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Extraction, Formulation, and Stability of a Natural Red Gel Food Color from *Beta vulgaris*

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ABSTRACT

Color is the most crucial component of every food product. It not only makes food more appealing, and is most likely associated with the freshness and quality of the product. While synthetic color is widely used for its vibrant hues and comparatively cheaper prices they come with serious concerns,they can trigger allergic reactions, with symptoms ranging from mild skin rashes to severe asthma attacks. Some food dyes, like Red 3, have been shown to cause cancer in animals,and there's evidence that others may also be carcinogenic. Several studies suggest a link between artificial food dyes and increased hyperactivity and other behavioral problems, particularly in children. Some research indicates these dyes may worsen ADHD symptoms.Increasing awareness of food safety and environmental impact has led consumers to actively seek products made with natural and sustainable ingredients. As people become more aware and health-conscious, there is a growing demand of safer and clean label products.Hence, the consumer's need and interest have driven them towards plant-based alternatives to the synthetic colorants in food products.*Beta vulgaris* commonly known as beetroot, have high levels of betalains and other phytochemical compounds that are associated with antioxidant activity.Beta vulgaris has been ranked among the most potent antioxidant vegetables,Red beet product consumption provides a significant effect on nearly all organs of the digestive tract: pancreas, liver, colon.This study delves into developing a natural colorant from *Beta vulgaris* with an eco-friendly extraction technique. It is further continued by characterization and formulation of the natural color. Plant-based colorant such as beetroot offers an eco-friendly alternative to synthetic dyes, helping reduce environmental contamination and dependence on petroleum-based chemicals. This research looks into *Beta vulgaris* as a strong replacement for synthetic colorants in the food industry.

Keywords: *Beta Vulgaris,* Extraction, Plant-Based Color, Red Food Dye, Stability, Synthetic Dyes.

INTRODUCTION

Food colors are additives that used in a lot of food products enhancing its aesthetic appeal, marketability of the products and role in shaping consumer preferences. Studies have shown that artificial colorings often raise concerns for human health and are therefore banned or restricted for use in many countries[1].Hence Plant-based colorants are gaining importance over synthetic dyes due to the rising concerns about environmental safety and health risks. Synthetic colors used in food products can cause majorhealth concerns like allergic reactions, cancer risk, as well as hyperactivity and neurobehavioral issues in children[2,3].Researchers hypothesize that the consumption of Red Dye 40 can cause inflammation in gut cells, increasing the risk of colorectal cancer. This may be potentially harmful for people with inflammatory bowel diseases (IBD)[3].Three dyes (Red 40, Yellow 5, and Yellow 6) have been found to be contaminated with benzidine or other carcinogens. At least four dyes (Blue 1, Red 40, Yellow 5, and Yellow 6) cause hypersensitivity reactions[4].Tartrazine, also known as Yellow 5, has been associated with behavioral changes including irritability, restlessness, depression and difficulty with sleeping, Benzedrine, 4-aminobiphenyl and 4-aminoazobenzene are potential carcinogens that have been found in food dyes.

The rationale for using synthetic colorants natural colorants is their stability, less sensitivity to heat, light, and pH, lesser quantities producing higher intensities, and a cheaper mode of synthesis[5].Examples of prohibited colorants being sold and still in use in other countries include Patent Blue V, Quinoline Yellow, Ponceau 4R, Amaranth, Rhodamine B, and Azorubin.[6].As consumers become more aware they are starting to feel the need to stay away from synthetic food colors and are choosing natural, plant-based ones instead. Therefore, there has been a significant shift towards natural dyes due to their sustainable and non-toxic nature making them a good alternative for food products [7].They are ranked higher than other fruits and vegetables that are known for excellent health-promoting properties [8]. Red beetroot is well known as an "internal cleansing" substance and provides a mild laxative effect[9]. This research has been done on*Beta vulgaris*commonly known as beetroot. Its rich red pigment, due to compounds called betalains, offers not only natural color but also antioxidant properties [10].It is a good source of fiber and is also a rich source of vitamins (Vitamin C, Vitamin B2, Vitamin B6, Vitamin A, Vitamin E)[11]. This study is based on the development of a red gel food color, extraction and formulation using *Beta vulgaris* (beetroot). The research aims to create a stable, vibrant, natural and non-toxic alternative to synthetic dyes. By addressing common challenges like shelf life, color stability, and consistency, offering a safe, plant-based color that meets consumer demand for clean-label products[12].

MATERIALS AND METHODS

Collection and Preparation of Plant Material

Fresh *Beta vulgaris* were purchased from a local vegetable market in Bhopal, Madhya Pradesh, India.The plant sample was authenticated and certified by a botanist at Minor Forest Produce Processing & Research Centre (MFPPARC), Bhopal. Firstly, the beets were washed and cleaned thoroughly under running tap water in order to remove any dirt or foreign matter, if present. It ensured the removal of contaminants that could interfere with the further extraction process. Following the cleaning, beetrootwent for drying process. Were they were air-dried at room temperature in a well-ventilated room, away from direct sunlight for 4-6 hours. They were prevented from direct exposure to sunlight so as to prevent the degradation of heat or light-sensitive phytochemical compounds. the beetroot was then peeled, chopped into small pieces, and were grinded into a paste using a laboratory grinder. To make sure that a smooth and clean extract is obtainedthe juice was filtered twice first was filtered out with a fine muslin cloth to remove large particles, and then again through a filter paper to remove any remaining solids, which was then used in the formulation process.

Extraction

Filtered *Beta vulgaris*extract was then weighed on a weighing balance and then heated gently on a hot plate with continuous stirring, heating process continued until the extract was reduced to approximately 1/3 (one-third) of its original volume, to enhance the vibrancy of the product and to maintain the consistency. The concentrated extract was then left to cool down at the room temperature and was then mixed with approximately 25-28% of food-grade corn syrup, which acts as a natural thickener, providing a gel like consistency and improving the texture of the formulation subsequently,[13]. 8-12% vegetable glycerin was added to the mixture. Glycerin served as a natural humectant, aiding in moisture retention, smoothness, and overall stability of the gel color.To ensure preservation, safety, and colorstability, following natural preservatives were incorporatedCitric acid (0.2- 0.4%) is added to maintain an acidic pH to enhance pigment stability and inhibit microbial growth, Citric acid is a very strong synergist, especially with ascorbic acid. It also prevents browning of foods and increases their shelf life, since it also acts as a chelating agent[14,15], Ascorbic acid (0.1-0.3%) acted as a natural antioxidant to prevent oxidative degradation of pigmentsAscorbic acidis a powerful antioxidant that can be used in practically used worldwide.Sorbic acid (0.2- 0.3%) it provided mild antimicrobial protection to extend shelf life,Sorbic acid and sorbates are effective against yeasts and molds. Sorbate inhibits yeast growth in a variety of foods including wine, fruit juice, dried fruit, cottage cheese, meat and fish products.Vitamin E (0.1%) Acts as a natural antioxidant, improving the oxidative stability and shelf life of the food coloring, Rosemary extract (0.3-0.6%) it is a natural antioxidant that contributed to long-term color and oxidative stabilityPolyphenolic plant extracts, such as those from rosemary, previously mentioned and identified as a food additive have been used to act as antioxidants in foods [15].The obtained extract was deep red in color with a pinkish undertone and was stored in sterile airtight containers and was kept under refrigerated condition at 4°C until its further usage.

(a) **(b)** **(c)** **(d)**

Fig. 1. Extraction and formulation process of beetroot gel color

(a) Fresh *Beta vulgaris* (beetroot) purchased from the market.
(b) Peeled and chopped beetroot slices.
(c) Filtered beetroot extract.
(d) Final formulated red gel color with added base and preservative.

Phytochemical Testing

The final extract made from *Beta vulgaris*was subjected to different qualitative tests to detect phytochemicals such as alkaloids, flavonoids, terpenoids, phenols,betalains, saponins and glycosides using the standard tests[16,17].The foremost area of development in context to natural colorants is their use as nutraceutical compounds which provide health benefits through their bioactivities. Studies have reported that beetroot contains a considerable amount of vitamins, essential and non-essential amino acids that might result in their potential application as value-added ingredients in the functional food industry[18].(TABLE 1)(Fig.1).

Organoleptic Analysis

The organoleptic analysis of the final color extracted from*Beta vulgaris* was done under standard conditions including room temperature and ambient lighting. The analysis was conducted for certain parameters like color, odor, texture, solubility and stability over time[19]. The solubility check was done in water and compound chocolate. The tests were conducted on the raw gel form of the color as well as when incorporated into a food product like white compound chocolate,whipping cream(Table: 2)

Safety and quality testing

Microbiological tests and heavy metal testing were done to assure the safety and qualityof the Final gel food color prepared from *Beta Vulgaris*. Total Plate Count (TPC) was carried out to assess microbial load, while heavy metals like arsenic (As), cadmium (Cd), mercury (Hg), and lead (Pb) were tested to confirm the absence of toxic contaminants. The sample was submitted to CES Analytical and Research Services (I) Pvt. Ltd, Bhopal, Madhya Pradesh, India, for certified analysis. (Table: 3) (Fig. 3)

Application in food products:

The final beetroot gel color was tested in a few food items to see how well the color mixed with different mediums, its solubility, stability and to analyse the practical applications of the color. it was incorporated into commonly used food items i.e. whipping creamandwhite compound chocolate and water as it represents both fat-based and aqueous-based mediums. The gel was added according to the desired colour vibrancy and the product base, making sure it blended evenly without changing the texture or stability of thefood product. Majorly, the amount of color added was 0.5ml to 1 ml per product formulation (TABLE 4).

Water-Based Application

For aqueous application testing, 0.5 g of the beetroot gel color was added to 50 ml of distilled water at room temperature. Initially, the gel color settled at the bottom due to its slightly thicker consistency. However, when steered with a spoon, it dispersed uniformly, giving a bright red-pink solution. After mixing, the color remained stable for several hours without further settling, showing that while it is not fully water-soluble on its own, but it is easily dispersible when steered. This suggests its potential for use in water-based applications such as beverages, icing, and syrups.

Whipping Cream

Fresh whipping cream (50 ml) was whipped using an electric beater until soft peaks formed. At this stage, few drops of the beetroot gel color were added and then was gently mixed into the cream using a spatula. The color blended smoothly, giving a soft pink hue. The incorporation of the gel color did not affect the texture or consistency of the whipped cream. Whipped creamremained stable, as no curdling or water release was observed, showing that the formulation is suitable with dairy-based products and suitable for use in desserts, cake toppings, and frostings.

White Compound chocolate

White compound chocolate (50 g) was gently melted using the double boiling method to avoid direct heat exposure and to preserve the texture of the chocolate. When the chocolate was fully melted, approximately 1 g of the *Beta Vulgaris*gel color was addedwith continuous stirring. The gel mixed evenly into the chocolate without causing any clumping or texture disruption. The mixture gave a vibrant and smooth pink color, with excellent pigment distribution and no oil separation was observed. After thorough mixing, thechocolate was poured into a silicone mould for it to cooldown and solidify at room temperature. The gel color is highly compatible with fat-rich food matrices and effective in confectionery applications[20].

RESULT

Phytochemical Compounds

Qualitative tests conducted to detect the presence or absence of certain phytochemical compounds in the final gel food color of*Beta vulgaris* showed up the presence of some of the bioactive compounds. The dye made from *Beta vulgaris*tested positive for phytochemical compounds including alkaloids,Betalains, phenols, Glycosides, Tannins and

Carbohydrates. Flavonoids, Terpenoid, anthraquinones and Saponins were absent in the gel color of *Beta vulgaris*.(Fig.1). (TABLE 1).

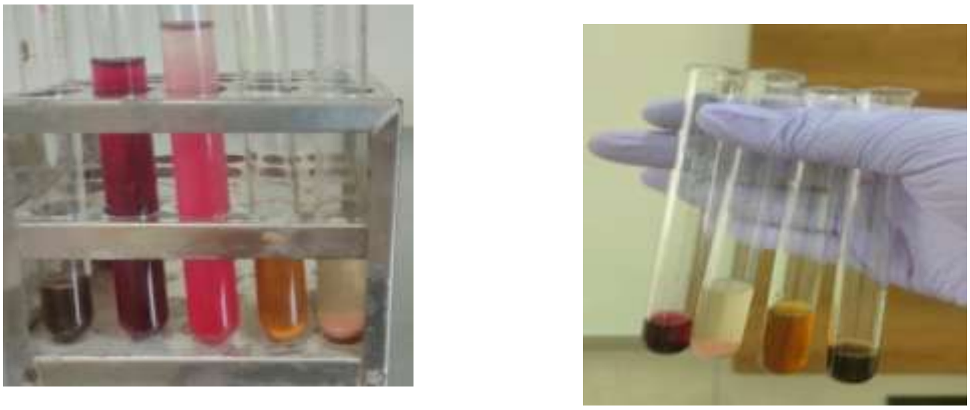


Fig.1: Phyto-Chemical Analysis Of *Beta Vulgaris*

Table 1: Phytochemical Test of *Beta vulgaris*dye

Phytochemical Compound	Test used for detection	Result (Present / Absent)
Alkaloid	Wagner’s Test	Present
Flavonoid	Lead Acetate Test	Absent
Terpenoid	Salkowski’s Test	Absent
Betalains	pH-based visual detection method	Present
Phenol	Ferric Chloride Test	Present
Glycosides	Keller-killiani test	Trace
Saponins	Foam Test	Absent
Tannins	Ferric Chloride Test	Present
Carbohydrates	Molisch’s test	Present

Organoleptic Analysis

Organoleptic test was conducted on the final colorof *Beta vulgaris*. The final*Beta vulgaris* extract was obtained as deep red with pinkish undertone, in color (Fig. 2), which remained stable over time and when incorporated into other food products. The texture of the gel color was smooth and uniform, without any lumps. It had a mild, earthy scentcharacteristic of beetroot, which does not alter the scent or taste of the base food products like whipping cream or chocolate.Overall, the organoleptic analysis confirmed that the gel food color is well-accepted, and suitable for use in various food applications. Detailed overview of organoleptic analysis for parameters like color, odor, texture, solubility in water and oils, and stability is presented in (TABLE 2).

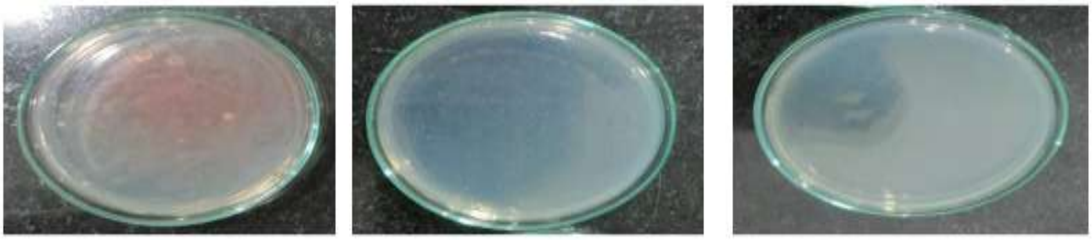
Fig. 2 Final Extract Obtained From *Beta Vulgaris*

Table 2: Organoleptic Analysis Of *Beta Vulgaris*gel Color

Parameter	Observation (Extract only)	Observation (Incorporated Product)
Color	Dark red with pinkish undertone	Dark pink (compound chocolate)
Odor	Mild (natural beet scent)	No unpleasant smell
Texture	Thick, glossy, and smooth	Easy to mix
Taste	Slightly sweet	Neutral in food does not alter food flavor
Appearance	Smooth gel consistency	No separation or lumps
Stability over time	No change after four months	Good shelf life and color retention

Microbiological tests and heavy metal testing

Total Plate Count (TPC) was carried out to assess microbial load, while heavy metals like arsenic (As), cadmium (Cd), mercury (Hg), and lead (Pb) were tested to confirm the absence of toxic contaminants,The total plate count (TPC)*Beta vulgaris*extract, at various dilutions (10^{-9}, 10^{-6}, 10^{-2}) was found to be 4.4×10^2 CFU/ml, which is within the permissible limit specified by FSSAI ($\leq 10^3$-10^4 CFU/ml).The heavy metal analysisshowed that the levels of arsenic (As), cadmium (Cd), mercury (Hg), and lead (Pb) were allwithin the permissible limitsspecified by FSSAI - As (< 1.1 mg/kg), Cd (< 1.5 mg/kg), Hg (< 1.0 mg/kg), and Pb (< 2.5 mg/kg). (Fig. 3) and (Table3)



(a) (b) (c)

Fig. 3 Microbial load test of*Beta vulgaris*gel color at various dilutions; (a) Extract with dilution 10^{-9}, (b) Extract with dilution 10^{-6} and (c) Extract with dilution 10^{-2}

Table 3: Microbial Load Test of *Beta vulgaris*gel color

S. No.	Test Parameters	Unit	Test method	Result
	Residue & Contaminants (Heavy Metals)			
1.	Arsenic (As)	mg/kg	CES/LAB/SOP/FOOD/09	0.030
2.	Cadmium (Cd)	mg/kg	CES/LAB/SOP/FOOD/09	0.006
3.	Mercury (Hg)	mg/kg	CES/LAB/SOP/FOOD/09	0.012
4.	Lead (Pb)	mg/kg	CES/LAB/SOP/FOOD/09	0.022
	Microbiological Testing			
5.	Total Plate Count	cfu/ml	IS:5402:2021/P-1	4.4×10^2

Application in food products

The final*Beta vulgaris*gel color showed different shadesranging from soft pink to bright reddepending on the type of food it was added to (Fig. 4). It blended well into chocolate, whipping cream, and water-based applications, and the color stayed stable and appealing even after six months of storage in the refrigerator (Table 4).

(a) (b)

Fig. 4: Food products incorporated with the *Beta vulgaris*Gel Food Coloring

(a) whipping cream (b) White Compound chocolate

Table 4: Performance of *Beta vulgaris*Gel Food Coloring in Different Food Products

Cosmetic Product	Color Behavior	Dispersion Quality	Texture	Color Stability
White Compound chocolate	Vibrant pink	Uniform	Smooth and glossy	No fading or separation
Whipping Cream	Soft pink	Even after folding	Light and airy maintained	No fading, stable
Water (after stirring)	Bright red-pink	Dispersed after stirring	No residue	Stable after mixing

CONCLUSION

This study highlights the potential of*Beta vulgaris* (beetroot) as natural alternatives to synthetic dyesin the food industry. The final color prepared from *Beta vulgaris*exhibited great color vibrancy, smooth gellike texture, solubilityin both water-based and fat-based food products likewater, chocolate, and whipping cream, The gel demonstrated positiveresult in microbial safety, heavy metal testing and organoleptic test. Plant-based colorants such as*Beta vulgaris*(beetroot) offer an eco-friendly alternative to synthetic dyes, helping reduce environmental contamination and dependence on petroleum-based chemicals.

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