ORIGINAL ARTICLE

Formulation and Evaluation of Nutraceutical Dosage form from *Moringa oleifera, Amaranthus caudatus*, and *Fagopyrum esculentum*

Ritu Saini, Meenakshi Bajpai

Institute of Pharmaceutical Research, GLA University, Mathura, Uttar Pradesh, India

Abstract

Background: Recent years have seen a rise in the popularity of nutraceutical foods and related items as the importance of nutrition for health and wellness has come to light. Their potential health benefits, which extend beyond basic nutrition, make them extremely important in the control and management of health disorders. Nutraceutical foods are extremely rich in vital components, such as micronutrients, vitamins, minerals, and antioxidants. These components not only have a high nutritional value but also support healthy immune and physiological systems, which can help prevent disorders related to nutrition. **Objectives:** This study employs three potential crops – *Fagopyrum esculentum*, *Amaranthus caudatus*, and *Moringa oleifera* – to generate and assess nutraceutical granules. The exceptional nutritional profiles of these crops, which contain a range of bioactive compounds, amino acids, minerals, and vitamins, are well known. **Materials and Methods:** The granules were made using the wet granulation technique using different binders (potato and maize starch), and they were then examined for a number of assessment characteristics. **Results:** The nutraceutical granules showed improved physicochemical and micrometric capabilities compared to their powdered versions, the findings showed. It was found that the granules' *in vitro* disintegration profile may reach 99.62%. **Conclusion:** Because of their exceptional mineral (iron) content, they are affordable and practical alternatives to the traditional formulations that are available for the therapy of nutritional problems such as iron deficiency anemia.

Key words: Amaranth, buckwheat, granules, *Moringa* leaf powder, nutraceutical dosage form

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 the 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 health-care programs have been developed to address various nutritional deficiencies such as anemia (iron deficiency), goitre (iodine deficiency), and blindness (Vitamin A deficiency), with fortification of food with vitamins and minerals. The outcomes of these health-care 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 nutraceuticals are in the spotlight.[2,3] This has led to a greater understanding of the role of nutraceuticals as a preventative medical approach that prevents sickness or damage by supplying nutrients essential to sustain a healthy and disease-free body.[4-7]

Address for correspondence:
Ritu Saini, Institute of Pharmaceutical Research, GLA University, Mathura, Uttar Pradesh, India.
Phone: +91-9639649272.
E-mail: akanshapharma24@gmail.com

Received: 12-05-2024
Revised: 13-06-2024
Accepted: 26-06-2024

Nutraceuticals are nutritional supplements that are composed of components of dietary foodstuffs and sold in the form of medicines. They have the advantage of offering protection against a wide range of health conditions.[8,9] The 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 and 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 populations and escalating health-care 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 and 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 caudatus* (*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 fibers), they also contain a variety of micronutrients, phytonutrients, and antioxidants with promising bioactive effects.

M. oleifera generally called by names such as *Moringa* tree or drumsticks tree, is a wonderful remedy presented to us by 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 bioactive phytochemicals.[17,18] The leaves are packed with nutrients such as Vitamins A, C, and E; minerals such as 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 such as urinary tract infections, HIV-acquired immunodeficiency syndrome, Herpes simplex virus, Epstein–Barr virus, and hepatitis. It has also been reported to be effective in promoting lactation, improving catarrh function, reducing malnutrition and weight, and treating scurvy. In addition, it also has been found to possess antiseptic and antioxidant activity,[20] with anti-anemic and anti-hypertensive potential.[21-24]

A. caudatus, an annual weed plant, is known for its slightly flavored edible leaves and seeds and 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 such as wheat and rice, amaranth seeds constituted with higher levels of protein and unsaturated fatty acids with a well-proportioned content of amino acids. Moreover, they offer a richer assortment of minerals such as calcium and iron; Vitamins such as A, K, B6, C, E, and B; and fibers, serving as a 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, *F. esculentum* also known as buckwheat is an herbaceous plant and a pseudo-grain crop[30] just like amaranth. Buckwheat groats (triangular-shaped grain-like and hulled seeds)[31] are highly nutritious, offering a wide range of essential nutrients. They are rich in dietary fibers, trace elements, flavonoids – rutin and quercetin, and essential fatty acids.[32] In addition to that, they also possess high levels of minerals such as magnesium, iron, calcium, and phosphorous and antioxidant-rich Vitamins A, B-complexes, C, and E.[33] It has been characterized by its potent antioxidant activity, anti-inflammatory potential, and anti-hypertensive potential, which are valuable for the treatment of cardiovascular disorders.[34] In addition, it has been demonstrated to possess anti-cancer, anti-allergic, hepato-protective, anti-diabetic, anti-fibrotic, anti-fatigue, anti-hyperlipidemia, 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 through 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.

MATERIALS AND METHODS

Collection of herbs

M. 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 was purchased from Prince Scientific. The remaining reagents and chemical substances used were all of analytical grade.

Preparation of herbal powder

The leaf powder of *Moringa* was sourced, whereas 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]

Organoleptic characterization

The organoleptic characterization of *Moringa* leaves powder (MLP), amaranth grains powder (AGP), and buckwheat groats powder (BGP) was carried out by analyzing their color, odor, and taste of the powdered herbs at room temperature.[36-38]

Preliminary phytochemical screening of herbal powders

Each of the powders (MLP, AGP, and BGP) was 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.

Procedure for testing Alkaloids

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

Procedure for testing Anthraquinones

A few mL of each of the test solutions were shaken with benzene (10 mL) and filtered. Then, the filtrate was shaken with 10% (5 mL) ammonia solution.

Procedure for testing cardiac glycosides

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

Procedure for testing flavonoids

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

Procedure for testing phenolics

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

Procedure for testing saponins

Approximately 5 mL of each test solution was shaken in a test tube for about 5–7 min.

Procedure for testing tannins

Approximately 2 mL of each of the test solution was mixed with ferric chloride solution (5% w/v).

Procedure for testing carbohydrates

To each of the test solutions, about 2–3 drops of Molisch's reagent were added. To this mixture, about 2 mL of concentrated H_2SO_4 was transferred through the sideways of the test tube.[30,31]

Standardization of herbal powders

Determination of ash content

Each of the powder was poured into the pre-weighed crucible (A) at a weight of 2 g (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

"B" g of herbal powder gives = (A–C) g of ash

100 g of herbal powder gives = 100× (A–C) %w/w of ash.

Determination of moisture content

Each of the powdered samples weighing 2 g (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 h 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 using the following expression[40]:

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

Micromeritic characterization of herbal powder

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 powders 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 using the following expression[41]:

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

Bulk density and tapped density

Approximately 15 g (w) of each sample was poured into a dry measuring cylinder. Leveling the powder without tamping is important, and the apparent volume (V_0) was measured after the powder had been leveled. 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]:

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

Determination of Carr's index and Hausner ratio

The findings of bulk density and tapped density were substituted into the following expressions for the calculation of Carr's index and Hausner ratio[41]:

$$Carr's\ Index\left(\%\right) = \frac{\rho t - \rho b}{\rho^{t}} \times 100$$

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

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]

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]

In vitro dissolution study

The *in vitro* dissolution of the granules was assessed utilizing USP-apparatus type-II (paddle type). The granules equivalent to 1 g of the herbal powder 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 50/min. Aliquots of the dissolving medium (5 mL) were collected from the container at intervals of 5, 15, 30, 45, 60, 90, and 120 min and immediately replaced with 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. The 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 Rutin[17,32,44] for different time-points were used to assess the degree of dissolution.[19]

RESULTS

Organoleptic characteristics

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

Pre-liminary phytochemical screening of herbal powder

The preliminary phytochemical analysis of all powder samples (MLP, AGP, and BGP) was done and results revealed the presence of phytoconstituents such as alkaloids, cardiac glycosides, flavonoids, phenolics and tannins, and saponins,

Table 1: Composition of nutraceutical granules of Moringa leaves, amaranth grains, and buckwheat groats powder

Ingredients	*Moringa* formulation				Buckwheat formulation				Amaranth formulation			
	MF1	MF2	MF3	MF4	BF1	BF2	BF3	BF4	AF1	AF2	AF3	AF4
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	qs	qs	qs	qs	qs	qs	qs	qs	qs	qs	qs	qs
Stevia (S)	qs	qs	qs	qs	qs	qs	qs	qs	qs	qs	qs	qs
Preservative (P)	qs	qs	qs	qs	qs	qs	qs	qs	qs	qs	qs	qs

Table 2: Organoleptic characteristics of powders

Parameters	MLP	AGP	BGP
Color	Vibrant green	Creamy yellow color	Grayish brown color
Odor	Smells like henna powder	Nut-like smell	Earthy and nutty
Taste	Slightly bitter like matcha	Slightly nutty and earthy	Earthy and nutty

MLP: Moringa leaves powder, AGP: Amaranth grains powder, BGP: Buckwheat groats powder

although carbohydrates were found to be present only in AGP and BGP and absent in MLP as shown in Table 3.

Standardization of herbal powders

Physicochemical 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.

Micromeritic characterization of herbal powder

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

Evaluation of nutraceutical granules

The results of a range of tests conducted on different granules were produced. The organoleptic characteristics of the granules are improved from their powdered forms as mentioned in Table 6. In general, 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. In general, 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.

Table 3: Phytochemical screening of MLP, AGP, and BGP

Phyto-constituents	MLP	AGP	BGP
Alkaloids	+	+	+
Anthraquinones	-	-	-
Flavonoids	+	+	+
Cardiac glycosides	+	+	+
Phenolics	+	+	+
Tannins	+	+	+
Saponins	+	+	+
Triterpenes	-	-	-
Carbohydrates	-	+	+

MLP: Moringa leaves powder, AGP: Amaranth grains powder, BGP: Buckwheat groats powder

Table 4: Moisture content and ash value of herbal powders

Parameters	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

MLP: Moringa leaves powder, AGP: Amaranth grains powder, BGP: Buckwheat groats powder

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, *M. oleifera*

Table 5: Flow properties and bulk powder characteristics of herbal powder

Parameters	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

MLP: Moringa leaves powder, AGP: Amaranth grains powder, BGP: Buckwheat groats powder

Table 6: Organoleptic characteristic of nutraceutical granules

Parameters	MF1	MF2	MF3	MF4	AF1	AF2	AF3	AF4	BF1	BF2	BF3	BF4
Color	Vibrant green				Creamy reddish				Creamy reddish			
Odor	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			

granules were found to have a better dissolution rate of Rutin (up to 99.62%) in 120 min as compared to granules of amaranth and buckwheat seeds.

DISCUSSION

The formulator might gain an understanding of issues pertaining to the herbal powders by examining the organoleptic qualities [Table 2]. The phytochemical screening [Table 3] was performed to identify the herbal powders and found to be within the acceptable range. The resulting moisture content of the herbal powders ranging from 4.3% to 8.4% is under the permitted range and indicates the ability to inhibit the growth of yeast, fungi, or bacteria due to its low value.[21] The percentage of ash value is from 0.52 to 3.52% for the herbal powders. According to FSSAI guidelines, the herbal powders' total ash level on a dry basis cannot be higher than 7.50%[45] [Table 4]. The micrometric characterization [Table 5] of the powders indicated their sticky nature, so to make them flowable, granulation of the powders is required. Flavors like tomato powder and sweetener like stevia were also added to the granules to make them more palatable by improving their taste and smell.

Nutraceutical granules were then formulated by herbal powders (MLP, AGP, and BGP). To determine, if the granules were suitable for use, different parameters such as organoleptic properties, flow properties, bulk powder characteristics, and physicochemical properties were evaluated on the granules [Tables 6 and 7]. Organoleptic examination, flow properties, bulk powder characteristics, and physicochemical properties were analyzed [Tables 6 and 7]. The flow properties of the granule are directly connected to the angle of repose, which was found to be between 23° and 32° which is quite good[41] and improved in comparison to the powdered state. The % compressibility and Hausner ratio of the granules were also good in granules, i.e., (7–21)% and (1.07–1.24) which was (18–28)% and (1.22–1.38) in the powdered state. Although the bulk density and tapped density were not much improved which were 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 two binders (potato starch and maize starch) at concentrations 2–5% 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) showed a better release profile of the reference marker (Rutin) which was about 99.62% in uniform manner within 120 min. The solubility of the herbal powders was enhanced by its granule formation, which increased the powder's surface area in contact with the dissolving media. It is anticipated that lower drug solubility will result in a reduced dissolution rate. Furthermore, the Noyes–Whitney law states that the surface area and concentration gradient are directly related to the dissolution rate. The drug release from amaranth and buckwheat granules was uniform; however, it was not as pronounced as that from *Moringa* leaf granules.

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
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

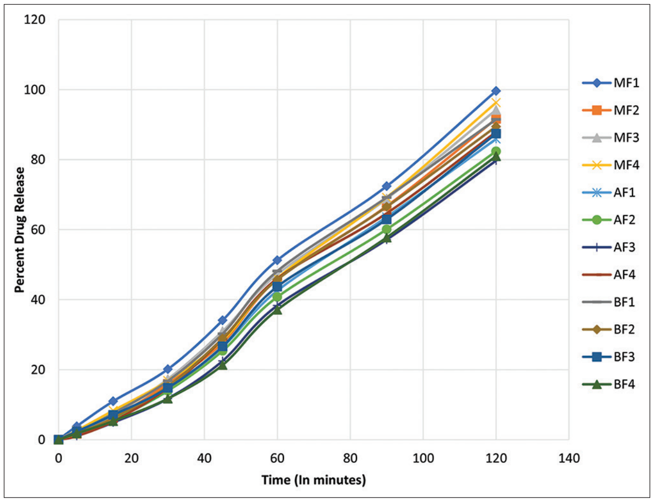

Figure 1: *In vitro* drug release profile of reference marker (Rutin) present in *Moringa*, amaranth, and buckwheat granules

CONCLUSION

Experiments have been conducted to determine the feasibility of the formulation of nutraceutical granules derived from *M. oleifera* leaf powder, AGP, and BGP. Organoleptic properties, physicochemical 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 cost-effective, making it a cost-effective product.

ACKNOWLEDGMENT

The authors wish to thank GLA University, Mathura, Uttar Pradesh, India, for providing time-to-time help and support.

REFERENCES

1. Malve H, Bhalerao P. Past, present, and likely future of nutraceuticals in India: Evolving role of pharmaceutical physicians. J Pharm Bioallied Sci 2023;15:68-74.
2. Temple Norman J, Gladwin KK. Fruit, vegetables, and the prevention of cancer: Research challenges. Nutrition 2003;19:467-70.
3. Whitman M. Understanding the perceived need for complementary and alternative nutraceuticals: Lifestyle issues. Clin J Oncol Nurs 2001;5:190-4.
4. Heyland DK. In search of the magic nutraceutical: Problems with current approaches. J Nutr 2001;1:2591S-5.
5. Kalra EK. Nutraceutical - definition and introduction. AAPS PharmSci 2003;5:E25.
6. Sumi Y. Research and technology trends of nutraceuticals. Sci Technol Trends 2008;28:10-22.
7. Klein C, Sato T, Meguid MM, Miyata G. From food to nutritional support to specific nutraceuticals: A journey across time in the treatment of disease. J Gastroenterol 2000;35 Suppl 12:1-6.
8. Pagan JD, Crandell K, Duren S, Crandell K, Duren S. Advances in Equine Nutrition. Nutraceuticals: What are they and do they Work? Vol. 2. Nottingham: Nottingham University Press; 1998.
9. Rajasekaran A, Xavier R. Nutraceuticals as Therapeutic Agents: A review on Occurrence of *Bacillus thuringiensis* in Faeces of Herbivorous Farm Animals and Microscopic Analysis of a Native *Bacillus thuringiensis* Strain from Malaysia that Produces Exosporium-Enclosed Parasporal Inclusion View Project Molecular Docking Studies of Flavones in Gentianaceae Family against Liver Corrective Targets View project. Available from: https://www.researchgate.net/publication/268427982 [Last accessed on 2023 Nov 06].
10. Rajam RP, Murugesan G, Vadivelkumar K, Menachisundaram V. Nutraceuticals-a review. World J Pharm Res 2019;8:1355-74.
11. Doke RM, Mahale AM, Karanjkar AR, Amge SA, Doke RM. Recent trends for neutraceuticals in Indian market. Indo Am J Pharm Res 2013;3:4001-20.
12. Ruchi S, Amanjot K, Sourav T, Keerti B, Sujit B. Role of nutraceuticals in health care: A review. Int J Green Pharm 2017;11:S385-94.
13. Shinde N, Bangar B, Deshmukh S, Kumbhar P. Nutraceuticals: A review on current status. Res J Pharm Technol 2014;7:110-3.
14. Brar SK, Kaur S, Dhillon GS. Nutraceuticals and Functional Foods: Natural Remedy. USA: Nova Science, Inc.; 1998.
15. Faizullabhoy M, Wani G. Global Market Insights. Nutraceutical Market - By Product (Functional Foods {Baby Food, Cereals}, Dietary Supplements), Form (Capsules, Tablets, Gummies), Condition (Weight Management, Joint Health, Skin, Hair), Distribution Channel (Pharmacies), Global Forecast, 2023-2032. Asia Pacific, Latin America, North America, Africa and Europe: Global Market Insights; 2023. p. 1-270.
16. Alsammarraie HJ, Khan NA, Mahmud R. Formulation, evaluation, and *in vivo* anti-inflammatory and anti-arthritic activities of *Moringa* granules. Int J Appl Pharm 2021;13:112-20.
17. Alsammarraie H, Khan N, Mahmud R, Bin Asmawi M, Murugaiyah V. Preformulation, stress stability studies and HPLC-UV method development and validation for 95 % ethanol extract of *Moringa oleifera* Lam. Leaves. Bull Fac Pharm Cairo Univ 2019;57:114-26.

18. Islam Z, Rashadul Islam SM, Hossen F, Mahtab-ul-Islam K, Hasan R, Karim R. *Moringa oleifera* is a prominent source of nutrients with potential health benefits. Int J Food Sci 2021;2021:6627265.
19. Muazu J, Suleiman Z. Design, formulation and tableting properties of aqueous leaf extract of *Moringa oleifera*. Br J Pharm Res 2014;4:2261-72.
20. Rani KC, Parfati N, Ekajayani NI, Kurniawan IM, Kristiani NP. The development of *Moringa* leaves effervescent granules with effervescent agent of citric acid and sodium bicarbonate. Pharmaciana 2021;11:225-38.
21. Okoye EI, Awotunde TO, Morales TG. Formulation and characterization of *Moringa oleifera* leaf granules. I: Micromeritic properties. Res J Pharm Technol 2013;6:66-74.
22. Gopalakrishnan L, Doriya K, Kumar DS. *Moringa oleifera*: A review on nutritive importance and its medicinal application. Food Sci Hum Wellness 2016;5:49-56.
23. Rani NZ, Husain K, Kumolosasi E. *Moringa* genus: A review of phytochemistry and pharmacology. Front Pharmacol 2018;9:108.
24. Sierra-Campos E, Téllez-Valencia A, Aguilera-Ortíz M. Standardization based on chemical markers of *Moringa oleifera* herbal products using bioautography assay, thin layer chromatography and high performance liquid chromatography-*Serinus canaria* microbiota view project *Moringa oleifera* View project. Malaysian J Analyt Sci 2020;24:449-63.
25. Jimoh MO, Okaiyeto K, Oguntibeju OO, Laubscher CP. A systematic review on *Amaranthus*-related research. Horticulturae 2022;8:239.
26. Kour DP, Gupta N. Health benefits and uses of Amaranth. Just Agric 2022;2:1-6.
27. Maurya NK, Arya P. *Amaranthus* grain nutritional benefits: A review. J Pharmacogn Phytochem 2018;7:2258-62.
28. Singh A, Punia D. Characterization and nutritive values of Amaranth seeds. Curr J Appl Sci Technol 2020;39:27-33.
29. Peter K, Gandhi P. Rediscovering the therapeutic potential of *Amaranthus* species: A review. Egypt J Basic Appl Sci 2017;4:196-205.
30. Malgorzata W, Maria SŚ, Urszula KK. Buckwheat, as a food component of a high nutritional value, used in the prophylaxis of gastrointestinal diseases. Eur J Plant Sci Biotechnol 2010;4:1-8.
31. Przybylski R, Gruczyyska E. A review of nutritional and nutraceutical components of buckwheat. Eur J Plant Sci Biotechnol 2009;3:10-22.
32. Badamtsetseg S, Badamkhand D, Sukhdolgr J, Baigalmaa TS. Biologically active substances in buckwheat (*Fagopyrum tataricum* L.) cultivated in Mongolia. Mong J Biol Sci 2006;4:57-61.
33. Sofi SA, Ahmed N, Farooq A, Rafiq S, Zargar SM, Kamran F, *et al*. Nutritional and bioactive characteristics of buckwheat, and its potential for developing gluten-free products: An updated overview. Food Sci Nutr 2022;11:2256-76.
34. Nalinkumar A, Singh P. An overview of buckwheat (*Fagopyrum* spp)-an underutilized crop in India-nutritional value and health benefits. Int J Med Res Health Sci 2020;9:39-44.
35. Singh MC, Gujar KN, Singhvi I, Kashibai S. Optimization, evaluation and stability study of nutraceutical powder formulations developed from edible seed and leafy-vegetable sources. Int J Pharm Sci Res 2020;11:1617.
36. Okumu MO, Mbaria JM, Kanja LW, Gakuya DW, Kiama SG, Ochola FO. Phytochemical profile and antioxidant capacity of leaves of *Moringa oleifera* (Lam) extracted using different solvent systems. J Pharmacogn Phytochem 2016;5:302-8.
37. Evans WC. Trease and Evans Pharmacognosy. 16th ed. Edinburgh: Saunders Limited; 2009. p. 585-9.
38. Kokate CK. Practical Pharmacognosy. 3rd ed. Delhi: Vallabh Prakashan; 2005. p. 107-21.
39. Taiwade R, Walke S, Pise SA, Pise AG, Mahajan U. Formulation and evaluation of nutraceutical rejuvenator for sports persons. Res J Pharm Technol 2019;12:3903.
40. Gawali VB, Bhalsingh M, Dalvi NB, Tarkasband YS. Development and evaluation of polyhebral powder formulation as energy booster. J Pharmacogn Phytochem 2018;7:1576-80.
41. Aulton ME, Taylor KM. Aulton's Pharmaceutics the Design and Manufacture of Medicines. 5th ed. Edinburgh: Elsevier; 2018. p. 196-8.
42. Singh MC, Gujar KN. Preparation and evaluation of nutraceutical formulations of leaves of *Trigonella foenum* Graecum, *Coriandrum sativum*, *Raphanus raphanistrum* and *Anethum graveolens*. Int Res J Pharm 2018;9:164-9.
43. Chaudhari SP, Bangar JV, Akuskar GK, Ratnaparkhi MP. Development and validation of UV spectrophotometric method for simultaneous estimation of rutin and quercetin in niosome formulation. Der Pharm Lett 2014;6:271-6.
44. Manyelo TG, Sebola NA, Hassan ZM, Ng'ambi JW, Weeks WJ, Mabelebele M. Chemical composition and metabolomic analysis of *Amaranthus cruentus* grains harvested at different stages. Molecules 2022;27:623.
45. Palamthodi S, Shimpi S, Tungare K. A study on nutritional composition and functional properties of wheat, ragi and jackfruit seed composite flour. Food Sci Appl Biotechnol 2020;4:63-75.

Source of Support: Nil. **Conflicts of Interest:** None declared.