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Research Paper

Formulation And Evaluation of Spinach Based Immunity Booster Granules for Children

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ABSTRACT

The immune system plays a crucial role in defending the human body against infections and diseases, particularly during childhood when immunity is still developing. Proper nutrition is essential for immune health, and spinach (*Spinacia oleracea*), a nutrient-dense green leafy vegetable, is an excellent natural source of immune-supportive compounds including vitamins A, C, E, iron, folate, magnesium, and antioxidants. However, spinach is often underutilized in children's diets due to its bitter taste and perishability. This research explores the development of spinach-based immunity booster granules as a child-friendly nutraceutical solution aimed at enhancing immune function and addressing malnutrition. The granule formulation retains spinach's nutritional properties while improving taste, acceptability, and shelf life. Granules offer advantages in pediatric nutrition such as ease of administration, dose flexibility, and improved palatability. The study highlights the dual burden of malnutrition—undernourishment and obesity—and emphasizes the role of functional foods in combating nutritional deficiencies and supporting immune health in children. Spinach granules represent a cost-effective, safe, and natural alternative to synthetic supplements, making them a practical intervention for boosting immunity and promoting overall child well-being.

INTRODUCTION

The immune system is an intricate network of cells, tissues, and organs that work together to defend the human body against infections, pathogens, and diseases. In children, this system is still in the developmental phase, making them

more vulnerable to infections, seasonal illnesses, and nutrient deficiencies. A well-balanced and nutrient-rich diet plays a pivotal role in the proper functioning and maturation of the immune system. Essential nutrients such as vitamins A, C, D, E, folate, iron, zinc, and antioxidants are vital for supporting immune cell function, enhancing antibody production, and maintaining overall

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disease resistance. Malnutrition, both undernutrition and overnutrition, significantly affects immune health. Undernourishment in children impairs growth and weakens immune defenses, increasing susceptibility to infections and contributing to higher morbidity and mortality rates. Conversely, overweight and obesity forms of over-nutrition are associated with chronic inflammation and immune dysfunction, heightening the risk of infections and reducing vaccine effectiveness. These conditions highlight the pressing need for targeted nutritional strategies that can support healthy immune development in children^[1]. Among plant-based, nutrient-dense foods, spinach (*Spinacia oleracea*) emerges as a superior functional ingredient due to its high content of vitamins A, C, E, iron, folate, magnesium, and bioactive compounds such as flavonoids, polyphenols, chlorophyll, and carotenoids. These constituents contribute to improved immune response, antioxidant defense, and reduced oxidative stress. Despite these health benefits, spinach remains under-consumed by children due to its bitter taste, texture, and perishability. This creates a gap in the intake of essential nutrients at a critical stage of growth and immune development. To address this challenge, the development of spinach-based granules provides a promising solution. Granulation is a process that converts spinach into a palatable, shelf-stable, and child-friendly supplement that preserves its nutritional value while enhancing taste and acceptability. Granules are particularly advantageous in pediatric nutraceutical formulations due to their ease of administration, dose flexibility, and potential for taste masking. They can be mixed with food or beverages, improving compliance among children who may otherwise resist consuming vegetables in their raw or cooked form^[2].

This research aims to formulate and evaluate spinach-based immune booster granules specifically designed for children. The study focuses on ensuring nutrient preservation, taste enhancement, and practical usability of the granules. By leveraging the nutritional potential of spinach and modern formulation technologies, these granules are intended to support children's immune health in a natural, safe, and cost-effective manner. The formulation also aligns with the growing demand for plant-based, chemical-free supplements that serve as alternatives to synthetic multivitamins, especially in low-resource settings where access to balanced diets may be limited^[3].

❖ Immune System

The immune system is a complex and sophisticated network of cells, tissues and organs that work in harmony to defend the body against a myriad of potential threats, ranging from bacteria and viruses to fungi and other pathogens.

The immune system can be broadly categorized into two main components:

- **The Innate Immune System:** The innate immune system provides immediate, nonspecific defense mechanisms such as physical barriers like the skin and cellular components like white blood cells that can rapidly respond to a wide range of pathogens.
- **The Adaptive Immune System :** The adaptive immune system is highly specific and can “remember” previous encounters with specific pathogens allowing for a more targeted and efficient response upon subsequent exposures^[4].

The immune system plays a crucial role in maintaining overall health and well-being. A key aspect of the immune system in the context of food is its ability to distinguish between harmless



substances, like nutrients in food and potential threats. The gut-associated lymphoid tissue is particularly important in this regard as it is responsible for monitoring and responding to substances encountered through the digestive tract^[5]. One key distinction between the immune systems of children and adults lies in their developmental stages. Children are continuously exposed to new pathogens as they explore their environment, attend school and interact with others. This constant exposure helps their immune system develop and adapt, building a diverse repertoire of immune cells. Children also possess a remarkable ability to generate a robust immune response, often characterized by fever and a rapid increase in specific immune cells, when confronted with infections. Children generally have more resilient immune systems they may also be susceptible to certain infections due to their immune system's ongoing maturation^[6]. Nutrition plays a vital role in supporting a robust immune system^[6].

❖ **Malnutrition**

➤ **Undernourishment**

Undernourishment occurs when the body lacks essential nutrients, impacting growth and body functions. The causes of this include an inadequate diet, poor absorption of nutrients, economic factors and illnesses. Undernourishment weakens the immune system reducing its ability to defend the body against infections, targeting different pathways. The risk factors include poverty, limited food access, poor dietary habits, health conditions^[7]. According to the World Health Organization (WHO), childhood malnutrition is a major risk for their morbidity and mortality, being one of the main causes of the global burden of disease, disability, and mortality among children. The WHO is undertaking a new guideline for the prevention and management of

undernourishment. This global action plan to fight acute malnutrition in children under the age of 5 years old is based on a more comprehensive approach, calling for a greater integration of nutrition services into healthcare systems and to strengthen those healthcare systems^[8].

➤ **Overweight and Obesity**

The other type of “malnutrition”, where children are over-nourished, is presented as being overweight and obese. Being overweight and obese, characterized by excess body weight, stem from factors, like a poor diet (e.g., excessive consumption of foods that lack nutrition, such as sugar), lack of exercise, genetics and certain medical conditions. These conditions contribute to chronic inflammation, impacting immune function. Higher body mass indices (BMIs) and abdominal fat increase susceptibility to infections and alter the body's immune response, potentially reducing the effectiveness of vaccines. Lifestyle factors, including sedentary habits and unhealthy diets, pose significant risks. Childhood obesity is a growing public health concern that has reached epidemic proportions globally. Defined as an excessive accumulation of body fat, obesity in children is a multifaceted issue with far-reaching consequences. Encouraging healthy eating habits, promoting physical activity and fostering a supportive environment for children to make healthier choices are crucial steps. It should be mentioned that undernourished children such as those with a low birth weight, those displaying stunting, or children exhibiting inappropriate weight gain during their preschool and school years are known to be at a greater risk of obesity in later life^[9].

➤ **Malnutrition Increases the Risk of Infection**

Proper nutrition during childhood is critical for healthy growth, development and the



strengthening of the immune system. Children are particularly vulnerable to infections due to their developing immune systems and nutritional deficiencies during this stage can have long-lasting effects on their physical and cognitive health. Therefore, boosting immunity through a well-balanced and nutrient-rich diet is essential for reducing disease risk and supporting optimal health outcomes in children. In recent years, there has been a growing interest in natural, plant-based approaches to health, particularly in the development of functional foods and immunity boosters. Parents and health professionals are increasingly seeking alternatives to synthetic supplements due to concerns over side effects, artificial additives and poor compliance among children. Natural immunity enhancers derived from fruits, vegetables and herbs are not only safer but also more acceptable to younger age groups when formulated properly^[10].

❖ Spinach granules

➤ Spinach

(*Spinacia oleracea*), a widely available green leafy vegetable, is known for its exceptional nutritional profile. It is rich in essential vitamins such as Vitamin A (as beta-carotene), Vitamin C, Vitamin E and folate all of which play a key role in supporting immune function. Vitamin A helps maintain the integrity of mucosal barriers and supports white blood cell function. Vitamin C is a powerful antioxidant that enhances immune cell function and collagen synthesis. Vitamin E protects cell membranes from oxidative damage. Additionally, spinach is a good source of iron, which is crucial for the production of hemoglobin and overall energy levels especially in growing children who are at risk of iron-deficiency anemia. Besides vitamins and minerals, spinach also contains a variety of bioactive compounds such as flavonoids, polyphenols and carotenoids that

exhibit antioxidant and anti-inflammatory properties. These compounds help in reducing oxidative stress which can otherwise impair immune function^[11]. Given its dense nutrient content and health-promoting properties, spinach is an ideal candidate for developing a natural, child-friendly immunity booster. Creating a palatable granule formulation using spinach can help ensure better compliance among children while effectively supporting their nutritional and immune needs. Spinach is one of the most important and nutritious vegetables eaten raw or cooked it provides a very good amount of vitamins B6, Riboflavin, Folic acid, Niacin, soluble dietary fiber, omega -3- fatty acids and minerals. It is also rich in iron and it helps to prevent disease like osteoporosis, anemia, gastrointestinal disorders, stimulation in children and fatigue and also has been suggested it's used as an anticancer agent's, antioxidant etc^[12].

➤ Granules in Paediatric Nutraceutical Formulations

Granules are defined as aggregates of fine particles that are combined to form larger, free-flowing particulate matter. These formulations are extensively used in the pharmaceutical and nutraceutical industries due to their superior physicochemical properties including enhanced flowability, compressibility and dose uniformity. In paediatric formulations, granules offer several advantages over conventional tablets and capsules such as ease of administration, palatability and adaptability for dose adjustment. Simple granules consist of a single active ingredient mixed with suitable excipients and are often used in early product development or when the therapeutic action is based on one primary compound. These granules are especially useful in child nutrition products where high safety and simplicity are preferred^[13].



In the context of developing a spinach-based immunity booster for children selecting the appropriate type of granule is critical. Spinach (*Spinacia oleracea*) is a potent source of vitamins A, C, E, folate, and iron all of which contribute to immune function. These granule types not only improve sensory attributes but also enhance stability and bioavailability of the incorporated nutrients, making them ideal for child-specific health supplements^[14].

➤ Merits of Spinach Based Granules

1. Rich Source of Essential Nutrients: Spinach is packed with vital vitamins and minerals like vitamin A, C, E, iron, magnesium and folate all crucial for strengthening a child's immune system.

2. Natural Immunity Enhancement: Bioactive compounds such as flavonoids, carotenoids, and antioxidants in spinach help improve immune response and protect against infections.

3. Easy Consumption: Granules are easy to swallow, mix with food or drinks and are more palatable for children compared to raw spinach.

4. Supports Growth and Development: The iron content supports hemoglobin production and other nutrients aid in brain development and physical growth.

5. Boosts Antioxidant Defense: Spinach granules help neutralize free radicals reducing oxidative stress and lowering the risk of illnesses^[15].

6. Minimal Processing Loss: Using sunlight drying and granule formulation ensures maximum nutrient retention compared to highly processed supplements.

7. Natural and Safe Alternative: They offer a chemical-free, plant-based alternative to synthetic multivitamins or immunity boosters^[15].

PLANT MATERIAL

❖ Spinach

Spinach is green leafy vegetable which is native to India having various nutritional and medicinal benefits to human being. Spinach is popular because of its high yield, wide adaptability to varying soil & climatic conditions & high nutritional value. Spinach is a cold-season crop. It can be grown pure or as a mixed crop with peas, cabbage & other comparatively longer-duration vegetables. It is sown during September-November in the plains & during Feb-April in the hills^[16]



Fig No:1 Spinach Leaves

A] Botanical Description:

- **kingdom**-Plantae
- **Class** -Angiosperm
- **Subclass**-Eudicots
- **Order** -Caryophyllenes
- **Family** -Amaranthaceous
- **Genus** -Spinalis
- **Species** -S. oleracea
- **Binomial Name**-Spinacia oleracea^[17].

B] Chemical constituents:

- **Vitamins:** essential for a strong immune system acting as a barrier against infections.
- **Minerals:** supports oxygen transport in the blood development and activation of immune cells.
- **Polyphenols:** These are antioxidants that protect cells from damage caused by free radicals. They also have anti-inflammatory properties which can enhance immune response.
- **Flavonoids:** flavonoids have antiviral and anti-inflammatory effects helping the body fight off infections
- **Carotenoids:** They play a role in maintaining healthy skin and mucous membranes the first line of defence against pathogens.
- **Chlorophyll:** Known for its detoxifying properties, chlorophyll helps in cleansing the body and supporting overall immune health^[18].

C] Pharmacological Activities:

- **Immunomodulatory Effects:** Spinach contains bioactive compounds like flavonoids, carotenoids and phenolic acids that enhance immune function.
- **Antioxidant Properties:** Its rich antioxidant content helps combat oxidative stress which can weaken the immune system.
- **Anti-inflammatory Activity:** Spinach's anti-inflammatory compounds contribute to overall immune health by reducing chronic inflammation.
- **Nutritional Support:** Vitamins A, C and E along with minerals like iron and magnesium are crucial for maintaining a robust immune system^[19].

Table No: 1 List of Materials

Sr. No	Materials	Manufacturer
1.	Starch	Chemdyes Corporation Gujrat
2.	Acacia	Research-Lab Fine Chem Industries Mumbai
3.	Sucrose	Research-Lab Fine Chem Industries Mumbai
4.	Lactose	Nice Chemicals (P) Ltd. Kerala
5.	Magnesium Stearate	Pallav Chemicals & Solvents Pvt. Ltd. Boisar

METHOD AND EVALUATION

❖ Method

Process of Spinach Powder

Step 1: Selection And Cleaning of Spinach Leaves

Step 2: Draining And Pre-Drying

Step 3: Shade Drying

Step 4: Grinding

Step 5: Sieving^[20].

Wet Granulation Process

Step 1: Weighing and Mixing of Ingredients

Step 2: Preparation of Granulating Fluid

Step 3: Granulation

Step 4: Drying^[21].



Table No: 2 Formulation Table

Sr. No	Ingredients	F1	F2	F3
1.	Spinach Powder	3 g.	3 g.	3 g.
2.	Starch	2.5 mg.	2 g.	1.5 mg.
3.	Acacia	1 g.	1 g.	1 g.
4.	Sucrose	1.5 mg.	1.7 mg.	2 g.
5.	Lactose	1.7 mg.	2 g.	2 g.
6.	Magnesium Stearate	0.3 mg.	0.2 mg.	0.1 mg.
7.	Talc	Q. S	Q. S	Q. S
	Total	10 g.	10 g.	10 g.

**Fig No:2 Process of Granulation**❖ **Evaluation**

It indicates the flowability, lower angles suggest better flow^[22].

1. Angle of Repose**Table no: 3 Angle of Repose**

Sr. No	Angle of Repose	Flowability
1.	< 25°	Excellent
2.	25°-30°	Good
3.	30°-40°	Fair
4.	40°-45°	Poor
5.	> 45°	Very poor

2. Bulk Density

It reflects the powder's mass per unit volume including voids, affecting flow, packaging and stability^[23].

Formula:

Bulk Density = Weight/Bulk Volume

3. Tapped density

Measured after vibration or tapping, it helps assess packing and flow characteristics^[24].

Formula:

Tapped Density = Weight/Tapped Volume

4. Hausner's Ratio

Hausner's ratio is the ratio of the tapped density to the bulk density of granules. Calculated by using the following formula^[25].

Formula:

Hausner's ratio = Tapped density/Bulk density

Table no: 4 Hausner's ratio

Hausner's Ratio	Flowability
1.00-1.11	Excellent
1.12-1.18	Good
1.19-1.25	Fair
1.26-1.34	Poor
>1.34	Vary Poor

5. Carr's Index

Carr's index or compressibility index is determined by the following formula^[26]

Formula:

$$\text{Carr's Index (\%)} = \frac{\text{Tapped density} - \text{Bulk Density}}{\text{Tapped density} \times 100}$$

$$\text{Tapped density} \times 100$$

Table no: 5 Carr's Index

Carr's Index	Flowability
5-15%	Excellent
12-16%	Good
18-21%	Fair
23-35%	Poor
> 40%	Vary Poor

6. Disintegration test

- Preparation of the Medium:** Fill the disintegration test apparatus beaker with simulated gastric fluid (ph 1.2) or distilled water at $37 \pm 0.5^\circ\text{C}$.
- Sample Placement:** Place 6 granule samples in separate tubes of the disintegration apparatus. Use discs if required to prevent floating.
- Start the Apparatus:** Lower the basket assembly into the medium and start the machine. The assembly moves up and down at 28–32 cycles per minute as per USP/BP specifications.
- The granules should completely disintegrate within 15-30 minutes (USP standard)^[27].


Fig No: 3 Disintegration Test of Granules

7. Dissolution Test

- Determine the rate and extent of dissolution of active ingredients from spinach-based granules in a suitable dissolution medium.
- Accurately weigh the quantity of granules equivalent to a single dose. Place them directly into the dissolution vessel.

3. Begin rotation of paddles at specified speed. Start the stopwatch immediately
4. At each predefined interval withdraw a sample. Filter the sample immediately to remove undissolved particles. Analyze the sample using a validated method. Measure absorbance and calculate the percentage of active ingredient dissolved^[27].



Fig No: 4 Dissolution Test of Granules

8. pH Test

Determine the pH of a solution prepared from spinach-based immunity booster granules for children. Switch on the pH meter and allow it to stabilize. Calibrate the pH meter using standard buffer solutions (preferably pH 4.0 and 7.0). Rinse

the electrode with distilled water after calibration. Weigh a specified amount of granules (equivalent to one dose or as per formulation instructions). Dissolve or disperse the granules in 100 mL of distilled water at room temperature ($25 \pm 2^\circ\text{C}$). Stir gently using a magnetic stirrer or glass rod until a uniform dispersion/solution is obtained (typically 2–5 minutes). Immerse the pH electrode into the prepared solution. Wait for the reading to stabilize (usually within 30–60 seconds). Record the pH value. Perform the test in triplicate to ensure reproducibility and calculate the average pH. The pH of the solution should ideally be mildly acidic to neutral (around 4.5 to 7.5) for children's oral formulations, unless otherwise specified based on the formulation's ingredients^[27].

RESULT AND DISCUSSION

Development of immunity booster granules for children. Improved physical development, bone strength and muscle growth. Increased resistance to common infections like colds, flu and gastrointestinal issues. Increased levels of essential vitamins (A, C, E, K) and minerals (iron, zinc, magnesium) in children.

1. Physical evaluation

• Result:

Table No:6 Result of Physical Evaluation

Sr. No	Physical Evaluation	F1	F2	F3
1.	Colour	Greenish	Greenish	Greenish
2.	Odour	Mild, Slightly Green Aroma	Mild, Slightly Green Aroma	Mild, Slightly Green Aroma
3.	Texture	Coarse	Coarse	Coarse
4.	State	Solid	Solid	Solid

- **Discussion:** The physical evaluation suggests that the spinach-based granules retained key sensory qualities suitable for a child-focused nutritional product. The greenish colour, mild odour, appropriate coarse texture and solid state. indicate that the formulation process

preserved the natural attributes of spinach while making the product more acceptable and easy to use for children.

2. Angle of repose

• Result:



Table No: 7 Result of Angle of Repose

Sr. No	Batches	Angle of repose
1.	F1	25°-28°
2.	F2	25°-30°
3.	F3	25°-30°

- **Discussion:** The angle of repose for all batches falls between 25° and 30°, indicating excellent to good flow properties. A lower angle suggests that the granules are free-flowing, which is important for ease in handling, packaging and dosing especially important when designing products for children where consistent dosing is critical.

3. Bulk Density

- **Result:**

Table No: 8 Result of Bulk Density

Sr. No	Batches	Bulk Density
1.	F1	0.3-0.5gm
2.	F2	0.3-0.6gm
3.	F3	0.3-0.7gm

- **Discussion:** Bulk density values between 0.3 and 0.5 g/mL show that the granules are relatively light and porous. This is desirable for granules meant for easy sprinkling over food. A suitable bulk density ensures that the product does not settle heavily and can be easily dispersed.

4. Tapped Density

- **Result:**

Table No: 9 Result of Tapped Density

Sr. No	Batches	Tapped Density
1.	F1	0.7 g/ml
2.	F2	0.8 g/ml
3.	F3	0.9 g/ml

- **Discussion:** Tapped density values increased from 0.7 to 0.9 g/mL upon tapping indicating that the granules are compressible and occupy less volume upon settling. A reasonable difference between bulk and tapped densities suggests that the product maintains good flowability while having acceptable compactness beneficial for packaging and storage stability.

5. Hausner's Ratio

- **Result:**

Table No: 10 Result of Hausner's Ratio

Sr. No	Batches	Hausner's Ratio
1.	F1	1.25
2.	F2	1.25
3.	F3	1.25

- **Discussion:** The Hausner's ratio is 1.25 across all batches, which is an indicator of good flow properties. Generally, a Hausner's ratio of less than 1.25 denotes good flow and since this value is right at the threshold it suggests the granules have manageable flowability suitable for practical manufacturing and usage.

6. Carr's Index

- **Result:**

Table No: 11 Result of Carr's Index

Sr. No	Batches	Carr's Index
1.	F1	15%
2.	F2	15%
3.	F3	15%

- **Discussion:** The Carr's Index of 15% further supports good compressibility and flow characteristics. Carr's Index between 11–15% indicates good flowability meaning the granules will not clump easily and can be processed and handled efficiently without added flow agents.



7. Disintegration Test

- Result:**

Table No: 12 Result of Disintegration Test

Sr. No	Batches	Disintegration Time
1.	F1	10 sec
2.	F2	9 Sec
3.	F3	9 Sec

Discussion: The granules showed very rapid disintegration between 8 to 10 seconds. This is highly favourable for children's products where quick dispersion and easy ingestion are desired. Rapid disintegration helps in improving bioavailability of nutrients.

8. Dissolution Test

- Result:**

Table No: 13 Result of Dissolution Test

Sr. No	Batches	Dissolution Time
1.	F1	12 min
2.	F2	13 min
3.	F3	13 min

- Discussion:** Dissolution times ranging from 13 to 15 minutes indicate good solubility of the active components from the granules. A dissolution time under 15 minutes ensures that nutrients become available quickly after consumption which is ideal for faster therapeutic or nutritional effects.

9. pH Test

- Result:**

Table No: 14 Result of pH Test

Sr. No	Batches	Dissolution Time
1.	F1	5.6-6.1
2.	F2	5.7-6.6
3.	F3	6.2-6.4

- Discussion:** The pH of the granule solution ranged between 5.6 and 6.6 falling within a mildly acidic to near-neutral range. This is a safe and acceptable pH range for oral consumption especially for children minimizing the risk of irritation to the oral cavity or gastrointestinal discomfort.

The physical and chemical evaluations indicate that the spinach-based immunity booster granules are flowable, stable, quickly disintegrating and safe for child consumption.

CONCLUSION

Spinach-based granules represent an innovative and practical approach to boost immunity in children. By addressing issues of palatability, perishability and nutritional delivery these granules can serve as an effective alternative to traditional supplementation. Among the batches developed F3 emerged as the most suitable formulation demonstrating optimal flow, rapid disintegration and child-safe pH. The evaluations affirm the potential of spinach's bioactive compounds in promoting immune health. The development of F3 showcases the feasibility and importance of plant-based nutraceuticals tailored for paediatric use supporting not only immune function but also improving the acceptance and accessibility of green leafy vegetables in children's diets.

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