using a Whatman filter after being filtered through a cheese cloth. The filtered extract's quality parameters were then examined. (Das et al.,2019).

UAE has proven to be a highly successful extraction method for lowering the extraction temperature and amount of solvent used, as well as shortening the extraction time, which is particularly advantageous for the extraction of thermosensitive and unstable molecules. As a result, UAE has been frequently employed in literature to extract physiologically active chemicals. (Bruni et al.,2002). According to these investigations, UAE is more effective than traditional solvent extraction without UAE in extracting bioactive chemicals from various natural sources. Due to the substantial disruption of sample tissue structure caused by ultrasonic acoustic cavitation, UAE was quicker and more efficient in extracting bioactive components. (Romagnoli et al.,2002)

IV. ADVANTAGES AND DISADVANTAGES OF AMARANTH COLOR EXTRACTION TECHNIQUES

The study intends to capitalize on the nutritional benefits of amaranth because these products are not traditionally used in the food industry, resulting in nutritional and economic losses due to their poor nutritional use. As a result, through the production of amaranth cookies, we seek to promote the use of these foods by adding value to their industrialization, beginning with the transformation of the raw material into flour and then subsequently elaborate cookies that allow this product to be directed to all people of any age due to its nutritional benefits, for which a bromatological industrial and economic analysis validated through the analysis of variance and the cost-benefit analysis (Bravo Avalos et al.,2023). Synthetic dyes are frequently substituted with natural colors due to various advantages such as high light stability, minimal microbiological contamination, and low cost. However, current research indicates that synthetic food colors are harmful to human health. Amaranth - E 123 (AM), a synthetic water-soluble azo dye, is employed as an intriguing red color in a wide range of culinary goods, including chocolates, cake mixes, wines, coffee, syrups, and several other drinks. Under anaerobic conditions, amaranth has a deleterious impact on the functioning of the liver and kidneys due to the decreased form of aromatic amines. Furthermore, amaranth is not recommended for

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those who are sensitive to aspirin or for youngsters who exhibit hyperactive behavior. (Huy Hoang Do et al.,2023).

The utilization of plant-based raw materials in the food business is a contemporary trend, owing mostly to the health benefits provided by the natural substances found in them. One of the health advantages is the reduction of degenerative disorders (Delgado-Vargas et al., 2000). Amaranth (Amaranthus spp.) is abundant in bioactive chemicals, and its high betalain concentration makesit an appealing alternative to synthetic colours in the food business. The use of synthetic dyes should be limited due to the negative impact on consumer health (Swaroop et al., 2011).Furthermore, the antioxidant properties of polyphenols in amaranth offer value by preventing neurological illnesses, cancer, and obesity (Cory et al., 2018). This severely limits their use in AM analysis. For AM detection, electrochemical sensors provide a quick response and cost savings (Yongfeng, et al.,2023). Simple working electrodes, on the other hand, generally only detect target compounds like AM at high concentrations (Waterhouse et al., 2023). Improved methodologies are needed to detect AM in foods in a highly sensitive and selective manner. While dioecy confers evolutionary benefits, a disadvantage that is thought to occur naturally is that bottleneck events can result in populations that are depleted of one of the two both genders, and if not for gender reversion, the population would collapse and thus become locally extinct. (Marais GAB et al., 2017), Artificial gender manipulation, in which proportions of men and women could be biased towards one gender and the genetic factors involved are inherited in a non-Mendelian pattern via a gene drive system, was proposed as a possible strategy for management of weedy dioecious Amaranthus species, taking this disadvantage into account. (Tranel PJ et al., 2009).

V. APPLICATION OF AMARANTH IN FOOD

As a result of the increased demand for clean-label and sustainable food items, the extraction of natural colours from amaranth has sparked great attention in recent years. This review study investigates several ways for obtaining natural colours from amaranth and their uses in the food business. The vibrant colours of amaranth, together with its nutritional advantages, provide an interesting possibility for improving the aesthetic appeal and overall quality of a variety of food items. Food makers may offer aesthetically appealing and healthier solutions for customers by knowing and exploiting the potential of amaranth as a natural colourant.

5.1.Amaranth as a natural color source: -

Amaranth has a variety of natural hues, including betalains and anthocyanins, which give it its distinctive deep reds and vivid purples. These natural colours provide an enticing alternative to synthetic food colourants, which are being investigated owing to potential health risks. Extracting these natural hues from amaranth provides food manufacturers with a sustainable and healthy solution for addressing customer demand for clean-label goods.Because of its vivid colours, amaranth is a fantastic natural colour source, making it an appealing alternative to manufactured food colourants. The plant's rich betalains and anthocyanin makeup gives rise to its unique colours, which range from deep reds to strong purples.These natural colours have various advantages, including the absence of chemical additives and the possible health hazards connected with synthetic dyes. Natural colour extraction technologies from amaranth provide food makers with a sustainable and clean-label answer for improving the visual appeal of their goods. Various food products may be converted into aesthetically appealing creations by utilising the potential of amaranth as a natural colour source. Amaranth's natural colours can enhance the visual appeal of drinks and dairy products, as well as confectionary, bakery goods, and even sauces, dressings, and meat substitutes, while also delivering possible health advantages connected with the plant's bioactive chemicals.The food sector may embrace a more sustainable and health-conscious approach to product creation with amaranth as a natural colour source, addressing the expectations of customers wanting aesthetically appealing and clean-label food alternatives.

5.2.Beverages: -

Beverages give an excellent chance to utilise natural amaranth colour extraction technologies, giving visually appealing colours as well as possible health advantages. Amaranth extracts can be used to improve the aesthetic appeal and nutritional content of a range of drinks, including juices, smoothies, and herbal teas. Amaranth pigments, such as betalains and anthocyanins, not only give brilliant colours but also have antioxidant characteristics and possible health advantages. Manufacturers may produce aesthetically appealing items that stand out on shop shelves and attract consumers searching for natural and bright choices by putting amaranth extracts into beverages.Furthermore, the use of amaranth as a natural colour source corresponds with the clean-label movement, providing an alternative to synthetic food colourants, which may be seen negatively by health-conscious customers. Amaranth-infused beverages not only appeal to the eyes but also have a distinct flavour profile, making for a more delightful drinking experience. The natural colours of amaranth make it suitable for a variety of beverages, allowing for innovation in product development and providing customers with a greater selection of visually appealing and nutritionally good options.

5.3.Dairy product: -

Natural colour extraction methods from amaranth can improve the aesthetic appeal and nutritional value of dairy products. Manufacturers may create visually beautiful variants while providing critical nutrients and antioxidants by using amaranth extracts, flour, or seeds in yoghurts, cheeses, and ice creams. Furthermore, amaranth's natural colours may be used for aesthetic components such as colourful swirls or toppings, converting dairy goods into intriguing culinary pleasures. Dairy products provide a good foundation for using natural amaranth colour extraction processes, improving both visual appeal and nutritional value. Manufacturers may introduce brilliant colours while also adding critical nutrients and antioxidants to dairy products such as yoghurts, cheeses, and ice creams by introducing amaranth extracts, flour, or seeds.Natural pigments in amaranth, including betalains and anthocyanins, produce a spectrum of colours ranging from deep reds to vivid purples, resulting in visually pleasing varieties of dairy products. These natural colours not only improve the cosmetic attractiveness of dairy products, but they also improve the sensory experience of ingesting dairy products. Aside from their aesthetic appeal, amaranth-infused dairy products provide nutritional benefits. Amaranth is well-known for its high protein content, well-balanced amino acid profile, and diverse array of vitamins and minerals. Amaranth can improve the nutritional profile of dairy products, providing customers with a better option.Furthermore, amaranth's natural colours may be used to create ornamental components such as colourful swirls or toppings, converting dairy products into aesthetically appealing culinary masterpieces.

The use of amaranth as a natural colour source in dairy products corresponds with rising consumer desire for clean-label and natural food choices. Manufacturers may provide dairy products that fulfil the demands of health-conscious consumers looking for natural and sustainable options by substituting synthetic food colourants with amaranth-derived pigments. Amaranth-infused dairy products offer a way to stand out in the market by appealing to consumers who value both the aesthetic appeal and the nutritious quality of the items they buy. Overall, including amaranth into dairy products via natural colour extraction technologies is a win-win situation.It improves the aesthetic appeal, nutritional content, and marketability of dairy products while addressing customer needs for clean-label and healthier alternatives. The natural colours of amaranth are versatile, making it a useful component in the dairy business, allowing for creativity and the creation of goods that stand out on shop shelves.

5.4.Confectionery and bakery items: -

Amaranth's unique colours and healthy composition make it an ideal ingredient for confectionery and baking recipes. Amaranth flour puffed amaranth grains, or amaranth extracts can increase the nutritional profile of cookies, cakes, pastries, and bars while also adding a distinct flavour. The natural pigments derived from amaranth can be used to make vivid icings, glazes, or ornamental components, increasing aesthetic appeal and providing eye-catching delights for consumers. Confectionery and pastry goods provide an appropriate platform for the use of various methods of natural amaranth colour extraction. The addition of amaranth flour puffed amaranth grains, or amaranth extracts to cookies, cakes, pastries, and bars not only adds visually appealing colours but also improves the nutritional profile of these decadent sweets.Natural pigments in amaranth, including betalains and anthocyanins, produce brilliant colours that may be used to make colourful icings, glazes, or ornamental components that captivate customers' attention. Confectionery and pastry businesses may meet the growing demand for clean-label products while also producing aesthetically appealing and nutritionally filled pleasures by adopting amaranth as a natural colour source.

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5.5.Cereals and snacks: -

Amaranth incorporation into cereals and snack foods allows for the addition of vibrant hues as well as nutritional benefits. Amaranth may be used to make breakfast cereals, granola bars, and snack mixes to give aesthetic interest as well as a nutrient-rich supplement. Its natural colourants can be used to create visually interesting cereal clusters, snack coatings, or visually diverse layers, making these things visually appealing as well as nutritionally useful.Cereals and snacks provide an ideal chance to incorporate amaranth's natural colour extraction processes. Manufacturers may incorporate aesthetically appealing colours and increase the nutritious content of their goods by putting amaranth into morning cereals, granola bars, and snack mixtures.Natural pigments found in amaranth, such as betalains and anthocyanins, may be used to make colourful cereal clusters, snack coatings, or aesthetically different layers, making these items both visually attractive and nutritionally beneficial. The use of amaranth as a natural colour source enables the development of aesthetically appealing and healthier cereals and snacks, addressing customer desire for clean-label and nutritionally beneficial solutions.

5.6.Sauces and Dressings: -

Amaranth extracts can be used to give natural colour and nutritional value to sauces and dressings. Amaranth-derived colours, whether used in salad dressings, pasta sauces, or marinades, add to aesthetically pleasing and vivid culinary creations. Furthermore, the use of amaranth improves the nutritional profile of these products, offering customers healthier alternatives to typical condiments. The natural pigments derived from amaranth, such as betalains and anthocyanins, can enhance the visual appeal of sauces and dressings, making them more enticing to consumers. Furthermore, the addition of amaranth as a natural color source not only provides aesthetic benefits but also offers the potential for additional nutritional value. Amaranth-infused sauces and dressings align with the growing demand for clean-label and natural food options, providing a healthier and visually appealing alternative to condiments.

5.7.Meat and plant-Based Alternatives: -

Amaranth is utilised as a natural colourant in meat and plant-based alternatives. Amaranth extracts can be used to enhance the appearance of meat products such as sausages and burgers, making them more appealing to customers. Plant-based alternatives, such as veggie burgers or tofu-based foods, are also available. There are several techniques for extracting natural colour from amaranth, each catering to both meat-based and plant-based alternatives. In the case of meat-based choices, one popular way is to break down the amaranth pigments and extract the necessary colour using animal-derived enzymes.However, considering the increased desire for plant-based alternatives, researchers have concentrated on creating extraction procedures that are compatible with vegetarian and vegan diets. Plant-based solutions sometimes entail the use of plant enzymes or bioactive chemicals to extract colour from amaranth. These approaches not only solve ethical issues, but they also contribute to sustainable and ecologically beneficial practises, making them an appealing option for the food business. With ongoing developments in both meat-based and plant-based methods, the extraction of natural colour from amaranth provides a varied range of possibilities for a variety of dietary preferences and commercial demands.

VI. CONCLUSION

The extraction of natural colours from amaranth is a potential field of research due to the multiple health advantages linked with these pigments. For the extraction of these pigments, several techniques have been developed, including solvent-based extraction and non-solvent-based extraction methods.Solvent-based extraction procedures are simple and effective, and they frequently result in a high pigment yield. However, the usage of organic solvents might be troublesome due to its possible toxicity and environmental effect. Non-solvent extraction procedures, such as acid extraction and enzymatic extraction, are frequently seen as more ecologically friendly and safer options.The extraction process used is determined by several.

criteria, including the intended application of the pigments, the required pigment yield, and environmental issues. Whatever technique is utilised, it is evident that natural colour extraction from amaranth has immense potential for usage in a variety of applications including food, cosmetics, and medicines.Future study should concentrate on optimising extraction processes to increase pigment production and purity, as well as discovering new uses for these natural colours. Furthermore, efforts should be made to research the possible health advantages of these pigments as well as their methods of action.Overall, the extraction of natural colours from amaranth gives an intriguing prospect for the creation of ecologically acceptable and sustainable alternatives to synthetic dyes. Natural colourants are likely to gain in popularity as people become more aware of the possible health and environmental consequences of synthetic dyes. The development of effective and environmentally friendly ways for extracting natural colours from amaranth will be critical in addressing this need.

VII. FUTURE PERSPECTIVE

As a result of the various health advantages linked with these pigments, there has been a surge in interest in extracting natural colours from amaranth in recent years. Natural colours are increasingly being used in a variety of applications, including food, cosmetics, and medicines, as people become more conscious of the possible health and environmental consequences of synthetic dyes. As a result, developing effective and sustainable ways for extracting natural colours from amaranth has emerged as a key topic of study. Further optimisation of the extraction procedures will be required in the future to increase the yield and purity of the pigments. Efforts should be made to create efficient and ecologically friendly techniques.

As an alternative to typical organic solvents, the use of non-toxic and renewable solvents, such as ethanol derived from renewable sources, might be investigated. Furthermore, the development of novel non-solvent-based extraction technologies, such as ultrasound-assisted extraction, might boost extraction efficiency.

Furthermore, greater study into the possible health advantages of these natural pigments is required. Anthocyanins have antioxidant and anti-inflammatory effects, according to studies, but additional study is needed to fully understand their mechanisms of action and possible therapeutic uses. New uses for these pigments in industries such as medicine and biotechnology might open. Another intriguing area of future study is the production of new and novel food items employing natural colours derived from amaranth. As customers become more aware of the possible health dangers connected with synthetic dyes, the use of natural colours in food items has grown in importance. Because of the presence of antioxidants and other healthy substances, the use of natural colours in food items can give additional nutritional advantages.new avenues for their utilisation.Another major area of future study is the creation of new uses for natural colours produced from amaranth. The use of these pigments in bioplastics, for example, might give a more sustainable alternative to standard plastic dyes. Natural colour use in the textile sector might potentially give a more sustainable alternative to synthetic dyes, which are frequently connected with pollution and health problems.

Finally, developing sustainable and ecologically friendly agricultural practises for amaranth production is an essential subject of future research. Because of its high nutritional content and low environmental effect, amaranth production has been proved to be a sustainable alternative to traditional crops. However, further study is required to optimise agricultural practises and increase crop output.

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