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Formulation and Evaluation of Nutraceutical Dosage Form from Moringa Oleifera, Amaranthus Albus and Fagopyrum Esculentum

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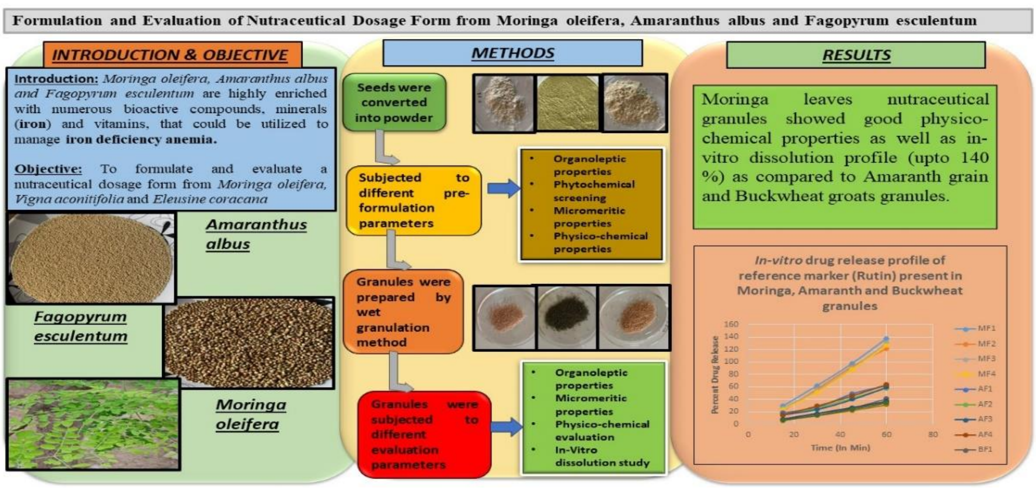
KEYWORDS

Nutraceutical granules; Moringa oleifera; Amaranthus albus; Fagopyrum esculentum; Herbal drugs.

ABSTRACT:
Nutraceutical food and its products are gaining popularity in recent times, owing to the growing recognition of the significance of nutrition for health and wellbeing. Their importance cannot be overstated in the control and management of the health problems by offering potential health benefits that go beyond basic nutrition. The nutraceutical foods are highly enriched with essential constituents like micronutrients, vitamins, minerals and antioxidants, etc., that can be incredibly nutritional as well as also performs the immunological and physiological functions which can be beneficial in preventing the nutrition related disorders. This research paper focuses on the development and evaluation of Nutraceutical granules using the three promising crops: Moringa oleifera, Amaranthus albus and Fagopyrum esculentum. These crops are renowned for their remarkable nutritional profiles, which include a variety of bioactive compounds, amino acids, minerals, and vitamins. Wet granulation technique was employed to produce the granules with different binders (potato and maize starch) and analyzed for various evaluation parameters. The results revealed that these nutraceutical granules showed good physico-chemical properties as well as in-vitro dissolution profile. These are the economical and feasible options for the conventional formulations available for the management of nutritional disorders like iron deficiency anemia due their remarkable mineral content.

Graphical Abstract



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1. INTRODUCTION

Hippocrates' philosophy of "food as medicine" has been widely accepted in the modern world since its inception in 400 BC. Food and nutrition play a fundamental role when it comes to health and pathophysiology of disease and their prevention. However, the importance of proper nutrition has been steadily increasing in recent years, particularly with the rise in lifestyle-related disorders. A lot of lifestyle health issues are linked to dietary choices, for instance obesity, hypertension, and diabetes (1). Poor nutrition can lead to a weakened immune system, making individuals vulnerable to a variety of infections.

In India several healthcare programs have been developed to address various nutritional deficiencies like anemia (iron deficiency), goitre (iodine deficiency) and blindness (vitamin A deficiency), with fortification of food with vitamins and minerals. The outcomes of these healthcare programs have highlighted the significance of fortified foods and nutraceuticals in promoting well-being. As science and cutting-edge technologies have advanced, new approaches to enriching food have become increasingly popular. Most people are more comfortable with medications than with foods, and this attitude has been steadily changing over the past decade as the nutraceuticals are in the spotlight (2,3). This has led to greater understanding of the role nutraceuticals as preventative medical approach that prevent sickness or damage by supplying nutrients essential to sustain a healthy and disease-free body (4–7).

Nutraceuticals are the nutritional supplements that are composed of components of dietary foodstuffs and sold in the forms of medicines. They have an advantage of offering protection against a wide range of health conditions (8,9). Nutraceutical market has seen a surge in interest from researchers and advanced methods for quantifying qualitative and quantitative variables. People are fed-up with the costly and technologically advanced approach to disease treatment in modern medicines are increasingly turning to nutraceutical products for complementary or alternative benefits (10–12). These products present us with a customized blend of nutrients and therapy that surpass what typical foods can offer (13).

Extensive research is being conducted on nutraceuticals and functional foods to understand their significance in promoting good health and preventing illness. The growing recognition among the general public about the correlation between diet and well-being has given rise to an unprecedented surge in the consumption of these food products, especially in nations with aging population and escalating healthcare expenses (14). According to the report of Global Market Insights, the nutraceutical global market size was predicted to be in excess of USD 423 billion in 2022, and is projected to inflate at a compound annual growth rate of 4.5% annually between 2023 to 2032 (15).

New bioactive phytochemicals have revived interest in botanicals (16). The plentiful presence of these active substances in different organic origins presents a great opportunity for enhancing general well-being, averting long-lasting ailments, and filling crucial dietary deficiencies. Out of the many nourishing elements accessible, *Moringa oleifera* (Moringaceae), *Amaranthus albus* (Amaranthaceae), and *Fagopyrum esculentum* (Polygonaceae), have gained significant interest as potential options for creating nutraceutical formulas because of their outstanding nutritional value and healing characteristics. In addition to their macronutrient content (i.e., protein and dietary fibres), they also contain a variety of micronutrients, phytonutrients, and antioxidants with promising bioactive effects.

Moringa oleifera generally called by names like moringa tree or drumsticks tree, a wonderful remedy presented to us by the nature, has a long history in medicine, with mentions in almost every traditional medicine reference with ancient writings dating back to 150 AD. It has long been revered for its distinctive nutritional value. While all parts of the moringa tree have medicinal properties, the leaves of the tree are the most beneficial due to their rich bio-active phytochemicals (17,18). The leaves are packed with nutrients such as- vitamins A, C and E; minerals like calcium, iron, and potassium; antioxidants; and proteins (19). Because of its wide-reaching health benefits, Moringa has found its way into traditional medicinal and food fortification programs. The plant has been demonstrated to be effective in the treatment of a vast range of health conditions, including infections like urinary tract infections, HIV-AIDS, Herpes simplex virus, Epstein-bar virus and hepatitis. It has also been reported to be effective in promoting lactation, improving catarrh function, reducing

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malnutrition and weight, and treating scurvy. Additionally, it also has found to possess antiseptic and antioxidant activity (20), with anti-anemic and anti-hypertensive potential (21–24).

Amaranthus albus, an annual weed plant, known for its slightly flavoured edible leaves and seeds, is stands out as a food supplement due to several advantages (25). Its gluten free pseudocereal grains make it a suitable candidate for individuals with gluten sensitivity or intolerance (26,27). In comparison to major true cereals like wheat and rice, amaranth seeds constituted with higher levels of protein and unsaturated fatty acids with a well-proportioned content of amino acid. Moreover, they offer a richer assortment of minerals like calcium, iron, etc., vitamins such as A, K, B6, C, E and B, and fibers, and serving as source of squalene- a triterpene known as an exceptional antioxidant with wide-ranging biological efficacy and phytochemical. Furthermore, the grains exhibit cardioprotective activity, anti-inflammatory effects, hepatoprotective properties, gastroprotective properties, anticancer activity, antidiabetic properties, antimicrobial effects, laxatives effects, spasmolytic effects, and bronchodilator properties (28,29).

Similarly, *Fagopyrum esculentum* also known as buckwheat is an herbaceous plant and a pseudo-grain crop (30) just like amaranth. Buckwheat groats (triangular-shaped grain like, hulled seeds) (31) are highly nutritious, offering a wide range of essential nutrients. They are rich in dietary fibres, trace elements, flavonoids- rutin and quercetin, and essential fatty-acids (32). In addition to that, they are also possess high level of minerals like magnesium, iron, calcium and phosphorous and antioxidant rich vitamins A, B- complexes, C and E (33). It has been characterized by its potent anti-oxidant activity, anti-inflammatory potential, and anti-hypertensive potential, which are valuable for the treatment of cardiovascular disorders (34). Additionally, it has been demonstrated to possess anti-cancer, anti-allergic, hepato-protective, anti-diabetic, anti-fibrotic, anti-fatigue, anti-hyperlipidaemia, anti-neurodegenerative, and anti-genotoxicity properties (33).

With this research paper, a comprehensive examination of the formulation development and manufacturing techniques as well as stringent quality assessment of nutraceutical dosage forms produced from the Moringa leaves, the Amaranth grains, and the Buckwheat groats was conducted. Given the abundance of bioactive compounds present in these plants and via outlining the scientific principles that underlie the preparation of these products, offers the potential for health benefits, plus we hope to gain treasured insights that can enable the development of innovative and efficacious nutraceutical products, as well as novel nutraceutical-related interventions addressing a broad range of health requirements and improved health indicators.

2. MATERIAL AND METHOD

2.1. Collection of Herbs

Moringa oleifera leaf powder was purchased from Thanjai Orgofarms Pvt. Ltd., Amaranth seeds and Buckwheat groats were purchased from Roorkee market, Uttarakhand, India. Potato starch and Maize starch were purchased from shop palace, Tomato powder was purchased from Shree Hari Industries, stevia was purchased from Parashakti Industries and Rutin were purchased from Prince Scientific. The remaining reagents and chemical substances used were all of analytical grade.

2.2. Preparation of Herbal Powder

The leaf powder of Moringa was sourced, while the seeds of Amaranth and Buckwheat seeds are plentiful in India. The seeds were bought, washed, and dried to a constant weight in a shade. The dry seeds were then ground in a mixing grinder and filtered through sieve No. 60. The powder of the leaf and seeds were then used to formulate nutraceutical granules (35).

2.3. Organoleptic Characterization

The organoleptic characterization of moringa leaves powder (MLP), amaranth grains powder (AGP) and buckwheat groats powder (BGP) was carried out by analysing their color, odour, and taste of the powdered herbs at room temperature (36–38).

2.4. Pre- liminary Phytochemical Screening of Herbal Powders

Each of the powder (MLP, AGP, BGP) were subjected to phytochemical analysis for the active constituents found in the powders, and findings were recorded as present (+) or absent (-) according to the color change.

2.4.1. Procedure for testing Alkaloids

Approx 5 to 10 ml of each test solution was mixed with 5ml of hydrochloric acid. Once the reaction completed, the solution was filtered and few ml was transferred to a test-tube. Along the sidewalls of the test tube, a few drops of Dragendorff's reagent were mixed.

2.4.2. Procedure for testing Anthraquinones

Few ml of each of the test solution was shaken with benzene (10 ml) and, filtered. Then the filtrate, was shaken with 10% (5 ml) ammonia solution.

2.4.3. Procedure for testing Cardiac Glycosides

Approx 5ml of each of the test solution was mixed with a few drops of $FeCl_3$ solution and few ml of glacial acetic acid. After that, through sideways of the test-tube walls 1ml of conc. H_2SO_4 was added.

2.4.4. Procedure for testing Flavonoids

Approx of each of the test solution was mixed with 2M HCL. Then 5 drops of sodium hydroxide (5%) were added.

2.4.5. Procedure for testing Phenolics

A few drops of Aqueous ferric chloride solution (10% w/v). was mixed in about 2ml of each of the test solution.

2.4.6. Procedure for testing Saponins

Approx 5ml of each test solution was shaken in a test-tube for about 5 to 7 minutes.

2.4.7. Procedure for testing Tannins

Approx 2ml of each of the test solution was mixed with Ferric chloride solution (5% w/v)

2.4.8. Procedure for testing Carbohydrates

To each of the test solution, about 2 to 3 drops of Molisch's reagent were added. To this mixture, about 2 ml of conc. H_2SO_4 was transferred through the sideways of the test-tube (37,38).

2.5. Standardization of Herbal Powders

2.5.1. Determination of Ash content:

Each of the powder was poured into the pre-weighed crucible (A) at a weight of 2g (B). The crucible was heated to 105°C to attain a constant weight, followed by a cooling period. Then the crucible along with its contents, was carefully reheated to draw out the moisture, and fully char the sample. The temperature was gradually raised until the sample became nearly carbon free. Subsequently, the sample was heated at a temperature of 600°C, at which the residue appeared nearly white, confirming the absence of carbon. The crucible as well as its contents were weighed (C) after cooling. The process (heating and cooling) was repeated until the residue weight reached a constant weight, representing no more substance loss occurring. Calculation of the ash value was done using the following expression (39):

Weight of empty crucible= A
Weight of herbal powder= B
Weight of crucible + Ash= C
Weight of Ash= A-C

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‘B’ g of herbal powder gives = (A-C) g of Ash
100g of herbal powder gives = 100x (A-C) %w/w of Ash

2.5.2. Determination of Moisture content: (gawali)

Each of the powdered sample weighing 2g (w1) was cautiously placed in individual glass petri dish (pre-heated and pre-weighed). The samples were then subjected to drying using a hot air oven with a temperature of 130° C for a period of 2 hours or until a consistent weight was attained. Following the drying process, the glass petri dish containing the samples was relocated to a desiccator for cooling, and subsequently, the petri dish was re-weighed (w2). The disparity in weight before and after drying was determined as the percentage of moisture content present in the sample by using following expression (40):

$$Moisture\ content\ (\%) = \frac{(w1 - w2)}{w1} \times 100$$

2.6. Characterization of Herbal Powder

2.6.1. Angle of Repose

On a plane surface, a funnel was fixed above a graph paper at a certain height. Through the funnel, each of the powder was poured and a conical pile was formed. The height (h) as well as its base radius were measured to estimate the angle of repose by using following expression (41):

$$Angle\ of\ Repose\ (\theta) = \tan^{-1} h/r$$

2.6.2. Bulk Density and Tapped Density

Approx. 15g (w) of each sample was poured in a dry measuring cylinder. Levelling the powder without tamping is important, and the apparent volume (V_0), was measured after the powder has been levelled. By using the following expression, the bulk density was calculated

$$Bulk\ density\ (\rho b) = \frac{w}{V_0}$$

In the following test, the same measuring cylinder, was tapped on a flat wooden surface, for about 50 taps from a little height and noted down as tapped volume (V_t) and the tapped density can be estimated as (42):

$$Tapped\ density\ (\rho_{t)} = \frac{w}{V_t}$$

2.6.3. Determination of Carr’s Index and Hausner Ratio

The findings of bulk density and tapped density were substituted in to the following expressions for the calculation of Carr’s index and Hausner ratio (41):

$$Carr's\ Index\ (\%) = \frac{\rho t - \rho b}{\rho^t} \text{x} 100$$

$$Hausner\ ratio = \frac{\rho t}{\rho^b}$$

2.7. Preparation of Granules

The nutraceutical granules were formulated by employing the technique of wet-granulation. All the ingredients were weighed and meticulously blended in accordance with the quantity specified in Table 1. The powder mixture was then supplemented with a small amount of binder paste until a wet mass was obtained. Then the wet mixture was strained using sieve No. 12. The prepared wet granules were then dried under a hot air oven at a temperature of 40°C. the granules were once again strained through sieve No. 14 to reduce the number of large granules. The same process was applied to each composition (19,20).

2.8. Evaluation of Nutraceutical Granules

Previously described methods were used to conduct various tests on the granules produced. These tests included evaluating the organoleptic characteristics; bulk density; tapped density; angle of repose; Carr's index; Hausner's ratio; and moisture content of the granules (39,41,42).

2.9. *In-vitro* Dissolution Study (Muazu)

The *in-vitro* dissolution of the granules was assessed utilizing USP-apparatus type-II (paddle type). The granules equivalent to 1g of the drug were immersed in 900 ml of 0.1M HCl buffer as the dissolving medium at a temperature of (37± 0.5) ° C and with paddle revolutions of 100 per minute. Aliquots of the dissolving medium (5ml) were collected from the container at the interval of 15, 30, 45, and 60 minutes and immediately replaced from fresh dissolution medium. Drug release at various time points was assessed by UV-visible Spectrophotometer (Elico SL-210) at 257 nm (43) after appropriate dilution. Percentage of drug release was computed and a graph was constructed in relation to time. The graphical assessment technique was employed for comparing the dissolving pattern, and the concentrations of the reference marker (17,32,44) for different time-point were used to assess the degree of dissolution (19).

3. RESULT AND DISCUSSION

3.1. Organoleptic Characteristics:

Examination of color, odour and taste were done at room temperature. The results of organoleptic characterization of MLP, AGP and BGP are presented in Table 2

3.2. Pre-liminary Phytochemical Screening of Herbal Powder

The preliminary phytochemical analysis of all powder samples (MLP, AGP, BGP) were done and results revealed the presence of phytoconstituents like alkaloids, cardiac glycosides, flavonoids, phenolics and tannins, and saponins, although carbohydrates were found to be present only in AGP and BGP and absent in MLP as shown in Table 3.

3.3. Standardization of Herbal Powders

3.3.1. Physico-chemical Parameter

The analysis of moisture content and ash content during nutritional analysis is of paramount importance as it has a direct impact on the nutritional content of the food materials, its shelf-life, storage and so on. The moisture and ash content of herbal powders were quantified in Table 4.

3.3.2. Characterization of Herbal Powder

The flowability of the powders were demonstrated by calculating the angle of repose, Carr's index and Hausner ratio. The flow of all the powders were fair to passable as the values ranges above 35°, (18 to 28)% and above 1.20 respectively. Table 5 illustrates the flow properties and bulk powder characteristics of powders.

3.4. Evaluation of Nutraceutical Granules

The results of a range of tests conducted on different granules produced. The organoleptic characteristics of the granules are improved from their powdered forms as mentioned in Table 6. Generally, the flow properties of these granules were superior to the ones produced with powders. This is due to the fact that the presence of a binder typically results in denser, larger granules than those produced with powder particles. Generally, the larger the powder particle size, the lower the surface activity, resulting in a better flow. Table 7 illustrates the micromeritic properties with the physico-chemical characteristics.

3.5. *In-vitro* Dissolution Study

The time of dissolution is based on the time taken by the granules to dissolve into the solution. The dissolution profile of different nutraceutical granules demonstrated an increase in dissolution rate (Figure 1). Furthermore, Moringa oleifera granules were found to have a better dissolution rate of Rutin (>100%) in 60 minutes as compared to granules of Amaranth and Buckwheat seeds.

4. Discussion

Herbal powders prepared produced from moringa leaves, amaranth grains and buckwheat groats were assessed for different pre-formulation parameters such as organoleptic characteristics, physico-chemical properties, bulk powder characteristics and phytochemical investigation and the study outcomes lied within the acceptable range. The herbal powders (MLP, AGP, BGP) were then converted into a nutraceutical dosage form i.e., granules. The granules were then examined for a range of evaluation parameters to assess their suitability for use. Organoleptic examination, flow properties, bulk powder characteristics, physico-chemical properties were analysed (Table 6 and 7). The flow properties of granule is directly connected to angle of repose, which was found to be between (23-32)° which is quite good (41) and improved in comparison to the powdered state. The % compressibility and Hausner ratio of the granules was also good in granules i.e., (7-21) % and (1.07-1.24) which was (18-28) % and (1.22-1.38) in powdered state. Although the bulk density and tapped density were not much improved which was found to be (0.43-0.61) and (0.51-0.72) respectively.

Each powder was then converted into four batches i.e., 24 batches were produced using 2 binders (potato starch and maize starch) at concentrations 2 to 5 %w/v. All 24 batches were then examined for *in-vitro* dissolution studies (Figure 1). The *in-vitro* dissolution profile of the granules revealed that the granules prepared from moringa leaf powder (MF1 to MF2) were showing better release profile of the reference marker (Quercetin) which was about 138% in uniform manner within 60 minutes. Although the granules of amaranth and buckwheat were also had a uniform drug release but less in comparison to moringa leaf granules.

5. Conclusion

Experiments have been conducted to determine the feasibility of the formulation of nutraceutical granules derived from Moringa oleifera leaf powder, Amaranth grains powder, and Buckwheat groats powder. Organoleptic properties, physico-chemical analysis, micromeritic properties, phytochemical screening and *in-vitro* dissolution study were carefully evaluated on the granules. The results suggest that these nutraceutical granules are advantageous due to its plant-based formulation, which reduces the risk of adverse side effects compared to other traditional formulations. This study emphasizes the potential of nutraceutical delivery through the use of moringa leaf granules and emphasizes the need for careful formulation design to attain optimal release profiles, thereby contributing to the broader scope of herbal nutraceutical research. It is an optimal supplement for iron deficiency anemia, as the herbs used in the granules are highly enriched with iron content and easily accessible throughout the year and also are cost-effective, making it a cost-effective product.

Conflict of Interest
The authors declare that they have no competing interests.

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FIGURES

Figure 1: *In-vitro* drug release profile of reference marker (Rutin) present in Moringa, Amaranth and Buckwheat granules

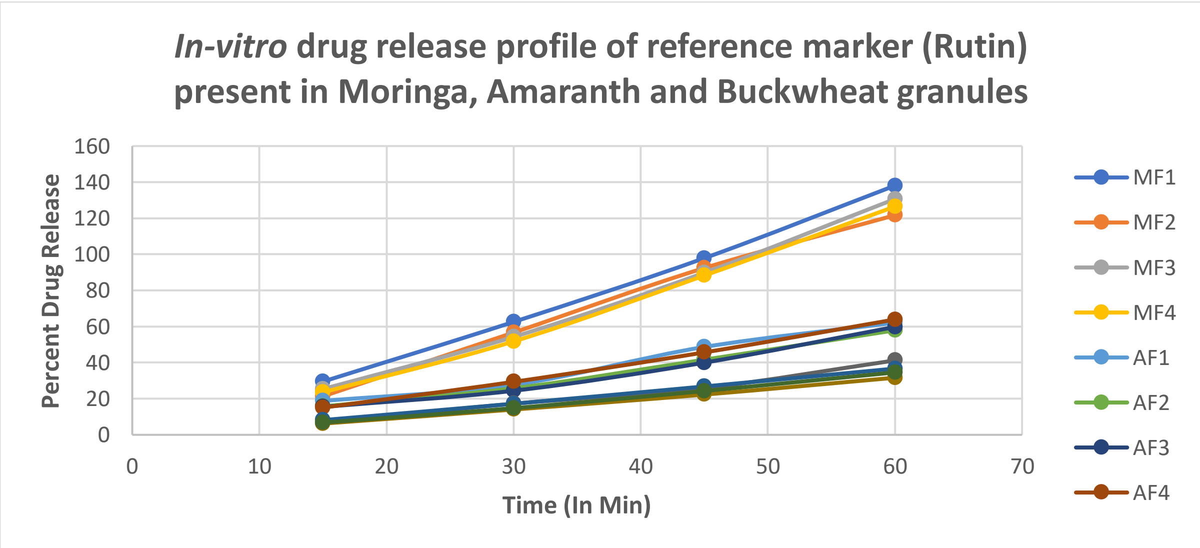

Figure 1: *In-vitro* drug release profile of reference marker (Rutin) present in Moringa, Amaranth and Buckwheat granules

TABLES

Table 1: Composition of Nutraceutical Granules of Moringa leaves, Amaranth grains, and Buckwheat groats powder

Table 2: Organoleptic characteristics of Powders

Table 3: Phytochemical Screening of MLP, AGP and BGP

Table 4: Moisture content and Ash value of Herbal Powders.

Table 5: Flow properties and Bulk Powder Characteristics of Herbal Powder

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Table 6: Organoleptic characteristic of Nutraceutical Granules

Table 7: Flow properties and Bulk Powder Characteristics of Nutraceutical Granules

Table 1: Composition of Nutraceutical Granules of Moringa leaves, Amaranth grains, and Buckwheat groats powder

Ingredients	**Moringa Formulation**				**Buckwheat Formulation**				**Amaranth Formulation**			
	MF 1	**MF 2**	**MF 3**	**MF 4**	**BF 1**	**BF 2**	**BF 3**	**BF 4**	**AF 1**	**AF 2**	**AF 3**	**AF 4**
Active Ingredient (g)	1	1	1	1	1	1	1	1	1	1	1	1
Potato Starch (%)	2	5	2	5	2	5	2	5	2	5	2	5
Maize Starch (%)	2	5	5	2	2	5	5	2	2	5	5	2
Tomato Powder	q.s.	q.s.	q.s.	q.s.	q.s.	q.s.	q.s.	q.s.	q.s.	q.s.	q.s.	q.s.
Stevia (S)	q.s.	q.s.	q.s.	q.s.	q.s.	q.s.	q.s.	q.s.	q.s.	q.s.	q.s.	q.s.
Preservative (P)	q.s.	q.s.	q.s.	q.s.	q.s.	q.s.	q.s.	q.s.	q.s.	q.s.	q.s.	q.s.

Table 2: Organoleptic characteristics of Powders

PARAMETERS	**MLP**	**AGP**	**BGP**
Colour	Vibrant green	Creamy yellow colour	Greyish brown colour
Odour	Smells like henna powder	Nut-like smell	Earthy and nutty
Taste	Slightly bitter, like matcha	Slightly nutty and earthy	Earthy and nutty

Table 3: Phytochemical Screening of MLP, AGP and BGP

PHYTO-CONSTITUENTS	**MLP**	**AGP**	**BGP**
Alkaloids	+	+	+
Anthraquinones	-	-	-
Flavonoids	+	+	+
Cardiac glycosides	+	+	+
Phenolics	+	+	+
Tannins	+	+	+
Saponins	+	+	+
Triterpenes	-	-	-
Carbohydrates	-	+	+

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Table 4: Moisture content and Ash value of Herbal Powders.

PARA-METERS	MLP	AGP	BGP
Moisture content (%w/w) Mean (n=3) ± SD	4.3 ± 0.09	7.4 ± 0.07	8.4 ± 0.25
Ash Value (%w/w) Mean (n=3) ± SD	0.52 ± 0.02	3.52 ± 0.01	2.73 ± 0.02

Table 5: Flow properties and Bulk Powder Characteristics of Herbal Powder

PARA-METERS	MLP	AGP	BGP
Carr's Index (%) Mean (n=3) ± SD	18.77 ± 0.105	27.73 ± 0.011	24.46 ± 0.011
Hausner Ratio Mean (n=3) ± SD	1.22 ± 0.011	1.38 ± 0.005	1.31 ± 0.011
Angle of Repose (°) Mean (n=3) ± SD	38.30 ± 0.025	36.50 ± 0.015	46.64 ± 0.026
Bulk density (g/ml) Mean (n=3) ± SD	0.413 ± 0.011	0.547 ± 0.020	0.619 ± 0.010
Tapped density (g/ml) Mean (n=3) ± SD	0.516 ± 0.004	0.753 ± 0.005	0.815 ± 0.005

Table 6: Organoleptic characteristic of Nutraceutical Granules

PARAMETERS	MF1	MF2	MF3	MF4	AF1	AF2	AF3	AF4	BF1	BF2	BF3	BF4
Colour	Vibrant green				Creamy reddish				Creamy reddish			
Odour	Smells like henna powder				Nut-like smell				Earthy and nutty			
Taste	Sweet with light matcha like				Sweet with slightly nutty and earthy				Sweet with little earthy and nutty			

Table 7: Flow properties and Bulk Powder Characteristics of Nutraceutical Granules

PARAMETERS	MF1	MF2	MF3	MF4	AF1	AF2	AF3	AF4	BF1	BF2	BF3	BF4
Carr's Index (%) Mean (n=3) ± SD	7.63 ± 0.07	8.62 ± 0.44	19.18 ± 0.06	18.47 ± 0.44	18.05 ± 0.08	19.31 ± 0.09	20.37 ± 0.23	16.45 ± 0.43	14.56 ± 0.42	13.15 ± 0.13	14.88 ± 0.06	14.48 ± 0.27

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Hausner Ratio Mean (n=3) ± SD	1.07 ± 0.005	1.08 ± 0.005	1.22 ± 0.015	1.21 ± 0.011	1.20 ± 0.011	1.24 ± 0.005	1.23 ± 0.023	1.18 ± 0.01	1.16 ± 0.01	1.15 ± 0.005	1.16 ± 0.005	1.16 ± 0.011
Angle of Repose (°) Mean (n=3) ± SD	29.16 ± 0.13	32.14 ± 0.12	30.40 ± 0.51	29.22 ± 0.02	26.06 ± 0.05	23.17 ± 0.15	27.90 ± 0.78	29.52 ± 0.27	31.28 ± 0.16	30.64 ± 0.55	27.01 ± 0.01	26.68 ± 0.58
Bulk density (g/ml) Mean (n=3) ± SD	0.48 ± 0.011	0.52 ± 0.010	0.43 ± 0.015	0.47 ± 0.021	0.51 ± 0.015	0.56 ± 0.021	0.53 ± 0.017	0.64 ± 0.040	0.56 ± 0.026	0.61 ± 0.025	0.59 ± 0.020	0.51 ± 0.010
Tapped density (g/ml) Mean (n=3) ± SD	0.51 ± 0.005	0.55 ± 0.015	0.54 ± 0.026	0.54 ± 0.035	0.60 ± 0.011	0.65 ± 0.032	0.64 ± 0.035	0.72 ± 0.017	0.65 ± 0.026	0.65 ± 0.025	0.66 ± 0.045	0.65 ± 0.037
Moisture content (%w/w) Mean (n=3) ± SD	1.63 ± 0.03	1.74 ± 0.04	1.76 ± 0.05	1.50 ± 0.13	1.93 ± 0.04	1.85 ± 0.04	1.87 ± 0.06	1.53 ± 0.10	1.65 ± 0.05	1.57 ± 0.08	1.33 ± 0.12	1.58 ± 0.12