International Journal for Multidisciplinary Research (IJFMR)
E-ISSN: 2582-2160 ● Website: www.ijfmr.com ● Email: editor@ijfmr.com

Green Gold: From Algae to Pharmacy – Formulation and Evaluation of Spirulina as Nature's Superfood in Nutraceutical Tablet Dosage Form

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Abstract:
Spirulina has gained attention as a nutrient-dense microalgal ingredient for the development of oral nutraceutical dosage forms. The present study was designed to formulate spirulina tablets by the wet granulation method and to optimise batch performance through reformulation and post-compression evaluation. Five experimental batches (F1–F5) were prepared using spirulina powder with selected pharmaceutical recipients, and batch F3 was identified as the optimised formulation based on its overall physical characteristics and processing behavior. Reformulation results demonstrated improved powder flow after granulation, confirming the suitability of wet granulation for converting spirulina powder into compressible granules. The optimized F3 tablets showed satisfactory weight uniformity, adequate hardness, liability within acceptable limits, appropriate disintegration time, and high content uniformity, indicating a mechanically stable and pharmaceutically acceptable dosage form. These results provide credence to spirulina tablets' potential as a promising nutraceutical formulation and lay the groundwork for future scale-up and in vivo testing. Protein is the cornerstone of nutrition and the most crucial dietary item for a healthy lifestyle because it may be used as a fat or a carbohydrate in addition to its own protein value. For every 2.2 pounds of body weight, an adult needs one gram of usable protein. The complex protein molecule is made up of several interrelated components. Amino acids are the building components of proteins. 23 distinct amino acids are produced during the breakdown of protein during digestion. Amino acids fall into two categories: essential and non-essential. Eight amino acids have been found to be necessary for growth. Furthermore, without these eight essential amino acids, our body is unable to synthesise the remaining fifteen (non-essential) amino acids. The eight necessary amino acids are the building blocks of protein, a balanced diet, and even general wellness. Spirulina is considered a fantastic diet because it has antibacterial properties and is non-toxic. It can be broken down without the need of chemicals or processing since it lacks a cellulose cell wall. The range of digestibility is 83–84%. Spirulina is said to be rich in protein, vitamins, essential minerals, amino acids, EFA such gamma linoleic acid, and antioxidant pigments like carotene.

Keywords: Spirulina, wet granulation, tablet formulation, nutraceutical dosage form, preformulation, tablet evaluation, content uniformity.

INTRODUCTION:

Tablets are solid dosage forms that contain medications; they are typically circular in shape and can be flat or biconvex. Tablets made using the compression process are referred to as compressed tablets.

Benefits

1. The tablet is simple to administer.
2. They are simple to administer.
3. These dose forms are more reliable.
4. They keep the dosage accurate.
5. They are the smallest and lightest dose form available.

Disadvantages:

1. Children and comatose patients have trouble swallowing tablets.
2. Some drug due hydrophobic and low-density character are not formulated as tablet.
3. Tablet manufacturing show increase level of product loss during processing.
4. Absorption of drug from tablet varies from patient to patient.
5. Drugs with bitter test and objectionable order may require encapsulation or coating.

Classification of tablets

The four primary classification classes for tablets are as follows:

A. tablet taken orally

1. Compress tablet
2. Multiple compress tablet or press coated tablet
3. Tablet with many layers
4. Maintain action pill
5. Tablet with an enteric coating
6. Tables covered in sugar
7. Tablet with a film coating
8. Tablets that can be chewed

B. Using tablets in the mouth

1. Sublingual buccal pill
2. Lozenges tablets and traches
3. Cones for teeth

C. A tablet given via an alternative method

1. Tablet implantation
2. The vaginal pill

D. The tablet that was used to make the solution

1. A fizzy tablet
2. Tablet dispensing
3. A hypodermic pill
4. Triturates in tablets

Spirulina

The blue-green microalga Spirulina, also called Spirulina platensis or Spirulina maximum, is a member of the Oscillatoriaceae family. and is considered one of the most remarkable groups of photosynthetic microorganisms. The genus name of the cyanobacterium Spirulina (Arthrospira), which belongs to the Oscillatoriacea family, comes from the helical or spiral shape of its filaments. Because of its high protein content (up to 55–70%), it is frequently referred to as a "natural superfood." carbohydrates (15–25%), essential fatty acids (18%), essential amino acids (50–70%), vitamins, minerals, and special pigments including chlorophyll, phycocyanin, and carotenes. Compared to many other algae, spirulina is extremely digestible due to its soft cell wall made of complex carbohydrates and proteins. Because of its immunostimulatory properties, spirulina increases the synthesis and activity of T-cells, macrophages, and bone marrow stem cells, as well as enhancing the thymus and spleen's ability to operate. According to in vitro research, spirulina may play a part in cancer prevention or adjuvant treatments by increasing nuclear enzyme activity and DNA repair. Spirulina provides advantages for the environment in addition to its health-promoting properties because it grows quickly even can be utilized as a source of nitrogenous fertilizer and help in the biodegradation and nitrogen fixation of wastewater or sewage water. Additionally, vitamins A, B, and E, amino acids, a substantial quantity of gamma linoleic acid, a fatty acid that supports cardiovascular health, and minerals like potassium, calcium, magnesium, zinc, selenium, phosphorus, and iron, complex sugar, enzymes, and trace elements. It promotes resistance to several infections and strengthens immunity. There have also been reports of the anticancer and antioxidant qualities. In metabolic disorders like diabetes, hypertension, and anemia, spirulina is crucial.

spirulina powder

History of Spirulina

Documented use of spirulina as a food source dates back to the Aztec Indians of Mexico and the other Maso-Americans, and the ancient kanyemba tribe living on the lakeside of the Lake Chad region of North Africa consumed it until the 16th century. It is understood that Aztecs used, cultivated, ate and sold it in the old Aztecs. The present-day Mexico City was once the capital of Tenochtitlan. spirulina that growing naturally on the surface of Mexico’s Lack Texcoco and Lack Chad has been harvested, dried and eaten by the people of those areas. The Spanish explores believed that it was regularly used at the dinner tables Aztecs around Lake Texcoco and sold as cake when Hernando Cortez and his soldiers discovered them in 1519.

Benefits of spirulina:

Some key benefits include: High-value biomass and fast-growing algal mass suitable for cultivation in wastewater, helping to reduce pollution. Growth in sewage-rich media, making it useful for biodegradation

and wastewater treatment. Ability to fix atmospheric nitrogen, allowing it to serve as a natural nitrogen source for agriculture.

Problem statement: spirulina powder shows poor flow and compressibility.

Research gap: Limited studies on optimized tablet formulation.

Aim: The primary goal of the current study was to make and assess spirulina tablets using the wet granulation process and then compress them into tablets, paying particular attention to batch F3 and examining its weight fluctuation, hardness, friability, disintegration time, and content. consistency and to determine an appropriate nutraceutical tablet composition for future advancement.

Material:

Chemical and excipients:

All ingredients used in this study were of pharmaceutical grade. The materials included spirulina powder, talc, magnesium, sodium starch glycolate, starch, and microcrystalline cellulose (MCC) and sucralose (sweetener). the excipients were obtained from certified pharmaceutical supplier and were used without any further purification. All excipients were of IP/USP-grade quality and complied with pharmacopeial criteria for usage in solid oral dose forms.

Table 1. Excipient selection and their roles

Excipient class	Example excipients	Typical use level (% w/w)	Primary function in spirulina powder	Key issues addressed
Diluents	Microcrystalline cellulose	1-3 % concertation	Improve bulk density, flow	Low bulk density, poor flow
Binders	Starch	2-10 % concertation	Promote granules cohesion	Capping, lamination, low hardness
Super disintegrant	Sodium starch glycolate	2-8 % concertation	Ensure rapid tablet breakup	Slow disintegration
Lubricants	Magnesium stearate	0.25-5 % concertation	Reduce die wall friction, prevent sticking and picking	Pigment sticking, ejection problem
Glidants	Talc	1-10 %	Improve powder flow	Poor flow, wight variation
Sweeteners	Sucralose	5-30 % or quantity sufficient	Improve taste, mouthfeel, especially in	Bittle / seaweed taste

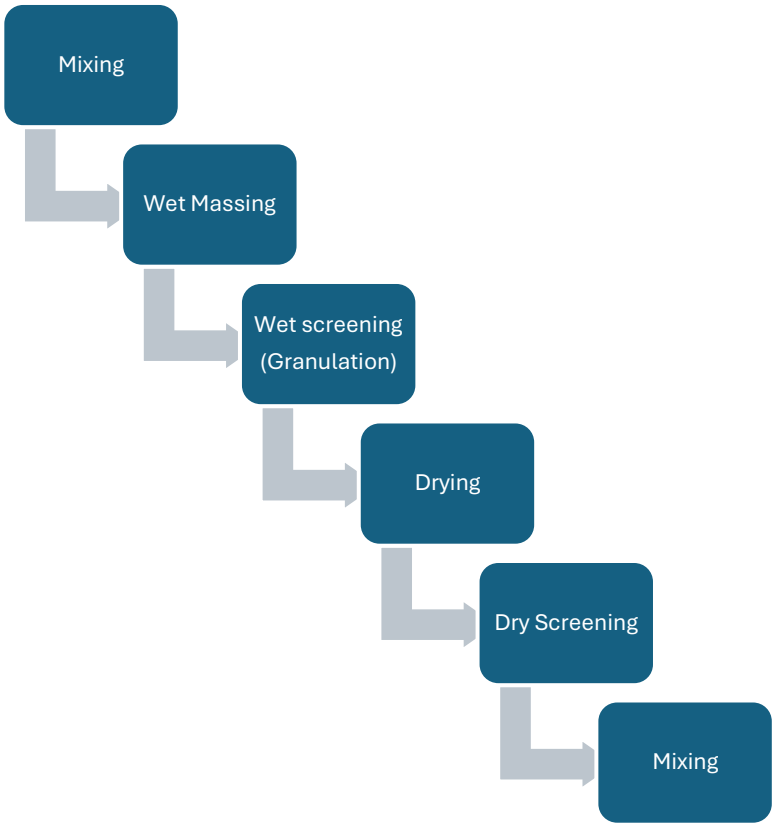
Method:

Five batches of spirulina tablet (F1-F5) were prepare using the direct compression after the wet granulation process.

Wet granulation: Using a liquid binder, small powders are transformed into bigger, multi-particle entities known as granules in this popular tablet production technique. Using a liquid binder as a dispersion to gently agglomerate the various particles into a blend is known as wet granulation. In the pharmaceutical sector, it is the most popular agglomeration procedure. The wet granulation process is used to make over

70% of tablets. Wet sizing, drying, compression, and wet massing of the powder blend with a granulating liquid are the only steps in this method. To create the required moist mass, the amount of binder fluid utilized in agglomeration must be carefully regulated. When handling granules, over-wetting makes them excessively hard, and under-wetting makes them too soft and friable. Because they are safer, aqueous dispersions are appropriate for drugs that undergo hydrolysis.

Fig 1: The Process of Wet Granulation



Steps:

1. Weighing: Every component is precisely weighed in accordance with the recipe.
2. Blending: The medication is evenly combined with diluents such starch and microcrystalline cellulose.
3. Granulation: To create a wet mass, a binder solution is added.
4. Wet Screening: To create granules, the damp bulk is run through a sieve.
5. Drying: Until a consistent weight is achieved, the granules are dried at 40–50°C.
6. Sizing: To obtain a consistent particle size, dried granules are run through a screen.
7. Lubrication: Glidants like talc and lubricants like magnesium stearate are added.
8. Compression: A tablet compression machine is used to compress the finished grains into tablets.

Tablet Punching Machine

Fig 2: Mechanism of Wet Granulation

Formulation Design:

Five batches of spirulina Tablet (F1-F5) were formulated using varying proportions of starch, sodium starch glycolate, and microcrystalline cellulose to maximize the tablet's properties. Table 2 provides an overview of each experimental batch's makeup.

Table 2: composition of different batch spirulina tablet (f1-f5).

Batch	Spirulina (mg)	Microcrystalline Cellulose (MCC)	Starch	Glycolate of sodium starch (mg)	Stearate of magnesium (mg)	Talc (mg)	Sweetener (mg)	Total (mg)
F1	500	60	20	10	5	5	3	603
F2	500	55	25	10	5	5	2	602

F3	500	65	15	10	5	5	5	600
F4	500	70	20	5	5	5	6	601
F5	500	50	30	15	5	5	5	605

Preformulation studies:

Before the final compression of tablet, preformulation studies were conducted on both the raw spirulina powder and the prepare F3 granules. These studies are essential to assess the materials' compressibility and flowability, which have a direct impact on the finished tablet's weight and content homogeneity

Table 3: Preformulation parameters of spirulina powder and F3 granules

Parameter	Spirulina powder	F3 granules
Angle of Repose	33.1	22.9
Bulk Density	0.45	0.625
Tapped Density	0.60	0.741
Carr's index	25	15.66
Hausner Ratio	1.33	1.186

The significance improvement in flow parameter for F3granules validates the efficiency of the wet granulation method. Upon processing the formulation into granules via the wet granulation method, a marked improvement in flow characteristics was observed. The F3 granules exhibited a significant reduction in the angle of repose to 22.9°, indicating 'excellent' flow properties according to standard pharmaceutical guidelines. Furthermore, the decrease in Carr's index to 15.66% and the Hausner ratio of 1.186 confirm that the granulation process successfully enhanced the compressibility and uniform particle distribution. To guarantee constant die filling, homogeneous tablet weight, and mechanical strength in the finished tablet dosage form, this change from a cohesive, fine powder to free-flowing granules is crucial.

Spirulina Tablet

Evaluation of Tablets:

Organoleptic Characteristics:

Color is a crucial tool for quick identification and consumer acceptability of many medicinal tablets. Eye contact can distinguish minute color differences, but it cannot precisely describe color. The presence of an odor in a batch of tablets may be a sign of a stability issue, such as the acetic acid odor associated with aspirin tablets; on the other hand, an odor may be a feature of the medicine, additional ingredients, or the dosage form. Consumer adoption of chewable tablets is influenced by taste. When developing a product, many businesses use tasting panels to assess consumers' preferences for various flavors and levels of flavor. Chips, fissures, and contamination from foreign solid materials are examples of tablet defects.

Color: Dark green to bluish-green (Due to presence of phycocyanin pigment)

Odor: Characteristic mild algae-like odor

Taste: Slightly bitter or characteristic taste (Sweetener added for taste masking)

Appearance: Smooth surface, Uniform shape, No cracks or defects

Texture: Non-sticky, Free from surface roughness

Weight Variation: If the acceptance value of the first ten dose units is less than or equal to 15%, the standards for dosage uniformity are met; if the acceptance value is higher than 15%, the next twenty units are tested and the acceptance value is determined. The conditions are satisfied if the final the 30 dosage units' acceptance value is less than or equal to 15%, and no dosage unit's individual content is greater than or equivalent to 25%. Die-filling and compression force were consistent during manufacturing, as evidenced by the tablets' mean weight of 600 mg and individual deviations being within the ±5% range.

Hardness & Friability: To survive mechanical shock during production, packing, and shipping, tablets need to have a specific level of strength, or hardness and resistance to friability. As a result, the friability of tablets is frequently tested as an additional indicator of their strength. A hardness of 5.20 kg/cm² combined with a low friability of 0.51% confirms that the tablets possess high mechanical strength and are sufficiently robust to withstand physical stress during handling and transportation.

Disintegration Time: For a medication to be easily absorbed by the body, it must be in solution. For the majority of tablets, disintegration—the breakdown of the tablet into smaller particles or granules—is a crucial initial step toward the solution. The selected super-disintegrant successfully promotes quick breakdown in the aqueous environment, as evidenced by the mean disintegration time of 10.17 minutes, which is well below the 15-minute pharmacopeial limit for uncoated tablets.

Content Uniformity: The drug content of 99.2% indicates that the active ingredient (spirulina) is uniformly distributed throughout the batch, with no significant loss of bioactive components during the wet granulation and drying phases. The potency of a tablet is expressed as the product's label strength in grams, milligrams, or micrograms (for some potent medications) of drug per tablet.

Table 4: physical and mechanical evaluation of F3 batch tablet

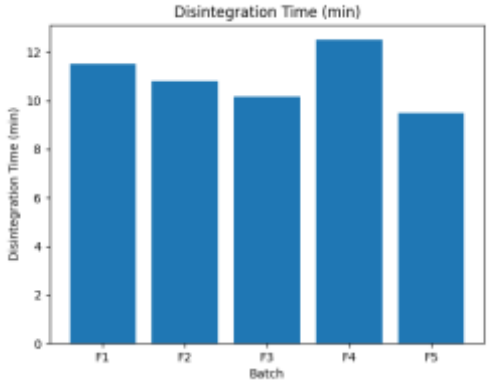
Test parameter	Observation / mean value	Acceptable Limits (pharmacopeial)
Weight variation	600 mg	5% for 600 mg tablet
Tablet Hardness	5.20 kg/cm	4-6 kg/cm
Friability	0.51%	<1%
Disintegration time	10.17 min	<15 min (uncoated)
Drug Content	99.2 %	90-110 %

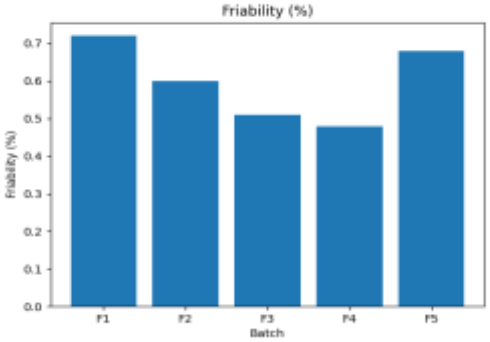
Result and Discussion:

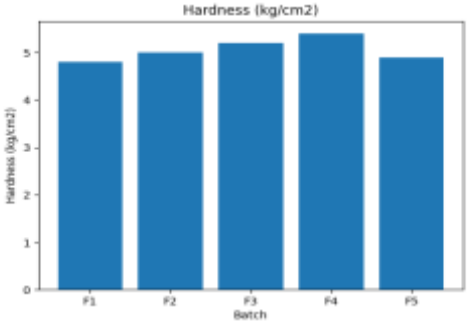
The current work effectively illustrates how to make spirulina tablets utilizing the wet granulation method. Batch F3 has the best mechanical and physical characteristics out of the five batches that were created. Weight fluctuation, hardness, and other evaluating parameters Pharmacopeial restrictions included drug content, disintegration time, and friability. Therefore, it can be said that the optimized F3 formulation is a stable and efficient dosage form for the nutraceutical administration of spirulina, laying the groundwork for further clinical research and scale-up.

The graphical result confirms that batch F3 was the most promising formulation out of all batches because it had the best mechanical strength and acceptable disintegration behavior.

Graph:







Conclusion:

The present study successfully formulated spirulina tablet by the wet granulation method. the obtained

results indicate that the selected combination of spirulina powder talc, magnesium stearate, sodium starch glycolate, microcrystalline cellulose, and sweetener was suitable for developing a stable nutraceutical tablet dosage form. The low friability and satisfactory disintegration behavior confirm that the formulation can withstand handling while still allowing proper tablet breakup after administration. Overall, the optimized F3 batch may serve as a useful basis for further scale-up, stability studies, and future clinical evaluation.

Acknowledgement:
The principal and pharmaceutics department of Swami Institute of Pharmacy, Abhona, are acknowledged by the authors for providing the setting for this study.

Future scope:
Further studies may focus on stability testing, scale-up of optimization F3 formulation and in vivo evaluation of spirulina tablet. Future study van explores bioavailability, antioxidant efficacy and clinical nutritional benefits of the optimize spirulina tablet to position it as a next-generation nutraceutical.

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