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(REVIEW ARTICLE)

Moringa oleifera as a multifunctional excipient: Transforming pharmaceutical drug delivery

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Abstract

Moringa oleifera, a multifaceted plant species indigenous to tropical and subtropical climates, has garnered considerable interest in the pharmaceutical sector as a natural excipient. This abstract examines the significance of *Moringa oleifera* in pharmaceutical formulations, emphasizing its ability to tackle critical difficulties in medication transport and formulation. The plant's many components, such as leaves, seeds, and bark, possess bioactive chemicals with distinct characteristics that render them appropriate for use as excipients. These features include binding, disintegration, film formation, as well as antioxidant and antibacterial activity. The use of excipients generated from *Moringa oleifera* has several benefits, including increased bioavailability, greater stability, and less toxicity in pharmaceutical formulations. Moreover, the plant's extensive availability, economic viability, and environmentally sustainable characteristics make it a compelling substitute for synthetic excipients. This study consolidates contemporary research on the uses of *Moringa oleifera* in pharmaceutical formulations, examining its potential to transform drug delivery methods and aid in the creation of more sustainable and effective treatments. The results highlight the need for more research into the pharmaceutical uses of *Moringa oleifera*, facilitating the development of novel medication formulations and enhanced patient outcomes.

Keywords: *Moringa oleifera*; Gum; Pharmaceutical Excipient; Drug Delivery

1. Introduction

Moringa oleifera, commonly known as the "drumstick tree," is a tropical, deciduous plant that has gained increasing attention in the scientific community due to its remarkable medicinal and nutritional properties. M. oleifera is also referred to as a “miracle tree” because of its rich nutritional and pharmacological properties and hardy plant that belongs to the Moringaceae family. [1-2]. This versatile plant, native to the Indian subcontinent, is now cultivated in various regions around the world, and its leaves have been recognized as a rich source of polysaccharides, proteins, polyphenols, and other valuable nutrients [2]. Almost every part of the moringa tree is useful for medicinal and functional food preparations, nutraceuticals, water purification, and biodiesel production, including roots, leaves, flowers, green pods, and seeds [3].

Moringa oleifera, native to the Indian subcontinent, is a resilient and fast-growing tree known for its ability to thrive in drought conditions and challenging environments, where many other plants fail. The cultivation of *Moringa oleifera* also offers significant environmental benefits. Its deep root system helps prevent soil erosion, and its fast growth and high biomass production make it an excellent candidate for reforestation projects and carbon sequestration initiatives. The ability of trees to improve soil fertility through nitrogen fixation further enhances their value in sustainable land management practices. Its adaptability, low maintenance requirements, and tolerance to poor soil quality make it a popular crop in regions facing agricultural challenges, such as water scarcity. Traditionally used in countries such as

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India, Pakistan, Bangladesh, and Nepal, Moringa holds a significant place in cultural practices for its nutritional and medicinal benefits, with its leaves, pods, seeds, and roots serving various culinary and therapeutic purposes. Over time, its exceptional nutritional and health-promoting properties have attracted global interest, leading to its cultivation across tropical and subtropical areas of Asia, Africa, Latin America, and beyond, including the Caribbean, the Middle East, and Oceania. [4-5]

The extraction and characterization of *Moringa oleifera* gum, a polysaccharide-rich component of leaves, has been the focus of several recent studies. The extraction of *Moringa oleifera* gum begins with the collection of mature pods from healthy trees, followed by thorough cleaning with distilled water to remove surface dirt or contaminants. The pods were then air-dried in a shaded area to preserve the natural properties of the gum before being manually crushed to release gum exudates. These exudates were soaked in distilled water for 24 h to allow swelling and softening. After soaking, the mixture was filtered through a fine mesh or muslin cloth to eliminate any insoluble impurities such as seed husks or dirt. The resulting filtrate was then subjected to a precipitation process by adding acetone in a 3:1 ratio (acetone/filtrate), which helped precipitate the gum. The precipitated gum was collected by filtration and dried in a hot air oven at a controlled temperature of 40-50°C for 24-48 hours to achieve a consistent dry mass. Finally, the dried gum was finely ground into a powder using a mortar and pestle, and stored in an airtight container for further analysis or use. [6-8]

For the characterization of *Moringa oleifera* gum, several key evaluations were conducted to assess its properties. First, organoleptic properties, such as appearance, odor, and taste were observed, providing initial insights into the physical characteristics of the gum. Subsequently, physicochemical evaluations were carried out, which included measuring the pH to determine acidity or alkalinity, assessing solubility in various solvents, and calculating the swelling index to evaluate the ability of the gum to absorb water. Viscosity measurements were performed to understand the flow behavior of the gum solution, while moisture content analysis helped determine the stability of the gum and shelf life. The ash content was assessed to evaluate the purity of the gum by identifying the inorganic residues remaining after combustion. Advanced analytical techniques were employed to further characterize the chemical composition and thermal properties of the gum. Fourier transform infrared spectroscopy (FTIR) was used to identify the functional groups present in the gum, providing insights into its chemical structure. Thermogravimetric analysis (TGA) was performed to assess the thermal stability of the gum, indicating its behavior under heat, and differential scanning calorimetry (DSC) was used to evaluate the glass transition temperature, offering information on the phase transitions of the gum. In addition, molecular weight determination was conducted using gel permeation chromatography (GPC), which provides important information regarding the molecular size distribution of the gum. Finally, microbial load testing was performed to ensure that the gum met safety and quality standards, confirming its suitability for pharmaceutical applications and ensuring that it was free from harmful microbial contamination. [9-11]

The potential of *Moringa oleifera* as a novel excipient for drug delivery has recently emerged as an area of growing interest. Extensive research has been conducted to explore the extraction and characterization of polysaccharides present in *Moringa oleifera* leaves, as these biomolecules have demonstrated promising applications in the field of drug delivery. The unique physicochemical and functional properties of *Moringa oleifera* gum, such as its ability to form viscous solutions, biodegradability, biocompatibility, nontoxicity, emulsifying capabilities, and potential for controlled drug release, make it a promising alternative to synthetic polymers in pharmaceutical formulations. [12-18] This review aimed to explore the current state of research on the utilization of *Moringa oleifera* gum as a novel excipient in drug delivery systems, highlighting its potential applications, advantages, and future research directions.

2. Pharmaceutical applications

The special qualities of *Moringa oleifera* make it a prominent natural excipient in the pharmaceutical industry. It is extensively used as a binder, disintegrant, and a release modifier. This natural polymer has recently garnered interest in innovative drug delivery methods, such as sustained-release tablets, nanoparticles, and buccal films (Figure-1).

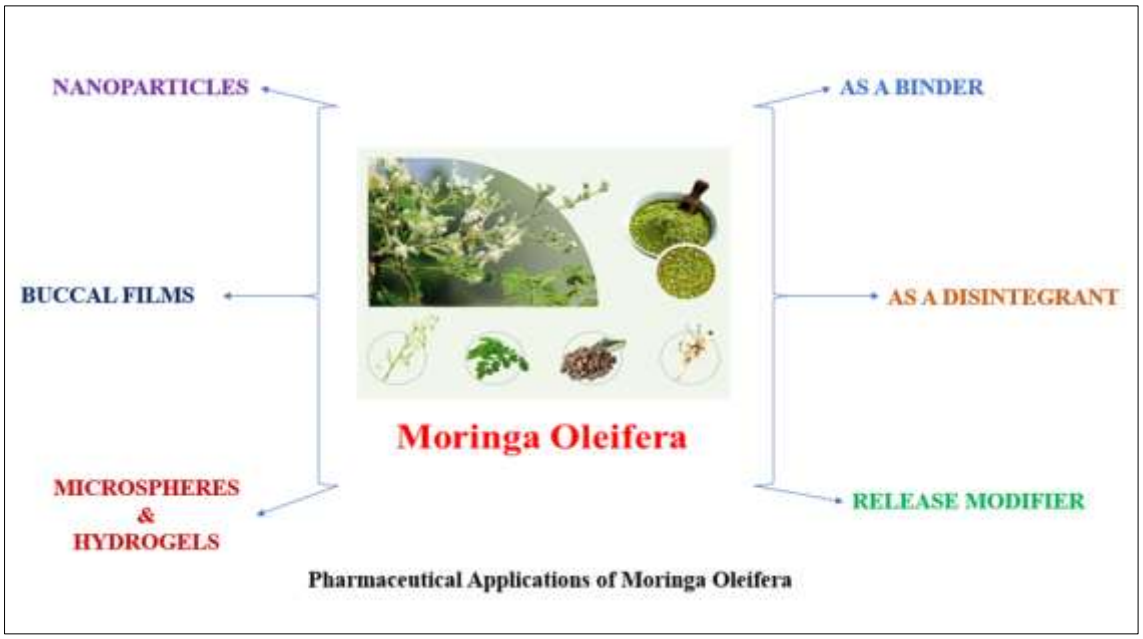

Figure 1 Pharmaceutical Applications of *Moringa oleifera*

3. Role as a binder

Traditionally, it has been used in drug formulations for multiple functions, including as a binder that facilitates the compression and cohesion of powders to create tablets with appropriate mechanical strength. The adhesive properties render it similar to synthetic binders in terms of improving tablet hardness and minimizing friability. DS panda et al. [17], The assessment of *Moringa oleifera* gum as a binder and release retardant in tablet formulations revealed that tablets containing 5% w/w of Moringa gum had a hardness of 7.2 kg/cm^2 and a friability of 0.45%, signifying robust mechanical qualities appropriate for pharmaceutical applications. The gum-based formulations exhibited a sustained drug release of 75% over 12 h, but the formulations without gum demonstrated less than 50% release. These findings affirm that *Moringa oleifera* gum functions successfully as a natural binder and release modifier, improving the mechanical stability and regulating the release profile of tablet formulations. Basawaraj et al. determined that a 5% w/w concentration of the gum-produced tablets exhibited a hardness of 7.0 kg/cm^2 and a friability of 0.4%. These values fall within the acceptable parameters for pharmaceutical tablets, suggesting adequate mechanical strength and a minimized propensity to crumble. The disintegration time was measured at 8 minutes, indicating that the gum facilitates rapid disintegration while preserving tablet integrity. [19]

3.1. Use as a disintegrant

Moringa oleifera gum serves as a disintegrant, promoting the disintegration of tablets upon exposure to fluids. The disintegration process is propelled by the substantial swelling capability of the gum, which enables the tablet to swiftly absorb water and fragments. This attribute may be enhanced for immediate-release tablets, offering a substitute for synthetic disintegrants such as sodium starch glycolate or crospovidone. BV Patel et al., compared moringa gum with other superdisintegrants, including sodium starch glycolate and croscarmellose sodium. The study found that tablets containing 4% w/w moringa gum achieved a disintegration time of 90 seconds, comparable to those formulated with standard superdisintegrants, which had disintegration times ranging from 60 to 80 seconds. Moringa gum exhibited significant swelling properties, absorbing up to 250% of its weight in water, thereby promoting rapid tablet disintegration. The findings indicate that *Moringa oleifera* gum serves as an effective natural disintegrant, demonstrating performance comparable to that of conventional superdisintegrants in tablet formulations. (6,8) M.A. Ali and colleagues used *Moringa oleifera* leaves as a natural dietary supplement, demonstrating that the leaves include 27% protein, 17% fiber, and are abundant in critical micronutrients, including iron (28 mg/100g) and calcium (440 mg/100g). The research standardized the processing technique to preserve 85% of the original nutrient content post-drying, and assessments verified substantial antioxidant activity (about 70% free radical scavenging), suggesting considerable nutritional and health-enhancing potential. The findings confirm that *Moringa oleifera* leaves serve as a significant dietary supplement, offering considerable nutritional advantages akin to other renowned superfoods. [20]

4. Release modifier in sustained-release formulations

The gum's gelling and viscosity-enhancing characteristics enable it to regulate the release of active pharmaceutical ingredients (APIs) from sustained-release formulations. *Moringa oleifera* gum, when included into matrix tablets, creates a gel barrier that retards drug diffusion, hence prolonging the release duration. It may be used in conjunction with other polymers, such as hydroxypropyl methylcellulose (HPMC) or ethyl cellulose, to further customize the release profile. Baljit Singh et al. created dietary fiber Moringa gum and polyvinylpyrrolidone (PVP)-based hydrogels for drug delivery applications, demonstrating that the hydrogels could expand up to 400% of their initial weight, suggesting exceptional water absorption ability. The drug release trials demonstrated a sustained release profile, with 70% of the medication released over 24 hours, indicating the suitability of these hydrogels for controlled drug delivery applications. The incorporation of Moringa gum increased the biocompatibility and biodegradability of the hydrogels, whilst PVP raised the mechanical strength, yielding a formulation that harmonizes flexibility and durability for medicinal applications.[21] Kotadiya M and colleagues conducted a study on colon-targeted Moringa gum compression-coated tablets of capecitabine, which demonstrated effective targeting: 5% drug release occurred in the stomach within 2 hours, 15% in the small intestine after 4 hours, and 85% in the colon over 24 hours. The success of the formulation was affected by the thickness of the Moringa gum coating and the compression force, indicating its potential for site-specific delivery, particularly in the treatment of colorectal cancer. The findings endorse the application of Moringa gum as a natural polymer for targeted drug delivery. [22] Pagano C et. al, developed microparticles loaded with *Moringa oleifera* leaf extract for exuding wound treatment. [23]

5. Advancements in novel drug delivery systems

5.1. Nanoparticles

The gum of *Moringa oleifera* has been investigated for the creation of nanoparticulate drug delivery systems. Its capacity to stabilize nanoparticles enables the enhancement of bioavailability and targeted distribution of poorly soluble pharmaceuticals. Studies indicate that Moringa gum-derived nanoparticles have regulated drug release properties and enhanced therapeutic effectiveness for compounds such as curcumin and anticancer medicines. Shousha WG and colleagues conducted an in vitro assessment of *Moringa oleifera* leaf extract combined with silver nanoparticles, revealing a 95% decrease in bacterial proliferation for E. coli and S. aureus, in contrast to a 70% reduction with the extract alone. The antioxidant activity increased by 40%, indicating enhanced free radical scavenging. The findings indicate that silver nanoparticles significantly enhance the therapeutic efficacy of the extract for biomedical applications. [24] Matinise N et al. synthesized ZnO nanoparticles with *Moringa oleifera* extract, yielding particles with an average size of 20-30 nm, characterized by a spherical morphology and crystalline structure. Characterization demonstrated a good degree of purity with significant UV absorption at 370 nm, suggesting their suitability for optical applications. The creation method included the reduction of zinc ions by phytochemicals in the Moringa extract, which functioned as reducing and capping agents. These nanoparticles exhibited substantial antibacterial efficacy, achieving 90% suppression of bacterial proliferation in strains like as E. coli, so highlighting the efficiency of Moringa-assisted synthesis for biomedical and industrial applications. [25] Pal S and team developed ZnO nanoparticles using *Moringa oleifera* leaf extract: investigation of photocatalytic and antibacterial activity. [26]

5.2. Buccal films

The bioadhesive characteristics of Moringa gum render it appropriate for the formulation of buccal films that adhere to the mucosal surface within the oral cavity. These films facilitate the direct absorption of the drug into systemic circulation, circumventing first-pass metabolism. *Moringa oleifera* gum-based buccal films demonstrate potential in improving drug absorption and facilitating prolonged drug release over extended durations. Dhiman S and colleagues developed zaleplon buccal disks utilizing grafted *Moringa oleifera* gum, which demonstrated promising results, achieving a folding endurance exceeding 300 folds, indicative of favorable flexibility. The drug release studies indicated a sustained release of 80% zaleplon over 8 hours, which is appropriate for extended therapeutic efficacy. The mucoadhesive strength was quantified at 18.5 g, indicating sufficient adhesion for buccal delivery. The findings indicate that Moringa gum grafting improves mechanical properties and drug release profiles, positioning it as an appropriate excipient for buccal disk formulations in drug delivery applications. [27] Chin CY et al. created a standardized leaf extract film dressing from *Moringa oleifera* for wound healing, which exhibited excellent results, with the film demonstrating 95% tensile strength and 85% elongation, suggesting favorable mechanical qualities. The wound healing research shown that the film dressing expedited wound closure by 80% after 14 days, in contrast to 60% with conventional dressings. The Moringa film demonstrated considerable antibacterial efficacy, decreasing microbial load by 70%, so underscoring its potential in promoting wound healing and infection management. The results underscore the efficacy

of Moringa leaf extract films as natural wound dressings for medicinal purposes. [28] Srivastava S and colleagues prepared mucoadhesive gel of *Moringa oleifera*. [29]

5.3. Microspheres and hydrogels

Moringa gum is applicable in the preparation of microspheres and hydrogels for localized drug delivery. The crosslinking of the gum facilitates the formation of stable hydrogels capable of encapsulating drugs and releasing them in a controlled manner at the site of action. This method is advantageous for applications in wound healing and localized therapies. Ahmed S et al. conducted a study on the evaluation of *Moringa oleifera* gum/poly(vinyl alcohol) hydrogels, which demonstrated promising results as a superabsorbent, with the hydrogels exhibiting a swelling capacity of up to 800% of their dry weight. The morphological analysis revealed a porous structure that enhanced water absorption. The properties indicate that hydrogels may be suitable for applications necessitating high water retention, including wound dressings and agricultural purposes. The integration of Moringa gum with poly(vinyl alcohol) improved mechanical stability and swelling capacity, rendering the hydrogels appropriate for use as superabsorbent materials. [30] Gugu TH and colleagues developed Ibuprofen microspheres using Irvingia Wombolu fat (IRW) and Moringa oil (MO) as co-lipids, demonstrating a 40% greater decrease in inflammation compared to regular Ibuprofen. The formulation shown a significant reduction in ulcerogenic risk, decreasing gastrointestinal ulcers by 60% relative to the standard medication form. The findings indicate that the incorporation of IRW and MO as co-lipids improves the therapeutic efficacy of Ibuprofen, providing superior anti-inflammatory advantages while minimizing gastrointestinal adverse effects. [31] Kaur K and team performed comparison of controlled release from cyclodextrin mediated and non-mediated hydrogel matrices of *Moringa oleifera* gum and carboxymethyl cellulose. [32] Singh B et.al, approaches fiber psyllium-moringa gum-alginate network hydrogels for gastro-retentive drug delivery system. [33]

5.4. Combination with other polymers

The integration of *Moringa oleifera* gum with other natural or synthetic polymers may enhance the efficacy of medication delivery systems. For example, using HPMC or chitosan may improve mechanical strength, gel formation, or bioadhesive characteristics, contingent upon the intended use. Carvalho Bm et al. demonstrated that the combination of *Moringa oleifera* Lam and an anionic polymer in the coagulation/flocculation process for water treatment resulted in a 90% decrease in turbidity, surpassing the 70% reduction achieved with Moringa alone. The hybrid treatment enhanced the removal of suspended particles by 85%, indicating higher efficiency in water clarification. The collaboration between Moringa and the polymer led to expedited settling periods and reduced dose requirements, making it a more efficient and environmentally sustainable option for water treatment applications. [34] Amina and her colleagues developed a *Moringa oleifera* oil/polyvinyl chloride (PVC) bionanocomposite film infused with silver nanoparticles, exhibiting significant antibacterial efficacy, resulting in a 98% decrease in bacterial proliferation for strains including E. coli and S. aureus. The film's mechanical characteristics were improved, exhibiting a 30% improvement in tensile strength, hence enhancing its durability and potential as an antibacterial packaging material. The findings demonstrate that the integration of silver nanoparticles into the Moringa oil/PVC matrix significantly enhances the film's antibacterial effectiveness, making it appropriate for biomedical and food packaging uses. [35] Badwaik HR and colleagues mentioned Moringa gum and its modified form as a potential green polymer for Pharmaceutical and biomedical field. [36]

6. Conclusion

In a nutshell *Moringa oleifera* gum has shown significant promise as a multifaceted and efficacious excipient in several medicinal applications. Its distinctive characteristics, including as binding capacity, disintegrant function, and potential to change drug release, provide it a significant natural substitute for synthetic polymers in drug delivery systems. The uses of gum encompass typical tablet formulations as well as sophisticated drug delivery technologies, including nanoparticles, buccal films, and hydrogels. The amalgamation of *Moringa oleifera* gum with other polymers has shown synergistic benefits, improving the overall efficacy of drug delivery systems. As research in this domain progresses, *Moringa oleifera* gum is set to assume a more prominent position in the advancement of novel, efficient, and sustainable medicinal formulations. Future research should concentrate on refining extraction techniques, investigating novel uses, and doing thorough in vivo assessments to fully harness the potential of this intriguing natural excipient in drug delivery.

Compliance with ethical standards

Disclosure of conflict of interest

The authors affirm that they have no known financial or interpersonal conflicts that would have appeared to have an impact on the research presented in this study.

References

[1] Li, L.-Z.; Chen, L.; Tu, Y.-L.; Dai, X.-J.; Xiao, S.-J.; Shi, J.-S.; Li, Y.-J.; Yang, X.-S. Six New Phenolic Glycosides from the Seeds of *Moringa oleifera* Lam. and Their α-Glucosidase Inhibitory Activity. Molecules. 2023; 28:6426.

[2] Saini RK, Sivanesan I, Keum YS. Phytochemicals of *Moringa oleifera*: a review of their nutritional, therapeutic and industrial significance. 3 Biotech. 2016;6(2):203.

[3] Saini RK, Shetty NP, Giridhar P, Ravishankar GA (2012) Rapid in vitro regeneration method for *Moringa oleifera* and performance evaluation of field grown nutritionally enriched tissue cultured plants. 3 Biotech. 2012(2):187–192.

[4] Leone, A., Spada, A., Battezzati, A., Schiraldi, A., Aristil, J., & Bertoli, S. Cultivation, Genetic, Ethnopharmacology, Phytochemistry and Pharmacology of *Moringa oleifera* Leaves: An Overview. International Journal of Molecular Sciences. 2015;16(6):12791-12835.

[5] Rockwood, J. L., Anderson, B. G., Casamatta, D. A. Potential Uses of *Moringa oleifera* and an Examination of Antibiotic Efficacy Conferred by M. oleifera Seed and Leaf Extracts Using Crude Extraction Techniques Available to Undergraduates." Journal of the American College of Nutrition. 2013;32(5):317-325.

[6] Patel VB, Chobey NE. Evaluation of *Moringa oleifera* gum as tablet disintegrant. Int J Pharm Pharm Sci. 2012;4(1):210–214.

[7] Kumar RS, Sundari AS, Kasturi M, Parkavi P. Application of *Moringa oleifera* and Terminalia Catappa gum as drug binder. World J Pharm Res. 2017; 6:546–549.

[8] Patel BV, Patel D. Study of disintegrant property of *Moringa oleifera* gum and its comparison with other Superdisintegrants. Int J ChemTech Res 2011; 3:1119–1124.

[9] Ahmed, I.; Sadiq, M.; Anwar, F.; Ali, H.; Khan, M. I. Physicochemical and Functional Properties of *Moringa oleifera* Gum as a Natural Disintegrant in Tablet Formulation. AAPS PharmSciTech. 2016;17(2):325-331.

[10] Zahra, A.; Hajiaghaee, R.; Ramezani, M.; Keshavarzi, Z. Fourier Transform Infrared Spectroscopy (FTIR) as a Useful Tool for Characterization of *Moringa oleifera*. Int. J. Biol. Macromol. 2018; 118:420-426.

[11] Zhang, Y.; Liu, D.; Zhang, M.; Cheng, Y.; Zhang, L. Thermogravimetric and Differential Scanning Calorimetric Studies of *Moringa oleifera* Seed Gum. Polym. Degrad. Stab. 2013;98(12):2650-2655.

[12] Zheng, Y., Zhu, F., Lin, D., Wu, J., Zhou, Y., Mark, B. Optimization of formulation and processing of *Moringa oleifera* and spirulina complex tablets. Saudi Journal of Biological Sciences. 2016; 24:122 - 126.

[13] Pagano C, Perioli L, Baiocchi C, et al. Preparation and characterization of polymeric microparticles loaded with *Moringa oleifera* leaf extract for exuding wound treatment. Int J Pharm. 2020; 587:119700.

[14] areek A, Pant M, Gupta MM, et al. *Moringa oleifera*: An Updated Comprehensive Review of Its Pharmacological Activities, Ethnomedicinal, Phytopharmaceutical Formulation, Clinical, Phytochemical, and Toxicological Aspects. Int J Mol Sci. 2023;24(3):2098.

[15] Uphadek, B., Shinkar, D., Patil, P., Saudagar, R. *MORINGA OLEIFERA* AS A PHARMACEUTICAL EXCIPIENT. International Journal of Current Pharmaceutical Research. 2018; 10(2):13-16.

[16] Dhakad, A., Ikram, M., Sharma, S., Khan, S., Pandey, V., Singh, A. Biological, nutritional, and therapeutic significance of *Moringa oleifera* Lam. Phytotherapy Research. 2019; 33: 2870 - 2903.

[17] Panda DS, Choudhury NS, Yedukondalu M, Si S, Gupta R. Evaluation of Gum of *Moringa oleifera* as a Binder and Release Retardant in Tablet Formulation. Indian J Pharm Sci. 2008;70(5):614-618.

[18] Vasanthan A; Senthilkumar KL; Gokulan PD; Suresh V; Venkateshwaran; Tamilselvi M; Shalini K; Preethi D. Formulation and Evaluation of Efavirenz Tablet Using *Moringa oleifera* As a Natural Polymer. Cur Res Pharm Sci 2022, 12, 51-58.

[19] Panda DS, Choudhury NS, Yedukondalu M, Si S, Gupta R. Evaluation of Gum of *Moringa oleifera* as a Binder and Release Retardant in Tablet Formulation. Indian J Pharm Sci. 2008;70(5):614-618.

[20] Ali, M. A., Yusof, Y. A., Chin, N. L., Ibrahim, M. N., Muneer, S. Development and Standardization of *Moringa oleifera* Leaves as a Natural Dietary Supplement. Journal of Dietary Supplements. 2018;16(1):66–85.

[21] Singh B, Kumar A. Development of dietary fibre moringa gum and polyvinylpyrrolidone based hydrogels for drug delivery application. Food Hydrocolloids for Health. 2021; 1:100008.

[22] Kotadiya RM, Savant NP, Upadhyay UM. Colon targeted moringa gum compression coated tablets of capecitabin: a factorial approach. Pharmacophore. 2019;10(1):21-29.

[23] Pagano C, Perioli L, Baiocchi C, et al. Preparation and characterization of polymeric microparticles loaded with *Moringa oleifera* leaf extract for exuding wound treatment. Int J Pharm. 2020; 587:119700.

[24] Shousha WG, Aboulthana WM, Salama AH, Saleh MH, Essawy EA. Evaluation of the biological activity of *Moringa oleifera* leaves extract after incorporating silver nanoparticles, in vitro study. Bulletin of the National Research Centre. 2019;43(1):1-3.

[25] Matinise N, Fuku XG, Kaviyarasu K, Mayedwa N, Maaza MJ. ZnO nanoparticles via *Moringa oleifera* green synthesis: Physical properties & mechanism of formation. Applied Surface Science. 2017; 406:339-47.

[26] Pal S, Mondal S, Maity J, Mukherjee R. Synthesis and characterization of ZnO nanoparticles using *Moringa oleifera* leaf extract: investigation of photocatalytic and antibacterial activity. International Journal of Nanoscience and Nanotechnology. 2018;14(2):111-9.

[27] Dhiman S, Bhatt S, Mannan A, Arora S, Singh TG. Formulation and characterization of zaleplon buccal disks using grafted *Moringa oleifera* gum. Journal of Applied Pharmaceutical Science. 2023;13(1):115-27.

[28] Chin CY, Jalil J, Ng PY, Ng SF. Development and formulation of *Moringa oleifera* standardised leaf extract film dressing for wound healing application. Journal of ethnopharmacology. 2018; 212:188-99.

[29] Srivastava S, Bind A, Yadav J, Srivastava R, Chaturvedee A, Sharma A. Preparation and evaluation of mucoadhesive gel of *Moringa oleifera*. World Journal of Pharmaceutical Research. 2024;13(17): 59-83.

[30] Ahmad S, Manzoor K, Purwar R, Ikram S. Morphological and swelling potential evaluation of *Moringa oleifera* gum/poly (vinyl alcohol) hydrogels as a superabsorbent. ACS omega. 2020 ;5(29):17955-61.

[31] Gugu TH, Agu GC, Uronnachi EM, Chime SA. Enhanced anti-inflammatory and ulcerogenicity of Ibuprofen microsphere formulations using Irvingia wombolu fat (IRW) and moringa oil (MO) as co-lipids. BMC Complementary Medicine and Therapies. 2023 ;23(1):249.

[32] Kaur K, Kaur L, Sharma M, Jindal R. A comparison of controlled release from cyclodextrin mediated and non-mediated hydrogel matrices of *Moringa oleifera* gum and carboxymethyl cellulose. Polymer Bulletin. 2024:1-25.

[33] Singh B, Sharma V, Mohan M, Sharma P, Ram K. Design of ciprofloxacin impregnated dietary fiber psyllium-moringa gum-alginate network hydrogels via green approach for use in gastro-retentive drug delivery system. Bioactive Carbohydrates and Dietary Fibre. 2023 ;29:100345.

[34] Carvalho Bongiovani M, Camacho FP, Nishi L, Ferri Coldebella P, Cardoso Valverde K, Vieira AM, Bergamasco R. Improvement of the coagulation/flocculation process using a combination of *Moringa oleifera* Lam with anionic polymer in water treatment. Environmental Technology. 2014;35(17):2227-36.

[35] Amina M, Al Musayeib NM, Alarfaj NA, El-Tohamy MF, Orabi HE, Bukhari SI, Mahmoud AZ. Exploiting the potential of *Moringa oleifera* oil/polyvinyl chloride polymeric bionanocomposite film enriched with silver nanoparticles for antimicrobial activity. International Journal of Polymer Science. 2019; 1:5678149.

[36] Badwaik HR, Al Hoque A, Kumari L, Sakure K, Baghel M, Giri TK. Moringa gum and its modified form as a potential green polymer used in biomedical field. Carbohydrate polymers. 2020; 249:116893.