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Current Progressions in Dual Drug Delivery: Exploring Tablet-In-Capsule Technology

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ABSTRACT

Background: This review article delves into the recent advancements in tablet-in-capsule (TiC) technology, a burgeoning field in pharmaceutical sciences that promises to revolutionize drug delivery and patient care .**Methodology:** An attempt is made to explore the strides made in enhancing drug stability, which is paramount for maintaining efficacy and extending shelf life. The development of controlled-release formulations is discussed, highlighting their role in improving therapeutic outcomes and patient compliance. The synergy of combination therapy within TiC systems is examined, offering a multifaceted approach to complex disease management. The article further investigates targeted drug delivery mechanisms, ensuring precise localization of therapeutic agents and thereby minimizing systemic side effects. Personalized medicine emerges as a focal point, with TiC technology at the forefront of customizing treatments to individual genetic profiles. An effort is also made to scrutinize the advanced manufacturing techniques that have streamlined the production of TiC systems, ensuring quality and consistency. Digital integration within TiC systems is evaluated for its potential to enhance monitoring and real-time adjustments of drug regimens. The use of environmentally friendly materials is emphasized, reflecting the industry's shift towards sustainable and biocompatible solutions .**Result:** The review addresses contemporary progression within TiC systems, underscoring the importance of safety and efficacy in complex therapeutic scenarios .**Conclusion:** In summary, the advancements in TiC technology encapsulate a multidisciplinary approach to drug delivery, offering innovative solutions that cater to the dynamic needs of modern medicine.

Keywords: Tablet in Capsule (TiC) technology, Cap-tab, Dual delivery, Combination therapy, personalized medicine.

INTRODUCTION

In the pharmaceutical field, capsule dosage forms represent a cornerstone of modern drug delivery, offering a versatile and effective means of administering medications to patients. Capsules consist of a gelatin or cellulose shell that encloses one or more active pharmaceutical ingredients (APIs), typically in powder, granule, or pellet form. This encapsulation provides several advantages over other dosage forms, including enhanced stability, improved bioavailability, and precise dosing.

Capsules can be filled with a variety of contents depending on the desired therapeutic effect and the properties of the active pharmaceutical ingredients. Here are some common fill materials for capsules:

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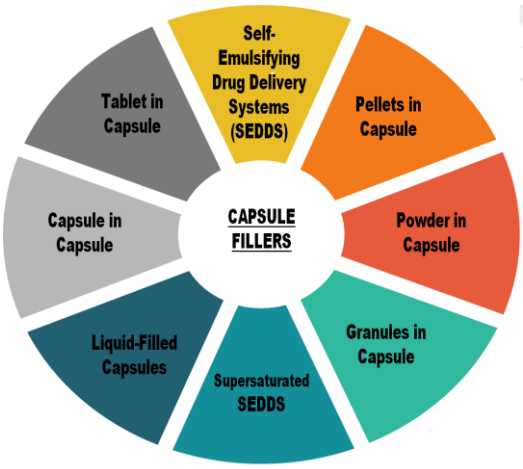

Figure 1: Capsule Fillers

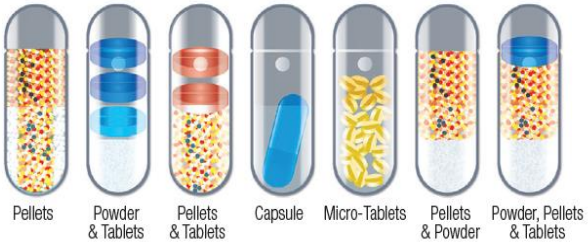

Figure 2: Multiple unit dosage fillers in capsule. [1]

Tablet in capsule (TiC) technology is a novel approach in the pharmaceutical sector that combines the benefits of both tablets and capsules into a single dosage form. This technology involves encapsulating mini-tablets within a capsule shell, allowing for various release profiles such as rapid release, sustained release, pulsatile release, and delayed-onset sustained release [2]. The mini-tablets can be designed with different lag times of release, enabling a biphasic delivery system that provides an initial rapid therapeutic effect followed by an extended release phase [2].

The impact of this technology on the pharmaceutical field is significant. It offers improved in-vivo dissolution performance compared to single-unit dosage forms, leading to more uniform bioavailability and clinical effects [2]. They offer a more patient-centric approach to medication delivery, addressing the unique needs of individual patients. For instance, the technology can be tailored for pediatric and geriatric patients who may have difficulty swallowing or require specific release patterns to manage their conditions effectively [3].

TiC technology represents a convergence of precision engineering and pharmacological science, epitomized by encapsulating tablets within a larger shell, can modify the pharmacokinetics of drugs, leading to improved drug solubility, dissolution, and absorption in the gastrointestinal tract and also enables the delivery of combination therapies, where synergistic effects can be achieved by targeting multiple disease pathways simultaneously. This unique configuration affords multifaceted advantages, ranging from the delivery of combination therapies to precise control over drug release kinetics.

Another key benefit of TiC technology is its ability to protect sensitive drugs from degradation and improve stability. The outer capsule shell acts as a barrier, shielding the enclosed tablets from moisture, light, and air, thereby preserving their potency and shelf-life. This is particularly advantageous for medications prone to degradation or those requiring long-term storage.

From a manufacturing perspective, tablet-in-capsule systems have streamlined the production process, allowing for more efficient and cost-effective production of complex medication regimens. The technology also supports the trend towards personalized medicine, where medications are customized for individual patient needs, improving therapeutic outcomes and patient compliance [4].

The impact of TiC technology in the pharmaceutical field is evident in the development of novel drug formulations across various therapeutic areas. From chronic diseases like diabetes and hypertension to oncology and neurology, this review aims to provide a comprehensive overview of TiC technology, elucidating its current impact and future perception in the pharmaceutical field.

BASIC STAGES IN FORMULATION OF TABLET IN CAPSULE

The preparation of tablet-in-capsule (TiC) formulations involves a meticulous process designed to ensure the optimal delivery of active pharmaceutical ingredients (figure. 3). Initially, tablets are manufactured using conventional methods such as direct compression or wet granulation, where APIs and excipients are blended and compressed into solid forms. These tablets are then encapsulated within hard gelatin capsules. The encapsulation process can be performed using automated machinery that precisely places the tablets into pre-formed capsule shells. This dual-layer system allows for controlled release of the drug, offering advantages in terms of stability, bioavailability, and targeted delivery. Additionally, the TiC approach enables the combination of multiple drugs within a single dosage form, facilitating combination therapy and improving patient compliance. Advanced techniques such as coating the tablets with enteric or sustained-release polymers can be employed to further modulate the release profiles. Throughout the formulation process, stringent quality control measures are implemented to ensure consistency, efficacy, and safety of the final product. The integration of digital technologies for real-time monitoring and adjustments enhances the precision and effectiveness of the TiC systems, paving the way for personalized medicine applications.

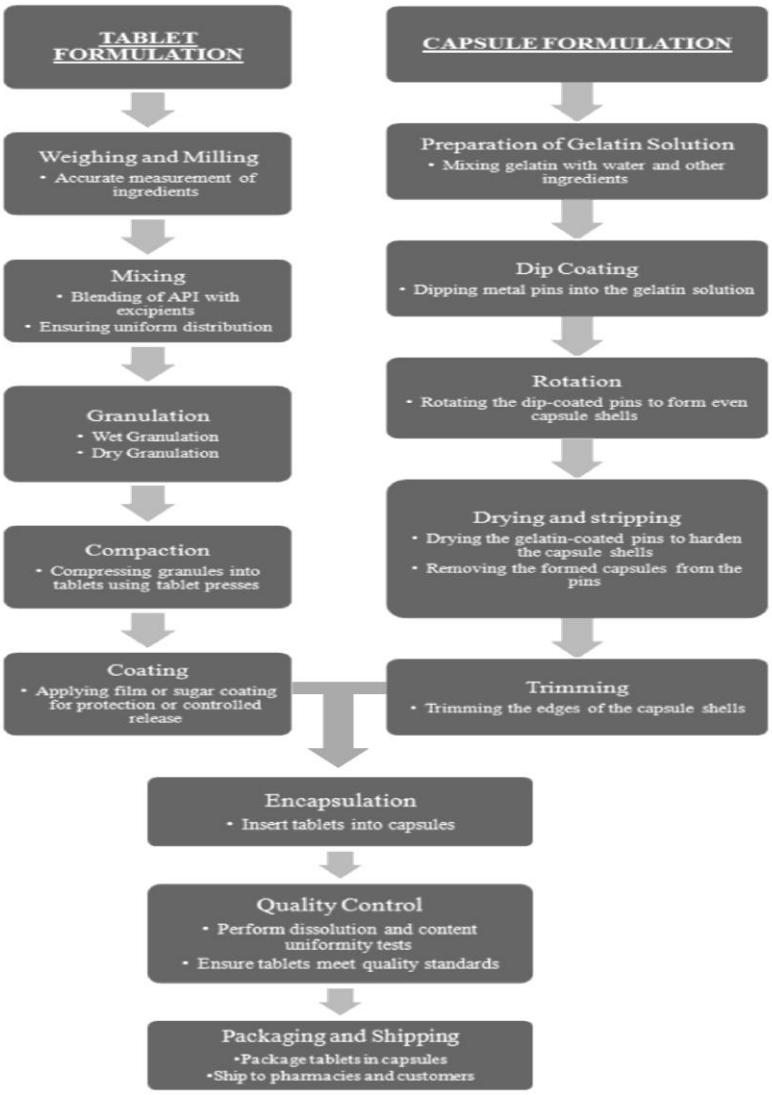

Figure 3: Flow chart of stages involved in the formulation of tablets in capsules

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CURRENTLY AVAILABLE MARKETED PRODUCTS OF TABLET IN CAPSULE

Commercially available tablet-in-capsules (mini tablet) are gaining popularity due to their advantages in flexibility, dosing accuracy, and suitability for various patient populations. Here are some examples of mini-tablets currently on the market:

Table No. 1: Commercially available mini tablet

BRAND NAME	API	DOSAGE FORM	THERAPEUTIC INDICATION	MANUFACTURER
Levetiracetam Desitin®	Levetiracetam	2 mm MT	Epilepsy	Desitin
Kalydeco®	Ivacaftor	2 mm MT	Cystic fibrosis	Vertex
Lamisil®	Terbinafine HCl	2 mm MT	Antifungal treatment	Novartis
Orfiril® Long	Sodium Valproate	MT	Epilepsy	Desitin
Pancrease MT®	Pancreatic enzymes	2 mm enter MT	Chronic pancreatitis cystic fibrosis	McNeil and Argus Pharmaceuticals
Creon®	Pancreatic enzymes	MT	Chronic pancreatitis cystic fibrosis	Solvay Pharmaceuticals
Ultresa®	Pancrelipase	MT	Pancreatic insufficiency	Aptalis Pharma US
Pradaxa®	Dabigatran Etexilate	MT	Anticoagulant	Boehringer Ingelheim

CURRENT FURTHERANCE IN TABLET IN CAPSULE TECHNOLOGY

The pharmaceutical landscape is witnessing a significant transformation with the advent of "Tablet in Capsule" technology, which has seen substantial improvements in recent years. This innovative approach combines the precision of tablet dosing with the versatility of capsules, allowing for more complex and controlled drug release mechanisms. Here are some current advancements in tablet-to-capsule technology:

Enhanced drug stability:

One of the most significant advancements in "Tablet in Capsule" technology is the enhancement of drug stability. This improvement is crucial as it directly impacts the efficacy and shelf-life of pharmaceutical products. The current progress in this area includes:

- **Innovative Coating Techniques**: The use of one-step dry coating technology has been a game-changer. It allows for the manufacturing of tablet-in-tablet formulations, which can protect the active pharmaceutical ingredient (API) from environmental factors without the need for solvent-based coatings [5].

- **Material Advancements**: The shift towards using advanced polymers and excipients in capsule shells has improved the barrier properties, protecting sensitive APIs from moisture, light, and oxygen, which are common causes of degradation [6].

- **Encapsulation of Liquids**: Recent technologies enable the encapsulation of liquids along with tablets within capsules. This not only enhances the bioavailability of APIs but also provides a protective environment that can extend the stability of the encapsulated drugs [7].

- **Freeze-Drying and Spray Drying**: TiC formulations now employ novel techniques such as lyophilization (freeze-drying) or spray-drying to stabilize drug formulations by converting them into dry powders or solid-state forms, minimizing chemical degradation and extending shelf life. By enhancing drug stability, these advancements in TiC technology ensure the preservation of therapeutic efficacy, bolstering the reliability and longevity of pharmaceutical products in the market.

Controlled release formulation:

"Tablet in Capsule" technology has seen remarkable advancements in controlled release formulations, which are pivotal for achieving precise therapeutic outcomes. The recent improvements in this domain include:

- **Matrix Tablets**: The development of matrix tablets, where the drug is homogeneously dispersed within hydrophilic or hydrophobic polymeric matrices, has been a significant step forward. These matrices control drug release through erosion under gastric pH conditions, aiming to mimic a zero-order release mechanism [8].

- **Bilayer Tablets**: Innovations in bilayer tablets have been particularly noteworthy. These tablets consist of an immediate release layer and a sustained release layer, providing a dual-phase pharmacokinetic profile. This design allows for the rapid onset of action followed by a prolonged therapeutic effect [9].

- **Coating Technologies**: Technological progressions in coating methods have been substantial. Enteric coatings have been refined to protect the drug until it reaches the intestine, where it can be released at a controlled rate without being affected by stomach acidity [10].

- **Novel Excipients**: The introduction of novel excipients has enabled the formulation of oral controlled-release systems that are more efficient and patient-friendly. These excipients play a crucial role in modulating the drug release rate and enhancing the stability of the formulation [11]. With continued research and development, controlled release formulations in TiC technology hold immense promise for revolutionizing the treatment of chronic diseases and improving patient outcomes.

Combination therapy:

The concept of combination therapy within the "Tablet in Capsule" technology has seen significant advancements, offering a new horizon in polypharmacy and patient-specific treatment strategies. The current progressions in this area include:

- **Multi-Drug Incorporation**: A tablet-in-capsule system can be designed to incorporate mini-tablets with modified drug release properties, allowing for the simultaneous administration of multiple drugs with different pharmacokinetics [12]. This innovation allows for the synergistic interaction of drugs with complementary mechanisms of action, thereby enhancing therapeutic efficacy while minimizing the risk of drug resistance.

- **Design Flexibility**: The technology provides the flexibility to combine various forms of drug delivery systems, such as immediate-release mini-tablets, sustained-release pellets, and even liquid formulations, all within a single capsule [12].

- **Fixed-Dose Combinations (FDCs)**: FDCs are being developed to improve patient compliance by reducing the pill burden, especially for chronic conditions where polytherapy is common. These combinations can be tailored to release each drug at the desired rate and site of action [12].

- **Therapeutic Efficacy**: By optimizing the release profiles of each drug within the capsule, combination therapy can enhance therapeutic efficacy and minimize potential drug-drug interactions [12]. These advancements in combination therapy within "Tablet in Capsule" technology represent a paradigm shift in pharmaceuticals, offering enhanced treatment outcomes for complex diseases while minimizing side effects and optimizing patient care.

Targeted drug delivery:

"Tablet in capsule" (TiC) technology has propelled targeted drug delivery to new heights, offering precision and efficacy in therapeutic interventions. Here are some of the key improvements:

- **Nanocarriers Integration**: The use of nanocarriers has been explored to improve targeted delivery. Works have been done on nanotechnology to engineer smart drug delivery systems capable of precisely targeting diseased tissues or cells while sparing healthy ones. These carriers can effectively deliver drugs to the desired site through mechanisms like the enhanced permeability and retention (EPR) effect and receptor-mediated active targeting [13].

- **Stimuli-responsive materials:** TiC formulations leverage stimuli-responsive materials that undergo conformational changes in response to specific physiological cues, such as pH, temperature, or enzyme activity, triggering drug release at the desired location.

- **Encapsulation Techniques**: Advances in capsule technology now enable the encapsulation of not just tablets but also liquids, pellets, or other capsules inside a larger capsule. This approach can improve the bioavailability of active pharmaceutical ingredients (APIs) and allow for customized release targeted to specific areas of the body [7]. Furthermore, advanced imaging techniques, including magnetic resonance imaging (MRI) and fluorescence imaging, enable real-time monitoring of drug distribution and uptake, guiding the optimization of TiC formulations for enhanced targeting efficiency. By harnessing the power of targeted drug

delivery within TiC technology, researchers are paving the way for more effective and personalized treatment strategies, minimizing off-target effects and maximizing therapeutic outcomes for patients.

Personalized medicine:

“Tablet in capsule" (TiC) technology has emerged as a key enabler of personalized medicine, offering tailored treatment approaches to individual patients based on their unique genetic makeup, disease characteristics, and treatment responses. One significant improvement lies in the adoption of additive manufacturing, also known as 3D printing, which allows for the rapid fabrication of complex TiC constructs with unparalleled control over geometry and composition. This enables the creation of patient-specific dosage forms. Some other advancements in this area includes:

Bioprinting: While research on bioprinted cap-tabs is limited, the potential for bioprinting in pharmaceuticals lies in its ability to create more natural and biocompatible drug delivery systems. Significant improvement can be done by Bioprinting taking precise control over the composition and structure of cap-tabs, making it possible to tailor drug formulations to individual patient needs. By incorporating specific drugs, biomolecules, or even patient-derived cells into the cap-tabs, personalized therapies can be developed to target a variety of medical conditions. By incorporating bioactive molecules or growth factors it can promote tissue regeneration and wound healing [14].

- **Genetic Profiling Integration:** The integration of genetic profiling represents a significant advancement in personalized healthcare, offering tailored treatment strategies based on an individual's genetic makeup. This integration involves the analysis of an individual's genetic information to identify genetic variations, mutations, and predispositions that may influence drug formulations and can be designed to optimize drug efficacy, patient centric action and minimizing adverse effects [4].

- **Customizable Dosage Forms:** Customized dosage forms play a crucial role in personalized medicine by providing tailored drug delivery solutions that meet the unique needs of patients. The ability to combine different types of mini-tablets within a single capsule allows for the customization of dosage forms to match patient-specific therapeutic requirements [15].

- **Modular Drug Delivery:** The capsule component of TiC technology provides a versatile platform for encapsulating modular tablet formulations. Capsule shells can be designed to accommodate different tablet sizes, shapes, and compositions, allowing for precise control over drug release kinetics, targeting specific sites, and also supporting patients' changing health status by providing dynamic treatment options.

- **Data-Driven Formulation**: Leveraging big data and AI, pharmaceutical companies can analyze vast amounts of patient data to predict which formulations will be most effective for specific patient groups, leading to more successful outcomes [15]. Additionally, the incorporation of biomarkers and diagnostic tools within TiC constructs enables real-time monitoring of treatment efficacy and disease progression, facilitating timely adjustments to therapy regimens.

Advanced manufacturing techniques:

The manufacturing techniques for “Tablet in Capsule” technology have undergone significant advancements, focusing on efficiency, scalability, and precision. The improvements in this sector are pivotal for the pharmaceutical industry as they directly impact the quality and efficacy of the final product.

- **Automation and Precision Engineering**: Advanced manufacturing processes now incorporate high levels of automation and precision engineering. This includes the use of robotic systems and AI to optimize the production process, ensuring consistency and quality at high volumes [3].

- **Rapid Prototyping**: Rapid prototyping in Tablet in Capsule (TiC) manufacturing revolutionizes the development of drug delivery systems. By leveraging advanced technologies like 3D printing, researchers rapidly iterate and optimize TiC designs, expediting the journey from concept to prototype. This approach allows for precise customization, material selection, and functional enhancements, leading to innovative TiC formulations tailored to specific drug requirements and patient needs [3].

- **Material Science Innovations**: The use of novel materials and excipients has improved the stability and release profiles of the tablets. These materials can enhance the mechanical strength of the tablets and provide better control over drug release rates [3].On addition, micro-fluidic based manufacturing processes have emerged as a promising approach for producing TiC formulations with precisely controlled drug release profiles and particle sizes, facilitating uniform drug distribution and enhanced bioavailability. Moreover, the integration of process analytical technology (PAT) and quality-by-design (QbD) principles into TiC manufacturing processes enables real-time monitoring and optimization of critical parameters, ensuring product quality and regulatory compliance.

Drug interaction :

A crucial consideration in polypharmacy and combination therapy is to minimizing the risk of drug interactions. The improvements in this area are aimed at enhancing patient safety and therapeutic efficacy:

- **Precision Dosing**: The ability to incorporate multiple mini-tablets within a single capsule allows for precise dosing of combination therapies which can control drug release kinetics and pharmacokinetics. This reduces the risk of drug interactions by ensuring accurate delivery of each medication at its optimal dosage [15].

- **Barrier Layers**: TiC formulations can incorporate inert excipients or encapsulation materials that act as barriers to physical and chemical interactions between co-administered drugs, preserving their stability and efficacy throughout storage and transit [15].

- **Time-Release Separation**: By incorporating innovative release mechanisms, such as microencapsulation, nanoparticles, and pH-responsive coatings, TiC formulations can modulate the release rates of individual drug components, reducing the likelihood of concurrent peaks in plasma concentrations and minimizing the potential for drug-drug interactions [16].

- **Innovative Excipients**: The use of novel excipients can modulate the release profiles of drugs and act as protective agents. This can help in preventing drug degradation or interaction within the capsule, ensuring that each component retains its intended effect [2].

- **Predictive Analytics**: The integration of pharmacokinetic modeling and simulation techniques enables predictive assessment of potential drug interactions during the formulation design phase, guiding the selection of compatible drug combinations and dosing regimens [15]. Additionally, TiC technology leverages advanced formulation strategies, such as co-crystallization and solid dispersion, to enhance the solubility and bioavailability of poorly soluble drugs, thereby reducing the required dosage and mitigating the risk of drug interactions due to high concentrations. By addressing drug interactions through innovative formulation and delivery approaches, TiC technology enhances the safety and efficacy of combination therapies, optimizing therapeutic outcomes for patients while minimizing the risk of adverse drug reactions.

Digital integration:

Significant advancements in "tablet in capsule" (TiC) technology have been driven by the seamless integration of digital solutions, transforming drug delivery systems into intelligent, data-driven platforms.

- **Smart Sensors:** The incorporation of smart sensors and wireless communication capabilities into TiC formulations, enabling real-time monitoring of patient adherence, physiological parameters, and treatment responses. These digital sensors, embedded within the capsule shell or tablet core, can detect ingestion events, measure biomarkers in bodily fluids, or track drug release kinetics, providing valuable insights into patient compliance and therapeutic outcomes.

- **Automation and Robotics**: The transition from manual encapsulation methods to automated processes has been a significant leap forward. High-speed encapsulation systems equipped with advanced dosing mechanisms and quality control features have become the norm, increasing production speed and ensuring consistent product quality [6].

- **AI and Machine Learning**: The incorporation of AI into capsule production processes has been transformative. For instance, ACG's capsule manufacturing facility in Madhya Pradesh, India has adopted generative AI, which has revolutionized standard operating procedures and workforce training. This integration has earned ACG a place in the World Economic Forum's Global Lighthouse Network, highlighting the impact of AI on manufacturing efficiency [6].

- **Cloud Computing and IoT**: The use of cloud computing and the Internet of Things (IoT) in capsule manufacturing enables better connectivity and data exchange across the production chain. This facilitates remote monitoring, control, and optimization of manufacturing operations [17].

- **Block-chain Technology**: Digital integration extends beyond the patient-provider interface to encompass supply chain management, with TiC capsules equipped with block-chain technology enabling end-to-end traceability, authentication of pharmaceutical and compliance with regulatory standards [17]. Advanced data analytics and artificial intelligence algorithms process the collected data, generating actionable insights for healthcare providers to optimize treatment regimens and improve patient outcomes.

Environmental friendly material :

"Tablet in Capsule" technologies have also been directed towards the use of environmentally friendly materials, reflecting a growing trend in the pharmaceutical industry to adopt sustainable practices. Here are some of the key improvements:

- **Biodegradable Polymers**: The shift towards biodegradable polymers for capsule shells, such as hydroxypropyl methylcellulose (HPMC), is a significant step towards sustainability. These materials are not only vegan but also reduce the environmental impact compared to traditional gelatin capsules [18]. These biopolymers serve as sustainable alternatives to traditional petroleum-based plastics, reducing the environmental footprint associated with TiC production and disposal.

- **Water-Based Coatings**: The adoption of green manufacturing practices, a move away from solvent-based coatings towards water-based alternatives, which are less toxic and reduce volatile organic compound (VOC) emissions during the manufacturing process.

- **Recycling and Waste Reduction**: Advanced manufacturing processes are being designed to minimize waste and enable the recycling of materials. This includes the recovery of excess powder during the encapsulation process and the use of recyclable packaging materials.

- **Energy-Efficient Manufacturing**: Nowadays industries are adopting energy-efficient technologies to reduce the carbon footprint of manufacturing operations. This includes the use of renewable energy sources and the implementation of energy-saving measures in production facilities. By embracing environmentally friendly materials and practices, TiC technology aligns with global sustainability initiatives, contributing to the conservation of natural resources and the preservation of ecosystems while maintaining high standards of product quality and performance.

RESULTS AND DISCUSSION

The landscape of pharmaceutical technology is ever-evolving, and the advancements in tablet in capsule (TIC) technology have marked a significant milestone in drug delivery systems. This review has highlighted the pivotal developments that enhance drug stability, offer controlled release formulations, and enable combination therapy, all while ensuring targeted drug delivery. The integration of personalized medicine into TiC systems underscores the commitment to patient-centric care, tailoring treatments to individual needs.

Advanced manufacturing techniques have streamlined production, ensuring consistency and quality, while digital integration promises a future where drug delivery can be monitored and adjusted in real-time. The use of environmentally friendly materials in TIC systems not only aligns with sustainable practices but also opens new avenues for biocompatible and biodegradable options.

CONCLUSION

However, it's crucial to acknowledge the ongoing challenges, particularly in addressing drug interactions and ensuring the safety and efficacy of these complex formulations. Moving forward continued research and development efforts are essential to overcome these hurdles and unlock the full potential of tablet-in-capsule technology in improving patient care and advancing the field of medicine.

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DECLARATION OF INTEREST

We declare that we have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this review article.

REFERENCE

1. Contract Pharma. Trends in solid oral dosage delivery. 2021 Mar 1.
Available from: https://www.contractpharma.com/issues/2021-03-01/view_features/trends-in-solid-oral-dosage-delivery/

2. Sankar C, Manoranjan R, Vignesh R, Kovarthanan M. Tablet in Capsule Technology – Overview. Int J Pharm Res Appl. 2023;8(2):1955–60. Available from: www.ijprajournal.com
3. Gaikwad SS, Kshirsagar SJ. Review on Tablet in Tablet techniques. Beni-Suef Univ J Basic Appl Sci. 2020;9(1):1. doi: 10.1186/s43088-019-0027-7.
4. Siamidi A, Konstantinidou S. Investigation of a Novel 'Tablets In Capsule' Formulation System for the Modified Release of Mesalazine in Gastrointestinal-Like Fluids. Am Pharm Rev. 2018 Apr 20.
5. Mandave SV, Pandey NK. Current Advances in Tablet in Tablet as Drug Delivery System: A Review. In: Pawar PM, et al., editors. Techno-Societal 2022. ICATSA 2022. Cham: Springer; 2024. doi: 10.1007/978-3-031-34648-4_52.
6. F M. Capsule Manufacturing Technology: Innovations Shaping the Future. Tablets & Capsules. 2024 Apr 1. Available from: https://www.tabletscapsules.com/3641-Technical-Articles/612068-Capsule-Manufacturing-Technology-Innovations-Shaping-the-Future/
7. Bhat J, Dalvi M. Hard capsules: A holistic approach for oral drug delivery and formulation. ONdrugDelivery. 2023;(148):28-31.
8. Advancements in Sustained Release Tablet Formulations: A Review. Int J Sci Eng Dev Res. 2024;9(4):807–11. Available from: http://www.ijrti.org/papers/IJRTI2404112.pdf
9. Peña Fernández MÁ, editor. Formulation and Evaluation of Tablets of Different Drugs [Special issue]. Pharmaceuticals. 2022.
10. Jan MS, Alam W, Shabnam M. Fundamentals Applications of Controlled Release Drug Delivery. IntechOpen. 2023. doi: 10.5772/intechopen.113283.
11. Hadi M, Rao N. Novel Techniques in Formulations: An Overview. World J Pharm Res. 2012;1:1–17.
12. Wilkins CA, Hamman H, Hamman JH, Steenekamp JH. Fixed-Dose Combination Formulations in Solid Oral Drug Therapy: Advantages, Limitations, and Design Features. Pharmaceutics. 2024;16(178):178. doi: 10.3390/pharmaceutics16020178.
13. Li J, Wang Q, Xia G, Adilijiang N, Li Y, Hou Z, Fan Z, et al. Recent Advances in Targeted Drug Delivery Strategy for Enhancing Oncotherapy. Pharmaceutics. 2023;15(2233):2233. doi: 10.3390/pharmaceutics15092233.
14. Li J, Chen M, Fan X, et al. Recent advances in bioprinting techniques: approaches, applications and future prospects. J Transl Med. 2016;14:271. doi: 10.1186/s12967-016-1028-0.
15. Thomas F. Capsule Innovations: Speeding Up Drug Development. Pharm Technol. 2020;44(9).
16. Stegemann S. Capsules as a Delivery System for Modified-Release Products. In: Wilson C, Crowley P, editors. Controlled Release in Oral Drug Delivery. Advances in Delivery Science and Technology. Boston (MA): Springer; 2011. doi: 10.1007/978-1-4614-1004-1_14.
17. Almeman A. The digital transformation in pharmacy: embracing online platforms and the cosmeceutical paradigm shift. J Health PopulNutr. 2024;43(60):60. doi: 10.1186/s41043-024-00550-2.
18. Gren T. Capsule formulation: future trends. Eur Pharm Rev. 2023 Jul 10.

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