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Development and Characterization of Vitamin-Rich Fruit-Based Hydrogel Pearls for Pediatric Nutritional Supplementation.

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Abstract: -
Children's normal growth, development, and resistance to infections may be impacted by vitamin deficiencies and decreased immunity. The goal of the current project is to create and assess a fruit extract-based paediatric nutraceutical hydrogel pearls that will boost immune function and vitamin intake. Standardized extracts of kiwi, dragon fruit, sea buckthorn, acerola cherry, black currant, and alma, which are abundant in vitamin C, antioxidants, polyphenols, carotenoids, and other bioactive phytochemicals, are included in the formulation.
Hydrogel pearls was chosen as the dosage form due to its favourable taste, ease of administration, high acceptability, and enhanced compliance in kids. The formulation's natural combination of vitamins and antioxidants may help lower oxidative stress, boost immunity, and help avoid vitamin deficiencies.
Physical attributes, weight fluctuation, hardness, moisture content, vitamin C content, total phenolic content, antioxidant activity (DPPH assay), microbial quality, stability, and sensory acceptability will all be assessed for the prepared the hydrogel pearls.
The goal of the project is to use natural fruit extracts to create a functional hydrogel pearls for children that is safe, stable, and tasty. The suggested formulation may be used as a cutting-edge nutraceutical strategy to promote immunity and nutrition in children. Its efficacy and appropriateness for regular use in children will need to be confirmed by additional safety assessment and clinical research.

Keywords: - Hydrogel , paediatric , polyphenol , phytochemicals , sea bucthron , kiwi , acerola cherry , dragon fruit , black current , amla .

I. Introduction:

Insufficient consumption of vital vitamins and bioactive nutrients during childhood may negatively impact normal growth, development, and general health, paediatric nutrition is a crucial area of public health. Nutritional interventions are crucial for increasing micronutrient intake because vitamin and mineral deficiencies are frequently reported in children. [1] Because factors like taste, size, texture, swallowing ability, and dosage-form familiarity affect acceptability, conventional oral dosage forms may pose challenges in paediatric administration. Children frequently express preferences for age-appropriate and palatable oral formulations, according to studies assessing paediatric dosage-form preferences. [2,3]

Fruit-based nutraceutical formulations are an appealing substitute for traditional dosage forms and can supply naturally occurring vitamins and phytochemicals. In addition to being a great source of vitamin C, kiwifruit also has dietary fibre and other bioactive substances that have been linked to health and nutritional advantages. [4] Acerola cherries have the potential to be a functional food because they are particularly high in ascorbic acid and also contain carotenoids, phenolics, anthocyanins, and flavonoids. [5] Dragon fruit has been shown in experiments to have antioxidant and anti-inflammatory properties and contains bioactive substances such as phenolics, flavonoids, and betalain pigments. [6]

Sea buckthorn is a promising component of functional foods because it contains a variety of nutritious and bioactive substances, such as vitamin C, carotenoids, polyphenols, and phytosterols. [7] Anthocyanins, flavonoids, and other phytochemicals with anti-inflammatory and antioxidant properties are abundant in black currant. [8] Amla (Phyllanthus emblica) has been thoroughly studied for its antioxidant and other biological activities, and it is a significant source of vitamin C, phenolic compounds, tannins, and flavonoids. [9]

A straightforward method for adding bioactive components to a soft, gel-based oral formulation is to use hydrogel pearls made with calcium ions and sodium alginate. Calcium-alginate hydrogels, which can offer encapsulation and controlled-release properties, have been studied as

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bioactive compound carriers. Thus, a single hydrogel pearl containing extracts of kiwi, dragon fruit, sea buckthorn, acerola cherry, black currant, and amla may offer a novel fruit-based nutraceutical formulation meant to deliver several naturally occurring vitamins and phytochemicals in a potentially more palatable dosage form for children [10,11].

Types of Vitamin Deficiencies:

Nutrient	Main function	Deficiency signs in children	Effect on immunity	Good food source
vitamin a	Vision, growth, epithelial integrity.	Night blindness, dry eyes, poor growth.	Increase respiratory and gastro intestinal infection.	Carrot, sweet yolk potato, spinach ,mango ,egg
vitamin d	Bone health, calcium absorption.	Bone pain ,delay growth , rickets.	Increased susceptibility to respiratory infections	Sunlight exposure, fortified milk, egg yolk, fatty fish (salmon, sardines), mushrooms
vitamin c	Inadequate fruits/vegetables	Scurvy, bleeding gums, poor wound healing	Reduced immune cell function and delayed healing	Amla (Indian gooseberry), oranges, lemons, guava, kiwi, strawberries, tomatoes, bell peppers
vitamin e	Fat malabsorption, prematurity	Neuropathy, hemolytic anaemia	Impaired T-cell function and weakened immune response	Almonds, sunflower seeds, peanuts, spinach, vegetable oils, avocado
vitamin b6	Poor nutrition	Irritability, seizures, anaemia	Reduced antibody production and lymphocyte function	Chicken, fish, bananas, potatoes, chickpeas, whole grains
vitamin b12	Vegetarian diet, malabsorption	Megaloblastic anaemia, developmental delay	Decreased white blood cell function	Milk, curd, cheese, eggs, fish, meat, fortified cereals
folate (b9)	Poor diet, malabsorption	Megaloblastic anaemia, poor growth	Reduced DNA synthesis affecting immune cells	Green leafy vegetables, beans, lentils, peas, citrus fruits
iron	Dietary deficiency, blood loss	Pallor, fatigue, developmental delay	Impaired neutrophil and T-cell function; recurrent infections	Red meat, liver, spinach, lentils, beans, jaggery, dates, fortified cereals
zinc	Poor intake, chronic diarrhoea	Growth retardation, dermatitis, poor wound healing	Frequent diarrhoea, pneumonia, impaired cellular immunity	Meat, eggs, milk, beans, chickpeas, pumpkin seeds, nuts

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selenium	Inadequate intake	Muscle weakness, cardiomyopathy (rare)	Reduced antioxidant defence and immune response	Fish, eggs, chicken, whole grains, sunflower seeds, Brazil nuts (small amounts)

(Ref. 1)

Fruits used in hydrogel pearls: -

[Fig-1.1] Kiwi

Kingdom: Plantae
Clade : Angiosperms
Clade : Eudicots
Order : Ericales
Family : Actinidiaceae
Genus : Actinidia
Species : Actinidia deliciosa
Common name : Kiwi
Fruit type : Berry
Botanical name: Actinidia deliciosa (A. Chev.) C.F.Liang& R.Huan

Characteristics: -

kiwifruit is fruit rich in nutrients that contains a number of vital nutrients and bioactive substances. Its high vitamin C content, which significantly adds to its nutritional value and antioxidant potential, is one of its most notable characteristics [12,13].

Vitamin E, vitamin K, folate, potassium, dietary fibre, carotenoids, and polyphenolic compounds are also found in kiwifruit [12,14]. Actinidin, the main proteolytic enzyme found in kiwifruit, can improve the stomach and small intestine's ability to digest proteins [12,15]. In addition to vitamin C, kiwifruit's phenolic compounds, flavonoids, and carotenoids are linked to its antioxidant activity.

These substances might help prevent oxidative stress [16,17]. Although the strength of the evidence varies depending on the outcome, kiwifruit has also been studied for possible advantages on immune system, bowel, and digestive health [12]. Depending on the species, cultivar, maturity, and growing conditions, the concentration of vitamin C varies significantly. For instance, research has shown that Actinidia cultivars differ significantly in their ascorbic acid content [18].

Therefore, rather than assuming from published fruit values, the vitamin C content of the chosen kiwi extract should be experimentally determined for a standardized nutraceutical formulation Kiwi may thus be a source of antioxidant phytochemicals and vitamin C for the suggested paediatric nutraceutical hydrogel pearls. But kiwi is also known to cause food allergies in those who are susceptible, so adding it to a paediatric formulation necessitates a suitable safety evaluation and allergen labelling.

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[Fig-1.2] Dragon fruit

Kingdom : Plantae
Division : Angiosperms.
Class : Eudicots.
Order : Caryophyllales.
Family : Cactaceae.
Genus : Selenicereus (formerly Hylocereus).
Species : Selenicereus undatus**.**
Botanical name : Selenicereus undatus (Haw) D.R.Hunt

Characteristics: -

Dragon fruit, sometimes referred to as pitaya, is a well-known tropical fruit that is high in nutrients. It is a member of the genus Hylocereus, which is currently also categorized under Selenicereus. Carbohydrates, dietary fibre, vitamins, minerals, and a number of bioactive phytochemicals are all present [19,20]. The species, cultivar, maturity, and growing conditions all affect the nutritional makeup.

Potassium, magnesium, calcium, phosphorus, iron, zinc, and vitamins like C, E, and K have all been found in studies [19]. The antioxidant phytochemicals found in dragon fruit, such as flavonoids, phenolic compounds, and betalains, are especially noteworthy. Compared to some white-fleshed varieties, red-fleshed varieties typically have higher levels of phenolic compounds and more antioxidant potential [19,20].

The fruit's distinctive color and antioxidant qualities are attributed to the presence of significant pigments like betacyanins and betaxanthins. Phenolic acids, flavonoids, and pigments related to anthocyanins are additional bioactive substances that have been reported [20,21]. Dragon fruit extracts have been shown in experiments to have anti-inflammatory and antioxidant properties, but these results shouldn't be taken as proof that they have therapeutic benefits for kids.[21]

Dragon fruit has potential as a functional food and nutraceutical ingredient due to its nutritional makeup and bioactive components. Standardization and quantitative analysis of the extract are crucial before adding it to a paediatric formulation, though, because the concentration of specific nutrients and phytochemicals can differ significantly between cultivars [19,20]

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[Fig-1.3] Acerola cherry

Kingdom : Plantae
Clade : Angiosperms
Clade : Eudicots
Order : Malpighiales
Family : Malpighiaceae
Genus : Malpighia
Species : Malpighia emarginata DC.
Common names : Acerola, Barbados cherry, West Indian cherry

Characteristics: -

Acerola, also referred to as West Indian cherry or Barbados cherry, is a tropical fruit that is a member of the Malpighiaceae family. Malpighia emarginata DC is the accepted botanical name. Acerola is of significant nutritional and nutraceutical interest because it is one of the most abundant natural sources of vitamin C (ascorbic acid) [22]. Ascorbic acid, phenolic compounds, flavonoids, anthocyanins, and carotenoids are among the biologically active components found in acerola. These substances add to its nutritional value and antioxidant potential [22,23]. “

Depending on the cultivar, maturity stage, location, and processing technique, acerola's vitamin C content can differ significantly. Acerola varieties have been shown to have high ascorbic acid concentrations, and genotypes also differ in the amounts of specific phenolic compounds [23].

Acerola's polyphenolic and vitamin C components are linked to its significant antioxidant activity. Acerola extracts have been shown to have antioxidant activity in studies using DPPH and ABTS assays; the fruit's maturity stage has an impact on this activity [24].

Furthermore, acerola polyphenols may affect vitamin C uptake and cellular antioxidant mechanisms, according to experimental research. However, paediatric efficacy requires appropriate clinical evidence, so these results should not be directly interpreted as evidence of an immune-enhancing effect in children [25].

Acerola is a promising component for functional foods and nutraceutical formulations due to its high vitamin C and phytochemical content. Acerola may offer a significant natural source of vitamin C and antioxidant compounds for the suggested paediatric hydrogel pearls. However, because ascorbic acid is sensitive to processing and storage conditions, the final formulation should be standardized for vitamin C content and assessed for stability [23,26].

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[Fig-1.4] Sea buckthorn

Kingdom:Plantae
Division : Angiosperms
Class : Eudicots
Order:Rosales
Family: Elaeagnaceae
Genus : Hippophae
Species : Hippophae rhamnoides
Botanical name : Hippophae rhamnoides L.
Common names: Sea buckthorn, Seaberry, Sandthorn.

Characteristics: -

Sea buckthorn (Hippophae rhamnoides L.) is a small tree or deciduous, prickly shrub that is a member of the Elaeagnaceae family. It is found throughout temperate and mountainous regions of Eurasia. The fruit is regarded as the plant's most significant edible and nutritious component [27,28]. A variety of vitamins, minerals, carotenoids, polyphenols, flavonoids, tocopherols, phytosterols, and fatty acids are abundant in sea buckthorn fruits . The fruit is nutritionally unique because it contains both lipid-soluble and water-soluble bioactive compounds [27,28]. “

Ascorbic acid (vitamin C), carotenoids, tocopherols, flavonoids, tannins, and phenolic acids are among the fruit's significant antioxidant constituents. Sea buckthorn's total antioxidant potential is enhanced by the coexistence of hydrophilic and lipophilic antioxidants [28].

Another characteristic of sea buckthorn is its distinct fatty acid profile. Polyunsaturated fatty acids and other useful lipids can be found in oils extracted from fruit pulp and seeds. Because its lipid fraction may include omega-3, omega-6, omega-7, and omega-9 fatty acids, sea buckthorn is especially noteworthy [29]. “

Flavonoids are thought to be significant bioactive components of sea buckthorn. In the literature, sea buckthorn has been found to contain over 95 flavonoids, including flavonols and their glycosides [26]. Sea buckthorn has been studied for its antioxidant, anti-inflammatory, antimicrobial, cardio protective, hepatoprotective, and immunomodulatory properties due to its varied nutritional and phytochemical composition (PubMed). Many of these results, however, should not be directly interpreted as demonstrated therapeutic effects in paediatric populations because they are based on in-vitro and animal studies [27, 28, 30]. “

Therefore, sea buckthorn can be regarded as a valuable source of vitamin C, carotenoids, polyphenols, and other antioxidant compounds for the proposed paediatric nutraceutical hydrogel pearls. Because the concentration of bioactive components can differ based on cultivar, maturity, geographic origin, and processing conditions, standardization of the extract is crucial [27,28]. “

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[Fig-1.5] Amla

Kingdom : Plantae
Division : Angiosperms
Class : Eudicots
Order : Malpighiales
Family : Phyllanthaceae
Genus : Phyllanthus
Species : Phyllanthus emblica
Botanical : name Phyllanthus emblica L

Characteristics: -
Amla, also referred to as Indian gooseberry, is a member of the Phyllanthaceae family and is the fruit of Phyllanthus emblica L. Native to the Indian subcontinent and other tropical and subtropical parts of Asia, it is a significant edible and medicinal fruit [31,32]. "
The nutritional and phytochemical profile of amla fruit is rich. Minerals, amino acids, organic acids, vitamin C, and polyphenolic compounds are all present. The fruit's biological qualities are greatly influenced by its high concentration of polyphenols, tannins, phenolic acids, and flavonoids [31–33].Gallic acid, ellagic acid, tannins, terpenoids, alkaloids, flavonoids like quercetin and rutin, and other phenolic compounds are significant phytoconstituents found in amla [32, 33]. "
Amla's significant antioxidant activity is linked to its polyphenolic and vitamin C components. Numerous experimental models have been used to thoroughly examine its antioxidant potential [31, 33]. Additionally, P. emblica preparations have been shown in experimental studies to have anti-inflammatory, antimicrobial, hepatoprotective, cardioprotective, and immunomodulatory properties. Many of these results, however, should not be taken as proven therapeutic effects in children because they are based on preclinical research [31, 33].
Amla has significant potential as a functional food and nutraceutical ingredient due to its high nutritional value and abundance of antioxidant phytochemicals. Amla can provide antioxidant polyphenols and vitamin C to your suggested paediatrichydrogel pearls. However, since composition can change depending on cultivar, maturity, geographic origin, and processing conditions, the actual vitamin C and phytochemical content of the extract should be ascertained through experimentation [32, 34].

[Fig-1.6] Black Currant

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Kingdom: Plantae
Division : Angiosperms
Class : Eudicots
Order : Saxifragales
Family : Grossulariaceae
Genus : Ribes
Species : Ribes nigrum
Botanical name : Ribes nigrum L.
Common name : Black currant / Blackcurrant

Characteristics: -
Ribes nigrum L., the botanical name for black currant, is a small deciduous shrub that is a member of the Grossulariaceae family. The fruit, which is a dark purple to almost black berry, is well known for being a functional fruit with high nutritional value [35, 36].
Vitamin C, vitamin E, dietary fibre, organic acids, minerals, polyphenols, and polyunsaturated fatty acids are just a few of the vital nutrients and bioactive substances found in black currant fruits. Cultivar, growing conditions, maturity, and processing technique can all affect the composition [35, 37].
Anthocyanins, specifically delphinidin-3-O-glucoside, delphinidin-3-O-rutinoside, cyanidin-3-O-glucoside, and cyanidin-3-O-rutinoside, are the most distinctive phytochemicals of black currant. These pigments significantly contribute to the berries' antioxidant qualities and give them their distinctive dark purple-black color [35,36].
Other polyphenolic substances found in black currant include flavonols, proanthocyanidins, phenolic acids, and flavan-3-ols. These substances support the fruit's biological and antioxidant potential [35, 37].
Research has shown that black currant extracts have strong antioxidant properties, including the ability to scavenge free radicals using assays like DPPH and ABTS. Its anthocyanin and polyphenol content is closely linked to its antioxidant capacity [37,38].
The anti-inflammatory, antimicrobial, and immunomodulatory qualities of black currant have also been studied. However, a lot of biological effects that have been reported are based on preclinical or experimental research, so they shouldn't be regarded as proven therapeutic effects in paediatric populations [35,36].
Black currant can thus supply anthocyanins, vitamin C, and other antioxidant polyphenols for the suggested paediatric nutraceutical hydrogel pearls. Its addition might improve the formulation's antioxidant profile, but the finished product's stability, vitamin C content, and antioxidant activity should be assessed experimentally [35,38].

➢ THERAPEUTCSBENEFITSOFHERBAL HYDROGEL PEARLS

1. Activity of antioxidants:
Vitamin C, polyphenols, flavonoids, anthocyanins, and carotenoids are found in the herbal/fruit pearls made from amla, acerola cherry, black currant, dragon fruit, kiwi, and sea buckthorn. These bioactive substances may aid in shielding cells from oxidative stress because they have antioxidant qualities [39,44].
2. Support for vitamin C:
Vitamin C is especially abundant in amla and acerola cherries. As an antioxidant, vitamin C supports the production of collagen, the absorption of iron, and the healthy operation of the immune system [41,42,45].
3. Nutritional assistance:
The combination of six fruits offers a range of vitamins, phytochemicals, and other nutritional elements that may support growing children's nutritional needs and enhance a balanced diet [39,41,44].
4. support for the immune system:
While phytochemicals found in fruits like sea buckthorn, amla, and black currant have shown immunomodulatory potential in experimental studies, vitamin C is crucial for a healthy immune system [42,43,44,47]. But rather than curing or preventing infections, the pearls should be characterized as offering immune support.
5. Potential to reduce inflammation:
In lab and preclinical research, polyphenols, flavonoids, anthocyanins, and other phytochemicals found in dragon fruit, black currant, sea buckthorn, and amla have demonstrated anti-inflammatory activity [40,42,44].
6. Support for digestive health:
Dietary fiber and bioactive compounds found in kiwis may help maintain regular bowel movements and gastrointestinal health. Kiwi may therefore enhance the formulation's potential for digestive health [39].
7. Potential for broad-spectrum antioxidants:
Compared to a single-fruit formulation, a combination of six fruits with distinct phytochemical profiles may offer a greater variety of antioxidant constituents [39,44]. However, tests like DPPH or ABTS should be used to confirm the combination's superiority.

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8. Acceptability in children:

An appealing substitute for traditional tablets or capsules could be a soft, tasty, and well-designed hydrogel pearl. Studies on pediatric dosage forms show that children's acceptance of oral formulations is influenced by taste, texture, size, and ease of administration [46,47].

Fruit Wise Contribution :-

Fruit	Major bioactive/nutritional components	Potential benefit
Kiwi	Vitamin C, fibre, polyphenols	Nutritional, antioxidant and digestive-health support.
Dragon fruit	Betacyanins, polyphenols, flavonoids	Betacyanins, polyphenols, flavonoids.
Sea buckthorn	Vitamin C, carotenoids, flavonoids, fatty acids	Antioxidant and nutritional support .
Acerola cherry	Very high vitamin C, carotenoids, phenolics, anthocyanins	Vitamin C and antioxidant support.
Black currant	Anthocyanins, flavonoids, phenolic compounds, vitamin C	Antioxidant and anti-inflammatory potential.
Amla	Vitamin C, tannins, phenolics, flavonoids	Antioxidant and anti-inflammatory potential.

Literature Survey :-

According to the reviewed literature, children's vitamin and mineral deficiencies are significant nutritional issues. The review addresses the nutritional and health-related characteristics of particular fruits that may contain antioxidants, vitamins, minerals, and other bioactive substances.

The nutritional and health benefits of kiwifruit, including its vitamin C content and other nutritional components, have been studied. Studies and reviews discussing its composition, antioxidant qualities, and possible health advantages are included in the review's cited literature (12–18).

The nutritional makeup of dragon fruit as well as its anti-inflammatory, antioxidant, and other health-related qualities have been investigated. The review references reviews of dragon fruit's health effects and biochemical characterization (19–21).

Acerola is described as a fruit with a high vitamin C content. Its antioxidant activity, vitamin C and phenolic components, and possible nutraceutical uses are all described in the literature (22–26).

Vitamin C, carotenoids, tocopherols, flavonoids, and other bioactive substances are found in sea buckthorn. Its nutritional makeup, health advantages, and possible uses as a functional food have all been covered in earlier reviews (27–30).

The nutritional, bioactive, and health-related qualities of blackcurrant and amla (Phyllanthus emblica) are also examined. The referenced literature discusses these fruits' traditional uses, composition, pharmacological characteristics, and health advantages.

Additionally, the review emphasizes the connection between immune function and vitamin C (45). Furthermore, the literature highlights that certain reported health effects should not be directly interpreted as proven therapeutic effects in pediatric populations because they are based on in-vitro or animal studies.

The reviewed literature highlights the significance of proper formulation, standardization, processing, and storage stability for pediatric nutraceutical applications. The concentration of bioactive components can be impacted by variations in cultivar, maturity, geographic origin, and processing conditions.

II. Conclusion :-

Certain fruits, including kiwifruit, dragon fruit, acerola, sea buckthorn, amla, and blackcurrant, are potential natural sources of vitamins, minerals, antioxidants, and other bioactive compounds, according to the reviewed literature.

The reviewed studies give special attention to vitamin C and antioxidant components, which supports these fruits' potential for use in functional foods and nutraceuticals.

These fruits may be relevant to pediatric nutritional applications, according to the literature, but before creating a pediatric nutraceutical product, appropriate formulation, standardization, and stability testing are required.

Cultivar, maturity, location, and processing conditions can all affect the levels of nutrients and bioactive compounds. Conditions during processing

and storage are especially crucial for preserving the stability of the product and its vitamin C content.
Lastly, results from lab or animal research shouldn't be equated with established therapeutic benefits for children. To establish safety, acceptability, and efficacy in pediatric applications, additional standardized formulation, stability studies, and suitable clinical evaluation are needed.

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