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"Orodispersible Films as a Versatile Platform for Drug Delivery: Current Applications, Future Perspectives, and Novel Approaches"

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Abstract :

Orodispersible films (ODFs) have emerged as a promising and patient-friendly dosage form that rapidly disintegrates in the oral cavity without the need for water, offering unique advantages for pediatric, geriatric, and dysphagic populations. Their versatility extends across pharmaceuticals, nutraceuticals, and consumer healthcare, enabling the delivery of a wide range of active molecules, including small drugs, peptides, nutraceuticals, and even biologics. This review provides an overview of the current applications of ODFs in clinical practice and product development, highlighting marketed formulations and therapeutic areas where they have demonstrated significant benefits. Advances in formulation technologies—such as nanocarrier incorporation, self-emulsifying systems, and mucoadhesive polymers—are discussed in the context of improving drug solubility, stability, and controlled release. Furthermore, emerging approaches like 3D printing, electrospinning, and personalized medicine strategies are shaping the future of ODF design. Despite their potential, challenges such as limited drug loading capacity, stability issues with sensitive actives, and large-scale manufacturing hurdles remain to be addressed. Overall, ODFs represent a versatile platform for drug delivery with expanding horizons, poised to play a transformative role in precision medicine and patient-centric therapy.

Keywords: Oral film, Novel delivery, Onset of action, patient compliance, small molecules

I. Introduction

Recent advancements in pharmaceutical science have led to the development of a broad spectrum of therapeutic agents delivered through various dosage forms. The oral drug delivery market continues to dominate the global pharmaceutical landscape, reflecting its widespread preference due to factors like patient compliance, cost-effectiveness, and ease of administration. Oral solid dosage forms (OSD), including tablets and capsules, are anticipated to maintain market leadership due to their convenience and cost-effectiveness. Oral drug delivery is expected to reach approximately USD 3,815,895.3 million by 2035, demonstrating a compound annual growth rate (CAGR) of 5.9%.(1)

Solid oral dosage forms like tablets and capsules can be challenging to swallow for patients with conditions such as vomiting tendencies, bipolar disorder, oral cancer, and Parkinson's disease . To address this issue, orally disintegrating tablets (ODTs) have emerged as a convenient alternative to traditional tablet and capsule formulations. Orodispersible films (ODFs) are ultra-thin, stamp-sized, portable, and patient-friendly pharmaceutical dosage forms that can be administered without the need for water. They are especially beneficial for pediatric and geriatric patients with specific conditions like dysphagia, Parkinson's disease, and oral cancer.(2)ODFs are typically composed of plasticized hydrocolloids or their blends , which are formed into films using a solvent-casting method, followed by drying and sealing in moisture-resistant packaging and typically weighs less than 200 mg, its drug-loading capacity is lower compared to orally disintegrating tablets (ODTs), which can accommodate up to 500 mg of API. Consequently, ODFs are most suitable for potent active ingredients. Additionally, both the drug and any taste-masking agents may affect the film's mechanical properties . Therefore, careful consideration must be given to the molecular weight of the film-forming polymers , or alternatively, the use of specialized excipients may be necessary to optimize the formulation .However, several challenges can arise during manufacturing, including air entrapment, unsuitable viscosity of casting solutions, inadequate content uniformity, batch-to-batch variability, and complications related to organic solvents such as rapid evaporation or residual solvent content .Due to the limited space within the oral cavity, the size of ODFs must be restricted. Commonly accepted dimensions include 2 × 2 cm^2 with a thickness of 100 µm or 2 × 3 cm^2 with a thickness of 350 µm . Nevertheless, varying dose strengths can be achieved by cutting the same film

formulation into different shapes, making ODFs suitable for personalized dosing.(3)

The oral thin films market has experienced significant growth in recent years, increasing from $4.48 billion in 2024 to a projected $5.03 billion in 2025, with a compound annual growth rate (CAGR) of 12.2%.

This growth during the historical period is primarily attributed to improved patient compliance, rising demand among pediatric and geriatric populations, rapid onset of drug action, management of chronic diseases, and the convenience of over-the-counter (OTC) medications.Looking ahead, the market is expected to continue its rapid expansion, reaching approximately $8.72 billion by 2029, driven by a CAGR of 14.7%. Factors contributing to this projected growth include the rise of specialty pharmaceuticals, the advancement of precision medicine, increasing use of mental health medications, oral vaccines, and the integration of telemedicine services. Key emerging trends during the forecast period include innovations in drug delivery technologies, the rise of remote healthcare solutions, enhanced bioavailability, demand for convenient travel-friendly formats, and a growing preference for allergen-free formulations. Overall, the increasing demand for thin film drug delivery systems is a major driver propelling the growth of the oral thin film market.

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1.1 Overview

Terms such as thin-film, oral film, wafer, oral strip, orodispersible film, oral thin film, oral soluble film, dissofilms, buccal soluble film, mucoadhesive film, buccal film, and transmucosal film are commonly found throughout the literature. While these terms may appear straightforward, their meanings are often misinterpreted or misunderstood.

The European Pharmacopoeia (Ph. Eur. 7.4) has recently included oral films under the “Oromucosal Preparations” monograph, specifically categorizing “Orodispersible films” as a subchapter. In contrast, mucoadhesive buccal films are classified under the “Mucoadhesive Preparations” section. Therefore, it is important to read and interpret these designations carefully to avoid confusion.

Orodispersible films should not be mistaken for buccal films, and similarly, buccal films should not be limited to the definition of mucoadhesive films alone.(5)

These ultra-thin, stamp-sized, portable, and patient-friendly pharmaceutical dosage films are designed to rapidly disintegrate in the oral cavity, allowing them to be swallowed and subsequently absorbed into the systemic circulation through the gastrointestinal tract. This intent is clearly reflected in the official definitions provided by regulatory authorities: the European Pharmacopoeia (Ph. Eur. 7.4) defines orodispersible films as “single- or multilayer sheets of suitable materials, to be placed in the mouth where they disperse rapidly,” while the FDA describes them as a “thin layer or coating which is susceptible to being dissolved when in contact with a liquid.”(5–7)

Non-adhesive fast-dissolving films are typically formulated using low molecular weight (approximately 1,000 to 9,000 Da) hydrophilic polymers. While most orodispersible films are not specifically intended to be mucoadhesive, they may still display a certain degree of mucoadhesion owing to the intrinsic properties of the polymers employed.(6)

In addition, orodispersible films (ODFs) facilitate quick and uniform drug release, which can enhance the bioavailability of certain pharmaceuticals. The oral cavity, characterized by its rich blood supply and minimal enzymatic activity, presents an opportunity to improve the absorption of drugs with poor water solubility. This delivery route is especially beneficial for drugs classified as BCS Class II and IV. The rapid absorption through the oral mucosa helps bypass degradation in the acidic environment of the stomach and avoids first-pass metabolism in the liver. As a result, this approach is particularly advantageous for administering potent drugs used in acute medical

conditions, enabling a swift therapeutic response through oromucosal and pregastric uptake, as well as direct systemic entry via the jugular vein. However, it's important to note that some drugs still require absorption from the gastrointestinal tract to exert their effects.(8)

Orodispersible films (ODFs) have undergone a remarkable transformation, expanding from traditional small-molecule drug delivery to more complex and advanced therapeutic systems, including peptides, proteins, and nanocarrier-based formulations. Initially developed to improve patient compliance—especially among pediatric, geriatric, and dysphagic populations—ODFs now offer a versatile platform capable of addressing a wide range of therapeutic needs.From delivering small molecules, particularly those requiring rapid onset of action, such as analgesics, antiemetics, and antihistamines. Biologics like peptides and proteins that often require protection from enzymatic degradation and enhancement in mucosal permeability, achieved through excipients such as stabilizers, enzyme inhibitors, and permeation enhancers.and the Nanocarrier systems—such as nanoparticles, liposomes, and micelles—within ODFs enhance solubility, bioavailability, and potentially enable targeted and controlled drug release.

This article aims to summarize current trends and explore the future scope of ODF applications across these diverse therapeutic domains, highlighting their potential in revolutionizing personalized and precision drug delivery.

II. Formulation Composition and Design of ODFs

Oral films are composed of various key components tailored to their specific formulation and intended function, yet they generally share several common ingredients. The primary therapeutic element is the active pharmaceutical ingredient (API), which delivers the desired pharmacological effect. Polymers form the structural backbone of the film, providing mucoadhesive properties and mechanical strength, while plasticizers are incorporated to enhance flexibility and prevent brittleness. To improve patient acceptability, sweetening and flavoring agents are added to mask any unpleasant taste, and coloring agents are included for visual appeal. Salivary stimulating agents may be used to promote rapid dissolution in the oral cavity. Additionally, stabilizers ensure the drug's integrity and prolong shelf life, surfactants aid in achieving uniform drug distribution and solubility, and solvents are employed during the film-casting process before evaporating upon drying. Together, these components optimize the film's performance, stability, and ease of use. Also this suitable plasticizer and other excipients aimed to optimize physicomechanical properties in terms of homogeneous texture, smooth surface and ductility, and disintegration time. The disintegration time of ODFs is valuable, as it has a significant impact on drug release and thereafter bioavailability(9)

2.1 API

The APIs used in ODFs are chosen based on their therapeutic purpose, with key selection criteria including solubility for proper dissolution, stability for shelf-life maintenance, and pharmacokinetic properties to achieve the desired therapeutic profile. This comprehensive evaluation ensures effective drug delivery through the film format. Due to their thin, lightweight nature, orodispersible films (ODFs) present inherent challenges in accommodating high drug loads. The typical API capacity in these formulations is limited to approximately 100 mg per strip, though this threshold may vary based on several critical factors.(10) They are generally designed with a thickness not exceeding 100 μm and a total weight under 300 mg as they require significant amount of excipients including surfactant for product stability. The amount of active pharmaceutical ingredient (API) they can carry typically ranges from 5% to 30%. For oral administration, ODFs are made lightweight to allow rapid disintegration—usually within 60 seconds. However, buccal and sublingual ODFs are often composed of multiple layers, which reduces the proportion of drug that can be incorporated into the film.(11)

Due to direct exposure to the oral cavity, APIs that adhere to the mucous membranes and cause irritation—such as a burning sensation or excessive bitterness—may face limited application. For optimal absorption via the intended route, the API should be stable and readily soluble in saliva, with a suitable molecular weight. When formulated for buccal or sublingual delivery, the API should ideally have a low molecular weight to facilitate mucosal permeation. Conversely, for oral delivery, a higher molecular weight is preferred to avoid unintended buccal absorption. Additionally, the absorption of APIs is influenced by their physicochemical properties, including hydrophilicity or hydrophobicity and molecular structure. Notably, most active ingredients used in approved orally dissolving films (ODFs) exhibit poor water solubility, typically 3 g/L or less.(12)

To enhance the solubility of BCS Class II and IV drugs—commonly used in orodispersible films (ODFs)—solid dispersion techniques are considered

highly effective. The Biopharmaceutics Classification System (BCS) categorizes drugs based on their solubility and permeability, and many APIs formulated in ODFs fall into these less soluble classes. Among the available techniques, the solvent casting method proves especially suitable, as it employs polymers, surfactants, and organic solvents that are highly compatible with the drugs. When these components—polymers, surfactants, and solvents—are thoroughly stirred with the active pharmaceutical ingredient (API), a uniform dispersion of the crystalline drug is achieved within the polymer matrix. This homogeneous distribution is further supported by the presence of surfactants and plasticizers, leading to an efficient solid dispersion formulation with amorphous characters.(13–16) Compared to ODFs containing dissolved APIs, there has been relatively limited research on formulations that suspend poorly water-soluble drugs or incorporate solid particles to modify drug release or mask taste. However, recent studies have shown that embedding nanocrystal dispersions or microparticles into ODFs can significantly enhance drug dissolution rates and even support prolonged drug release.(17)

Table 1. List of class of drugs delivered through ODF

Therapeutic Condition	API	Dosage/Limit	Solubility in Water	Manufacturing Method	Reference
Antiepileptic	Phenytoin	5 mg per 2×2 cm² film	Poorly soluble (32 mg/L)	Solvent Casting with Cosolvent System	(18)
Antiemetic	Ondansetron HCl	2 mg	Slightly soluble	Solvent Casting with Nanoparticle Encapsulation	(19)
liver diseases and hepatitis B	Herpetrione	2.5 mg/cm2	Poorly soluble	Solvent Casting with Nanoparticles	(20)
Analgesic	Acetaminophen	~4.37 mg per film	Freely soluble	Hot-Melt Extrusion and Solvent Casting	(21)
Antimigraine	Rizatriptan	10 mg	Poorly soluble	Solvent Casting with Maltodextrin and Pullulan	(22)
Antiviral	ARV-110 (PROTAC)	5 mg in 200 mg Film	Poorly soluble	Hot-Melt Extrusion and Solvent Casting	(23)
Antipsychotic	Olanzapine	20 × 25 mm ODFs of 100 mg, which was designed to contain a 5 mg	Poorly soluble	3D Printing via Hot-Melt Pneumatic Extrusion	(24)
Antidepressant	Aripiprazole	0.45 mg/cm2	Poorly soluble	Electrospinning, Solvent Casting, and 3D Printing	(25)
Antihistamine & NSAID	Ranitidine HCl & Flurbiprofen	Not specified	Ranitidine: Freely soluble; Flurbiprofen: Poorly soluble	Solvent Casting with Lycoat® RS780	(26)
Anti-inflammatory	Meloxicam	6 mg	Poorly soluble	Solvent Casting with Sodium Alginate	(27)

2.2 Peptides/proteins delivery system through ODF

peptides are relatively short polymers, typically comprising approximately 20 to 50 amino acids that are highly valued for their unique and potent

pharmacological properties, often exhibiting superior therapeutic indices.(28) Despite challenges such as poor serum stability, rapid plasma clearance, and high manufacturing costs compared to small molecules, injectable peptides are achieving growing success. However, the oral route of administration offers significant advantages over parenteral methods, as evidenced by the fact that two-thirds of all pharmaceutical dosage forms are oral products (29). Developing peptides in an oral dosage form could not only reduce the expenses associated with sterile manufacturing of injectables but also eliminate the necessity for administration by healthcare professionals. while reformulating peptides into a non-sterile oral dosage form could offer financial benefits, these gains might be counteracted by the higher doses required due to lower oral bioavailability .(30)

Peptides face susceptibility to conformational instability, chemical instability, and enzymatic degradation at multiple stages of their life cycle, encompassing their formulation, storage, and systemic absorption. Their bioactivity can be compromised within gastric secretions due to the reduction of disulfide bridges and hydrolysis, hence they require structural stability for their biological activity ensuring their physical and chemical stability, a process where excipients play a crucial role. Given these challenges, stabilization procedures and the selection of stabilizing excipients are not universal for all proteins or peptides. Therefore, the formulation of oral films for protein/peptide delivery are carefully tailored to the specific protein or peptide being administered.(31) The ongoing development of materials for oral protein delivery, encompassing everything from small molecules to macroscopic systems, remains a crucial area of research. For the successful oral administration of protein drugs, it is imperative to identify materials that are immunologically inert, non-toxic, and capable of eliciting the desired therapeutic response. Among these materials are bioavailability enhancers, which are small molecules typically less than 900 Da that facilitate the gastrointestinal absorption of proteins. This category includes enzyme inhibitors, buffering agents, chelating agents, surfactants, bile salts, aromatic alcohols, and ionic liquids. These compounds are frequently incorporated with the protein, either by physical blending into a tablet or by solubilization within a capsule. Their mechanisms of action are diverse, encompassing improved transport across the mucus and cellular barriers, inactivation of proteases and other gastrointestinal enzymes, and stabilization of the protein's structure.(32)

Various classes of excipients have been explored to enhance the oral delivery of protein-based therapeutics by overcoming enzymatic degradation and improving intestinal permeation. Protease inhibitors such as N-acetylcysteine, camostat mesylate, soybean trypsin inhibitor, and aprotinin protect protein cargo from enzymatic degradation; however, they face limitations like rapid dilution, low potency, and potential cytotoxic effects at high doses. Acid pH modifiers including citric acid, fumaric acid, itaconic acid, and tartaric acid inhibit local proteases through pH modulation and may enhance paracellular transport by acting as chelating agents, although they can interfere with enteric coatings and cargo stability due to pH shifts. Chelating agents like EDTA, DTPA, and EGTA sequester metal ions to enhance paracellular transport and inhibit proteases, but their efficacy can be compromised by in vivo dilution and they may deplete essential trace elements. Surfactants such as SDS, SNAC, PPS, and palmitoylcarnitine help prevent protein aggregation, inhibit intestinal enzymes, and promote permeation, though they may induce nausea or require high concentrations to be effective. Aromatic alcohols, including propyl gallate, butylated hydroxytoluene, and butylated hydroxyanisole, facilitate transcellular transport and serve as antioxidants, though chronic exposure raises concerns about carcinogenicity. ionic liquids, including combinations like choline and geranate or nicotinic acid and trigonelline, can enhance protein solubility, reduce mucus viscosity, and improve intestinal permeation, though contaminants may destabilize their intermolecular interactions.

In addition to the advantages offered by possible use of excipients in oral film formulations for enhancing the bioavailability of proteins and peptides, other strategies can also be employed to achieve similar objectives that includes nano- and microparticle technology, which can enhance the permeability of protein/peptide in mucosal epithelial cells, prevent enzymatic degradation and maintain the stability of during processing, manufacturing, and storage. Javier et al carried out research to formulated insulin-coated nanoparticles -loaded films in comparison with ICNP-loaded ERL (Eudragit® RLPO) –HPMC films and a control insulin solution and characterized for morphology, mucoadhesion, and insulin release and found that ICNP-loaded ERL formulations were found to be more effective in terms of film performance and insulin permeation through the human buccal mucosa model, and thus are a promising delivery system for buccal administration of a peptide such as insulin.(33) Yu Tian et al., successfully developed fast-disintegrating, protein-containing oral dissolvable

films (ODFs) using a trehalose/pullulan base via both air-drying and freeze-drying methods.Their research demonstrated the good uniformity of content within these ODFs, evidenced by the small standard deviations observed for weight, thickness, and the enzymatic activity of the incorporated protein.They found that air-dried ODFs exhibited superior mechanical properties compared to their freeze-dried counterparts. Regarding protein stability, the trehalose/pullulan ratio had no effect on lysozyme stability, but increasing this ratio improved the stability of β-galactosidase. Interestingly, freeze-drying proved more favorable for process stability, while air-drying resulted in better storage stability for the proteins.(34)

Table 2. List of proteins and peptides delivery through ODF

Therapautic indication	Protein/Peptide	Manufacturing approach for oral delivery	Research outcome	Patents / Reference
Type 2 Diabetes	Insulin	Nanoencapsulation through antisolvent co-precipitation process	Enhanced film performance and insulin permeation were observed with ICNP-loaded ERL formulations, indicating their potential for buccal peptide (e.g., insulin) delivery.	(35)
	Exenatide (GLP-1 Analog)	Reverse micelle-loaded lipid nanocapsules	Novel nanosystem compatible with human use that synergizes its own biological effect with the effects of increasing the bioavailability of a GLP-1 analogue orally	(36)
		Self-emulsifying drug delivery system (SEDDS) with hydrophobic ion pairing	Enhanced mucus permeation; achieved ~14.6% relative bioavailability; significant reduction in blood glucose levels in rats	(37)

		Dual cholic acid-functionalized nanoparticles targeting apical sodium-dependent bile acid transporter	Enhanced uptake and transport of Exenatide; prolonged hypoglycemic effect; reduced blood lipid levels and organ lesions in diabetic rats	(38)
Prostate Cancer Treatment	Synthetic GnRH Antagonist (e.g., SHR7280)	Oral tablet formulation	Demonstrated dose-dependent suppression of LH, FSH, and testosterone; well-tolerated in healthy male subjects	(39)
Endometriosis-Associated Pain	Relugolix (Oral GnRH Antagonist)	Oral tablet formulation	Comparable pain reduction to injectable therapy; dose-dependent decrease in bone mineral density; well-tolerated over 24 weeks	(40)
Hormonal Regulation	TU2670 (Oral GnRH Antagonist)	Oral tablet formulation	Dose-dependent suppression of LH, FSH, and estradiol; well-tolerated in healthy premenopausal women	(41)
HIV/AIDS	Enfuvirtide (T-20)	Oral delivery systems using PLGA and alginate	Developed oral delivery systems for T-20 using PLGA and alginate, demonstrating sustained release and maintaining therapeutic levels in the bloodstream for over 24 hours in mice.	(42)
Obesity	Amycretin (GLP-1/Amylin Dual Agonist)	Oral tablet formulation using Rybelsus® technology	In a Phase 1 trial, participants taking the highest doses experienced an average weight loss of up to 13% of their body weight in just three months. Mild to moderate gastrointestinal side effects were reported.	(43)
Plaque Psoriasis	JNJ-2113 (IL-23 Receptor Antagonist Peptide)	Oral tablet formulation	In the Phase 2b FRONTIER 1 trial, JNJ-2113 demonstrated a dose-dependent improvement in skin clearance. At week 16, the highest dose group (100 mg twice daily) achieved a 78.6% PASI 75 response rate, compared to 9.3% in the placebo group. The treatment was well-tolerated, with adverse event rates comparable to placebo.	(44)
Postmenopausal Osteoporosis	EB613 (Oral hPTH(1-34) Peptide)	Oral mini-tablet formulation utilizing Entera Bio's	In a 6-month, double-blind, placebo-controlled Phase 2 study involving	(45,46)

		proprietary N-Tab™ technology	161 postmenopausal women with low bone mineral density (BMD) or osteoporosis, the highest dose of EB613 (2.5 mg) led to significant increases in BMD at the lumbar spine (2.7%), total hip (1.8%), and femoral neck (2.8%) compared to placebo. Additionally, there was a 30% increase in bone formation markers (PINP and osteocalcin) and a 21% decrease in bone resorption marker (CTX). The treatment was well-tolerated with no drug-related serious adverse events.	

2.3 Delivery of Nutraceutical & probiotics through ODF

Currently, nutraceuticals are gaining a lot of interest due to their nutritional and therapeutic potential.(47) Nutraceuticals are dietary supplements used to improve health, delay aging, prevent disease and support the proper functioning of the human body. They show promise in early-stage disease management and prevention**,** potentially reducing the need for therapeutic intervention. However, the efficacy of many beneficial food-derived bioactive compounds is often hampered by their poor permeability through the small intestine, necessitating the use of appropriate oral delivery technologies.(48) Orally Disintegrating Films (ODFs) have emerged as a highly promising platform for delivering a wide array of beneficial compounds, including nutraceuticals and probiotics.(49) Over the past few decades, ODFs encapsulating nutraceuticals have shown particularly encouraging results. Consumers are actively seeking for sugar-free, non-GMO, and vegan-friendly formulations and this has led to a 50% surge in herbal and vitamin-infused oral strips that cater to these preferences.(50)Orally Disintegrating Films provides a simple, cost-effective, and highly accessible platform for probiotic delivery directly in the mouth. This ODF overcomes key challenges in probiotic formulation: it's easy to produce, boasts an extended shelf life, and remains stable at room temperature without requiring vacum packaging. These attributes significantly streamline its distribution and commercialization, paving the way for widespread adoption. Given its ease of use, it's suitable for all demographics, including children and the elderly, indicating substantial market potential.

To validate the ODF's efficacy, the viability of the encapsulated microorganisms was rigorously assessed throughout the production process and during storage by enumerating viable cells. While confocal microscopy revealed a mix of live and dead cells, quantitative analysis confirmed a remarkably low loss of less than 15% of probiotics during ODF fabrication. Crucially, the probiotics maintained high viability over 90 days of storage. This ODF rapidly dissolves in the mouth, releasing the encapsulated probiotics, offering a simple and innovative vehicle for consistent probiotic intake.(51) In an another recent study, an oral fast-dissolving nanofilm encapsulating Lactobacillus plantarum was successfully formulated using pullulan (PUL)-based electrospinning. This formulation demonstrated excellent stability, with accelerated storage tests indicating a prolonged shelf life at 4 °C, characterized by an inactivation rate constant of 1.74×10^{-5}. Furthermore, the nanofilms exhibited rapid disintegration within 15 seconds in simulated saliva, underscoring their potential as an effective oral fast-dissolving probiotic delivery system.(52) A study conducted by Sinem et al. investigated the incorporation of the oral probiotic Streptococcus salivarius M18 into diverse biopolymer-based oral dissolving film (ODF) formulations. The biological activity of the ODFs containing M18 bioactive products was evaluated through their demonstrated inhibitory effect on the

proliferation of Streptococcus mutans, a known pathogen implicated in dental plaque and cavities. Moreover, an anti-proliferative effect on cancer epithelial cells was additionally observed. This study conclusively demonstrates that probiotic products can be integrated into bio-based thin films without a loss of activity, rendering this delivery platform promising for eliciting both local and potentially systemic therapeutic effects.(53)

Table 3.List of examples of ODF nutraceuticals.

Drug Name	The Active Substance	Dose	Region	Producer	Drug Action/Application
ZimUNat (ZIM Laboratories)	Biotin, zinc, folic acid, elderberry, melatonin, caffeine + L-theanine, chasteberry, lutein/zeaxanthin, ginger etc	ODS: doses like Biotin 40 µg + Zn 4 mg; Melatonin 3/5 mg; others	India	ZIM Laboratories	Oral thin-film supplements for hair, eye, immunity, PMS, stress, sleep, focus, iron-deficiency, nausea relief
PharmFilm® (Multivitamin)	Multivitamins, B-complex	Not disclosed	USA, Canada	MonoSol Rx	OTC nutraceutical supplement in oral film format for daily wellness
PharmFilm® (Melatonin)	Melatonin	Not disclosed*	USA, Canada	MonoSol Rx	Sleep aid delivered via rapid-dissolve oral film
Shilpa Therapeutics	Vitamin D3, Methylcobalamin, Simethicone	Vitamin D3 2000 IU, Methylcobalamin 1500 mcg, Simethicone 62.5 mg	India	Shilpa Therapeutics Private Limited	Vitamin D3 deficiency, diabetic and peripheral neuropathy, flatulence, adjuvant for hyperacidity.
CL Pharm	Collagen, various vitamins/minerals	N/A (e.g. Collagen: 2 Strips 1/day)		CL Pharm	General ODF technology, potential for nutraceuticals including collagen and other active ingredients.
Aavishkar	Vitamin B12, Vitamin D3, Electrolytes, Breath freshening agents.	Vitamin B12, Vitamin D3, Electrolyte blend	India (20+ countries)	Aavishkar Oral Strips Pvt Ltd	Common health supplements, kids supplements, geriatric care, oral health, women wellness, ingestibles.
Spaargin (Veda Vital)	Multivitamins, anti-acidity actives (lemon, blueberry strips), sleep oral strips	Oral strips (e.g., strawberry multivitamin)	India (Uttarakhand)	Spaargin Consumer Pvt Ltd (brand Veda Vital)	Oral strips for wellness: multivitamins, anti-acidity, sleep aid
Amway India	Vitamin D3	Mouth-dissolving jelly strips	India	Amway (Nutrilite D-fence	Bone health and immune support (Vitamin D3) especially targeting youth; part of Nutrilite brand.

DK Livkon	Vitamin B-complex, B12, Folic acid, Biotin; Sildenafil (pharma), Milk Thistle, Ginger	ODF strips (e.g., B12/B-complex, antioxidant strips)	complex, antioxidant strips) India (Mumbai)	D.K. Livkon Healthcare Pvt Ltd	Wellness and medicinal strips: vitamins, antioxidant "Hangout" (liver support), ED treatment
Soul Strips	Cordyceps militaris, Testofen (fenugreek extract), Melatonin + chamomile, valerian, etc.	45 SKUs (adults, kids, pets)	India → Global	Soul Strips (India)	Nutraceutical oral strips: libido/testosterone, sleep, pet health, women's health, general wellness.
Biovencer Healthcare	Ashwagandha, Vitamin B-Complex, B12, D3, Collagen, Melatonin, Biotin, Iron, Lutein & Zeaxanthin, etc	Fast-dissolving oral strips	India (Delhi NCR)	Biovencer Healthcare Pvt Ltd	Private-label oral strips for sleep, cognitive function, hormones, beauty (skin/hair/nails), immunity, etc.

Table 4. List of examples of ODF Probiotics

Drug Name	The Active Substance	Dose	Region	Producer	Drug Action/Application	Reference
Dr FiLL Prebiotics Oral Dissolving Film	Heat-treated prebiotics (Nano ECF), 100 billion CFU	100 billion CFU per strip; 2 strips/day	USA (via Amazon)	C.L.Pharm Co., Ltd.	Gut health and immune support via fast-absorbing oral film	(54)
Experimental ODF with Streptococcus salivarius M18	Streptococcus salivarius M18 cell-free probiotic extract	Research formulation (dose not specified)	India (research)	Academic study	Oral health: inhibits *S. mutans*, reduces dental plaque & cavities	(55)
Research ODF with Lactobacillus/Bifidobacterium	Lactobacillus acidophilus or Bifidobacterium animalis	Not dose-specified; lab-scale films	International (research)	Academic study	Oral cavity probiotic delivery; high viability post-manufacture	(56)
Probiotic instant film (patent)	*Bacillus coagulans* VHProbi C08	Not specified	China	Patent (unspecified seller)	Prevents diarrhea, supports gut health via oral film format	(57)

Str. salivarius M18 probiotic ODF (research)	Cell-free probiotic extract from *S. salivarius M18*	Not specified	India (research)	Academic group	Oral health: inhibits *S. mutans* → reduced plaque and cavities	(55)
ODF with *L. acidophilus*, research patent	Lactobacillus acidophilus	Not specified	India	Siddon Biotech / patent	Probiotic films maintain viable probiotic post HME processing	(58)
Probiotic mucoadhesive film for oral candidiasis (research)	Probiotic extract (strain not specified)	—	International	Academic study	Mucoadhesive film to inhibit *Candida albicans* in oral candidiasis	(59)
Heinemann/Favaro-Trindade ODF (L. acidophilus/B. animalis)	*L. acidophilus* or *B. animalis* subsp. *lactis*	n/a (research format)	Brazil (study)	Heineman n et al. university group	Oral health film delivering viable probiotics	(60)
Postbiotic ODF (L. plantarum & L. paracasei)	Postbiotic extracts from *L. plantarum* 226V & *L. paracasei* L26	n/a (research format)	Europe (study)	Academic researchers	Aims to prevent oral dysbiosis and caries	(61)
Orodispersible Film with *E. faecium* CRL183	*Enterococcus faecium* CRL183	n/a (research format)	Brazil (assumed)	Academic researchers	Deliver probiotics in mouth; targeted oral probiotic therapy	(62)
ProBiora3® / PerioBalance® / KForce Breath Guard	*Streptococcus salivarius* M18 / K12 strains	Not disclosed	USA	Blis Technologies (NZ/USA)	Oral health: reduces plaque, freshens breath, inhibits *S. mutans*	(63)

2.4 **Novel Polymers and Excipients**

Polymers are employed to impart hydrophilicity, flexibility, mouthfeel, and solubility of ODF. Pullulan, Gelatin and hypromellose are among the most commonly used water-soluble polymers for preparing oral strips. The film-forming polymer, which acts as the primary component of the ODF, can make up to 65% of the total dry weight of the film, A wide range of polymers has been explored as potential base materials for producing oral dissolving films (ODFs).(64) These include, but are not limited to, starch, modified starches, hydroxypropyl methylcellulose (HPMC) (such as hypromellose grades E3, E5, and E15), sodium carboxymethyl cellulose (NaCMC), gelatin, hydroxypropyl cellulose (HPC), and hydroxyethyl cellulose (HEC). Other investigated polymers are pectin, carboxymethyl cellulose (CMC), pullulan, locust bean gum, xanthan gum, guar gum, carrageenan, povidone-based polymers (polyvinylpyrrolidone, PVP), polyvinyl alcohol (PVA), polyethylene oxide (PEO), maltodextrins (MDXs), and various others and a blend of polymers is sometimes used.(65) These polymers must be non-toxic, non-irritating, and free of leachable impurities while exhibiting excellent wetting, spreadability, and shelf stability. Additionally, they should not cause secondary infections in the oral mucosa or dental areas. In addition to possessing adequate peel, shear, and tensile strength for optimal performance, ODFs must rapidly disintegrate in the oral cavity while maintaining their film-like characteristics. Crucially, the film should be soft and flexible to prevent any irritation or injury to the buccal cavity. Thermo-sensitive amorphous polymers are generally preferred due to their favorable thermal behavior. Unlike crystalline polymers, which possess an ordered molecular structure and are relatively hard with a distinct high melting point (Tm), amorphous polymers have a disordered molecular arrangement. As a result, their melting point is not sharply defined. At low

temperatures, amorphous polymers exist in a brittle, glassy state; as the temperature increases beyond their glass transition temperature (Tg), they become soft and rubbery. Upon further heating, they transition into a viscous liquid state, with the temperature at which this occurs often referred to as the melting temperature (Tm).(66–70) Thermoplastic polymers are used as film formers primarily to leverage their thermoplastic behavior in the glassy transition state. Unlike pure materials, which absorb a specific amount of thermal energy during phase transitions, polymers exhibit a rubber-like behavior even before the state change occurs. In the glassy phase, thermoplastic polymers maintain flexibility, elasticity, and fluidity while still retaining their shape and enabling internal material migration. This phase allows thermoplastics to exhibit fluidity through intermolecular entanglements, whereas thermosets display fluid-like characteristics due to physical bonds within their cross-linked structures. These thermal and mechanical properties make thermoplastics easier to mold and highly compatible for mixing with APIs and other excipients.(71–73,73,74)

Among the various polymers used in oral dissolving films (ODFs), pullulan stands out as one of the most commonly used film-forming agents. It is a naturally occurring polysaccharide obtained from the fermentation medium of *Aureobasidium pullulans*. Pullulan dissolves well at both high and low temperatures, has minimal taste or aroma, and exhibits relatively high thermal stability.(75)Notably, it possesses low oxygen permeability and exhibits excellent film-forming and mechanical properties. In addition to being transparent, flexible, and non-toxic, pullulan is also biocompatible and biodegradable. It is widely used as an excipient in health foods due to its rapid dissolution—faster than other film formers such as hydroxypropyl methylcellulose (HPMC)—and leaves minimal residue after use.(76)Even when used alone as a film-former, pullulan forms films with excellent mechanical strength and demonstrates good compatibility with a wide range of active pharmaceutical ingredients (APIs). Its linear, unbranched structure enables easier physical control and facilitates formulation adjustments with additives. Moreover, pullulan significantly enhances API stability by serving as an outstanding oxygen barrier—approximately 300 times more effective than HPMC film and 9 times more effective than gelatin film in reducing oxygen permeability.(77,78)

These films have been successfully utilized for the administration of medications such as diclofenac sodium, quinine hydrochloride, terbinafine hydrochloride, and aspirin. Their rapid-dissolving properties make them especially suitable for drugs classified under the Biopharmaceutics Classification System (BCS) class II, which typically exhibit low solubility but high bioavailability.When used as a matrix material in fast-dissolving oral formulations, pullulan significantly improves both solubility and bioavailability. For instance, griseofulvin—a drug used to treat fungal infections—demonstrated over 80% dissolution within 30 minutes when formulated with pullulan. Similarly, captopril, an antihypertensive agent, achieved complete dissolution in just 2 minutes and exhibited a 61% increase in bioavailability. Glipizide, a medication used to control blood sugar levels, showed a 10-fold improvement in solubility and reached 90% drug release within 5 minutes when incorporated into pullulan-based films.(79) Overall, pullulan's film-forming capability and rapid disintegration profile make it an ideal excipient for improving the oral performance of poorly water-soluble drugs.

Chemical modification of pullulan greatly improves the functional properties of its derivatives, making them well-suited for applications such as food coatings. For example, pullulan esters like pullulan acetate, pullulan propionate, and pullulan butylate have been investigated for their ability to preserve strawberries. These modified derivatives also hold potential for use in oral film formulations; however, their thermosensitive nature should be carefully considered during development.(80) Fabian Hernandez-Tenorio et al. conducted a study in which carboxymethylated derivatives of pullulan (PU) were synthesized and assessed for their effectiveness as coatings to enhance the postharvest preservation of blueberries. Monosol LLC in his patent describes water-soluble polysaccharide films, such as pullulan films, improved by the inclusion of carboxymethylcellulose (CMC). The films exhibit enhanced physical properties like tear strength while retaining good water solubility, making them suitable for edible film applications(81)

Whey protein isolate (WPI) is capable of forming films with diverse functional properties, largely influenced by its structural cohesion. While native WPI (NWPI) films have received relatively limited research attention, heat-denatured WPI (HWPI) films have been more extensively studied. Early research suggests that protein denaturation plays a critical role in the successful formation of WPI-based films.(82) Min-Ju Tsai et al. introduced an innovative method utilizing a common solvent to produce edible composite films composed of whey protein isolate (WPI) and zein. These composite films exhibited enhanced physicochemical properties compared to those made from each individual protein alone. The newly developed WPI/zein films were also heat-sealable and capable of dissolving in hot water.(83) Ziye Xu et al. developed oral fast-dissolving films (OFDFs) incorporating high loads of soluble resveratrol using various ratios of whey protein isolate (WPI) and alginate. The presence of WPI and/or

alginate enhanced the solubility of resveratrol, with glycerol further influencing this effect. The resulting films showed rapid disintegration and improved resveratrol permeation. These findings indicate that WPI and alginate are effective biopolymers for formulating OFDFs aimed at enhancing the oral delivery of resveratrol, suggesting the potential of such biopolymer-based films as carriers for polyphenol delivery.(84)

Hydroxypropyl methylcellulose (HPMC) and starch are among the most widely used polymers in the formulation of orally disintegrating films (ODFs), owing to their excellent film-forming abilities and rapid disintegration characteristics. HPMC, a semisynthetic cellulose ether, consists of a cellulose backbone chemically modified with methoxy (-OCH_3) and hydroxypropyl (-$OCH_2CHOHCH_3$) groups. These substitutions enhance its solubility, flexibility, and ability to form clear, stable films suitable for rapid disintegration in the oral cavity. Starch, a natural polysaccharide, particularly modified or pregelatinized starches, are highly suitable as film-forming agents for ODFs. They have the ability to form homogeneous and hydrophilic films and exhibit good mechanical properties, rapid disintegration, and strong mucoadhesiveness and can be used alone or in combination with other polymers like HPMC to optimize film performance (85) Lower grades of hydroxypropyl methylcellulose (HPMC), such as Methocel E3, E5, and E15, are particularly favored for film formation due to their low viscosity. HPMC has a high glass transition temperature and is classified based on the content of its substituents and viscosity, both of which influence its solubility–temperature relationship.To enhance specific functional properties of HPMC-based films, various additives are often incorporated into formulations.

Numerous studies have investigated the effects of these additives on the physicochemical characteristics of HPMC films. Notably, lipid compounds such as waxes, triglycerides (e.g., tristearin), and fatty acids (e.g., stearic and palmitic acids) are commonly used. These lipids significantly reduce water affinity and moisture transfer in the films due to their pronounced hydrophobicity, which stems from their high content of long-chain fatty alcohols and alkanes..(86) Starch-based films tend to form a gel upon contact with water, which can hinder their disintegration. In contrast, hydroxypropyl methylcellulose (HPMC)-based films disintegrate more readily, without exhibiting characteristic gel formation. Incorporating HPMC into the film matrix—partially replacing starch—effectively reduces the gel-forming tendency of the formulation, thereby enhancing disintegration. Microscopy results further suggest that higher concentrations of HPMC lead to films that are more heterogeneous and less cohesive, which may also contribute to a reduction in disintegration time.Ana Flávia et al. developed a novel oral disintegrating film (ODF) formulated Hydroxypropyl guar gum film with hydroxypropyl methylcellulose (HPMC) and guar gum (GG), incorporating the essential oil of Plectranthus amboinicus L. (EOPA). Despite the low retention of the active component after the drying process, which limited its antimicrobial effectiveness against the tested strains, the well-established antibacterial properties of EOPA in existing literature highlight its potential. This research opens new avenues for the development of antimicrobial ODFs for clinical use.(87)

Pectin, a naturally derived anionic polysaccharide composed mainly of poly(α-1,4-galacturonic acid) units, exhibits a wide range of functional properties due to variations in its degree of methylation and amidation. These structural differences make it suitable for diverse applications, including pharmaceutical formulations. In the context of orally disintegrating film (ODF) development, studies have shown that increasing the concentration of pectin results in films that are thicker and more flexible. However, this also leads to longer disintegration times. Therefore, using lower concentrations of pectin may be advantageous for achieving faster disintegration in pectin-based ODFs.(88,89) Drug release profile of the pectin can be adjusted by varying levels of methylation and amidation in its composition. Pectin generally exhibits excellent film-forming capability and is known to produce films with high hardness, even when cast in thin layers. One of its notable advantages is cost-effectiveness, as it allows for specification subdivision and tailored use. However, pectin also presents certain limitations. It is pH-sensitive, which can influence drug release characteristics, and it tends to impart astringency and bitterness to formulations. Additionally, its inherent hardness can make processing more challenging. To overcome these drawbacks and enhance the film's physical properties, pectin is often combined with other film-forming agents in formulation development.(90,91) Namon Hirun et al. developed pectin-based buccal films designed for the delivery of antifungal agents such as fluconazole. These films, which incorporate solid lipid nanoparticles, provide controlled drug release and enhanced bioavailability, offering an effective alternative to conventional oral formulations.(92)

Chitosan, a natural cationic polymer, consists of a linear sequence of monomeric units—2-acetamido-2-deoxy-D-glucopyranose and 2-amino-2-deoxy-D-glucopyranose—linked by β-(1→4) glycosidic bonds. Due to its crystalline structure, chitosan is soluble only in aqueous acidic solutions. It offers several advantageous properties, including biodegradability,

biocompatibility, low toxicity, and notable antimicrobial activity.(93)

Chitosan, unlike many other natural polymers, becomes positively charged when protonated under acidic conditions. This property enhances its mucoadhesive nature, as it readily interacts with the negatively charged epithelial surface. Additionally, chitosan can form strong interactions with partially negatively charged active pharmaceutical ingredients (APIs) or additives, which may help modulate drug release and improve oral absorption efficiency.However, chitosan presents several challenges as a film-forming agent. It is insoluble in alkaline conditions, and although it dissolves in acidic environments, its pronounced astringency can be a significant drawback. Furthermore, the structural arrangement of polymers and additives in a formulation can influence the free volume—when this volume is low, it often leads to increased film hardness and a slower disintegration or dissolution rate.

Exploration into chitosan derivatives, such as thiolated chitosan and trimethyl chitosan (TMC), has shown promise in improving oral drug delivery. These modifications enhance mucoadhesive properties and permeability, aiding in the effective delivery of peptides, proteins, and vaccines. For instance, TMC-based nanoparticles have demonstrated increased insulin absorption and protection against enzymatic degradation in the gastrointestinal tract.(94) Patrícia Batista et al. developed chitosan mucoadhesive films loaded with peptide–chitosan microparticles, presenting an innovative approach for buccal mucosa administration. These films offer an increased surface area, facilitating rapid disintegration and controlled release of the antihypertensive peptide in the buccal cavity, thereby enhancing bioavailability. They found that these mucoadhesive films not only improve the penetration of large molecules across the oral mucosal surface but also provide a protective effect for the microparticles (MPs), which in turn boosts the peptide's bioavailability.(95) Keshireddy AnjiReddy et al. developed a novel approach by synthesizing hyperbranched chitosan (HPCN) to create oral thin films and nanofibers loaded with donepezil, a drug used in the management of Alzheimer's disease. These formulations demonstrated rapid disintegration, occurring in approximately 15 seconds, and achieved 97% drug release within 45 minutes in vitro. In vivo studies showed enhanced bioavailability compared to commercial formulations, suggesting improved efficacy for treating neurodegenerative conditions.(96)

Gum polysaccharides can serve as film-forming agents or viscosity regulators to enhance the mechanical properties and texture of oral disintegrating films (ODFs), as well as improve mucosal adhesion. The ability of these films to adhere to mucosal surfaces helps maintain contact with the tissue, promoting controlled drug release. Common gum polysaccharides used in ODF formulations include xanthan gum, Tamarind Seed Polysaccharide, carrageenan, and gelan gum. The physical properties of these polysaccharides vary depending on their type when incorporated into an ODF. Due to their complex branched structures, gum polysaccharides have a large free volume and low glass transition temperatures (Tg). For example, the Tg of carrageenan is approximately 80 °C, while that of hydroxypropyl methylcellulose (HPMC) ranges from 170-198 °C. These complex structures create high viscosity due to intermolecular attractions when the polysaccharides are dispersed or dissolved, resulting in a dried composition similar to a gel. As a result, gum polysaccharides are typically used in smaller amounts compared to single polymer ODFs to prevent cracking caused by low free volume or to enhance softness. Additionally, they act as binders when used with large molecular weight polymers or when the primary component is incompatible with the solvent, leveraging the viscosity generated by their complex structure.(97) Pamula Reddy et al. developed microsized mouth-dissolving films using tamarind seed polysaccharide (TSP) for the release of amlodipine besylate, a drug for hypertension The amlodipine mouth-dissolving film, which contained higher amounts of the superdisintegrants CCS and SSG, demonstrated the fastest drug release onset.(98)

Plasticizers, which are low-molecular-weight additives, are incorporated into polymer solutions to enhance flexibility and plasticity. They lower the glass-transition temperature, converting polymers from hard, glassy materials to soft, rubbery ones. It is important to note that the moisture absorption properties of various plasticizers play a crucial role in influencing the characteristics of the films.(99) Plasticizers enhance flexibility by forming hydrogen bonds between the active pharmaceutical ingredient (API) and the hydroxyl groups of polymers, increasing atomic interactions while reducing atomic energy. This allows both the API and the plasticizer to be uniformly distributed within the polymers bulky spaces, improving elasticity and lowering the glass transition temperature (Tg).(100) Edible plasticizers, such as sugar alcohols, are commonly used where those with lower molecular weights interact more readily with polymeric hydroxyl groups, effectively imparting plasticity.(101) However, when multiple polymers are involved, those with weaker interactions with plasticizers may separate,

necessitating careful control of other excipient levels. Excessive plasticizer content can lead to plasticizer plasticizer interactions, resulting in undesirable film characteristics like excessive stickiness and high flexibility, often noticeable in the dried product. To avoid such issues, plasticizers are typically introduced during early film formulation at around 10% of the film-forming polymers weight. In practice, small quantities of sugar alcohols are often blended with other plasticizers such as glycerin and D-sorbitol for improved efficiency.(102,103) In recent advancements in oral dissolvable film (ODF) technology, a variety of novel plasticizers have been explored to improve mechanical properties, film flexibility, and drug delivery efficiency. Natural and bio-based plasticizers such as citric acid esters (e.g., triethyl citrate and acetyl triethyl citrate), sugar esters, and lactic acid oligomers (OLLA) have gained attention due to their GRAS status and excellent plasticizing effects without inducing tackiness.(104,105) Additionally, natural oils and fatty acid esters like castor oil derivatives and mono-/diglycerides contribute to both elasticity and improved mouthfeel. Emerging classes such as ionic liquids (ILs), particularly choline-based ILs, offer dual functionality as plasticizers and permeation enhancers, enhancing solubility and moisture retention within films.(106)

Another promising group includes deep eutectic solvents (DES), such as choline chloride-glycerol and choline chloride-urea systems, which serve as non-toxic, biodegradable plasticizers with added benefits of improved drug dispersion and film pliability.(107) Vitamin E TPGS (D-□-tocopheryl polyethylene glycol 1000 succinate) is another multifunctional excipient that functions both as a plasticizer and solubilizer, particularly effective for poorly water-soluble (BCS Class II) drugs. Moreover, low molecular weight polypeptides and amino acids like arginine, glycine, and proline have demonstrated plasticizing abilities through ionic or hydrogen bonding interactions, enhancing the elasticity of film matrices. Biopolymer-derived plasticizers, including chitosan oligomers and modified pullulan derivatives, are also under investigation for their potential to synergistically improve film characteristics when combined with traditional film-forming agents.(108) Collectively, these innovative plasticizers offer diverse functionalities, opening new perspectives in the design and performance optimization of ODFs for targeted and patient-friendly drug delivery.

various excipients are incorporated to optimize performance and improve patient acceptability in ODF. Solubilizers are often included to enhance the solubility of active pharmaceutical ingredients (APIs), particularly since many APIs are hydrophobic in nature. Surfactants are also utilized to lower the surface tension of the casting solution, thereby aiding in uniform film formation.

The choice and concentration of these excipients depend on the physicochemical properties of the specific API being formulated. Additionally, to address the unpleasant taste that can result from the exposure of hydrophobic materials during ingestion, flavors and sweeteners are commonly added. Sweeteners such as acesulfame-K, sucralose, aspartame, and stevia are frequently used sometimes in combination to balance sweetness intensity and the rate of taste perception, ensuring a more palatable dosage form.

III. Advanced Manufacturing Techniques for ODF

Oral Dissolving Films (ODFs), no larger than a postage stamp, offer a highly convenient and patient-friendly approach to drug delivery. Their individual packaging simplifies transportation and handling for consumers. Beyond their ease of use, ODFs are incredibly versatile, serving as excellent carriers for advanced drug delivery technologies like microparticles, nanocrystals, and self-emulsifying systems. These integrated technologies precisely control drug release rates, directly enhancing the drug's bioavailability. (109,110)

Despite their advantages, ODFs do have some limitations. Their restricted formulation space limits the amount of drug that can be loaded. For instance, the highest dose currently available on the market is a 100 mg sildenafil ODF, meaning ODFs are generally reserved for potent drugs. While palatability is key to patient compliance, the limited formulation space also restricts the inclusion of taste-masking excipients. However, techniques exist to effectively reduce or eliminate the astringent or bitter taste of many drugs.(111)

Various techniques employed for manufacturing of ODF includes Solvent-casting method, Hot-melt extrusion, Semi-solid casting, Solid dispersion extrusion, Rolling method, Printing method.(112) Industrial-scale manufacturing of Oral Dissolving Films (ODFs) primarily relies on solvent-casting technologies. This process involves preparing an aqueous or hydroalcoholic mixture of excipients (inactive ingredients) and active pharmaceutical ingredients (APIs). This liquid mixture is then cast onto a surface, dried to form a thin film, and subsequently cut into the desired size for individual doses. This process requires specialized equipment

typically found in facilities that produce transdermal patches, leading to a limited number of ODF manufacturers globally. Nevertheless, a significant advantage, similar to transdermal patches, is that the drug dose in an ODF is directly determined by its size. This allows the same production chain to be used for manufacturing batches with varying drug strengths.(113)

3.1 solvent casting method

The solvent casting method is a widely used and versatile technique for producing oral thin films (OTFs), known for creating flexible, rapidly dissolving films for efficient drug delivery. This method is particularly well-suited for heat- and light-sensitive active ingredients due to the lower temperatures involved in both incorporating volatile components and evaporating solvents. The preparation process is straightforward: water-soluble components are combined in a heated magnetic stirrer, followed by the addition of the medication and other excipients to form a viscous solution.(114) This solution is then cast into films, typically in a Petri dish at a lab scale, allowing the solvents to evaporate. Once dry, the films are cut into precise sizes based on their active ingredient concentration. Advantages of solvent casting include superior uniformity in thickness, better clarity, a fine gloss, and freedom from defects like lines, resulting in films with enhanced flexibility and overall physical properties. Furthermore, this method is generally cost-effective. However, there are limitations: trace amounts of residual solvents can remain, potentially hindering compendial compliance. The use of flammable or volatile solvents (e.g., methanol, ethanol) necessitates special safety precautions to prevent fire hazards. Additionally, proper packaging is crucial to protect the films from moisture, which can negatively impact their stability and mechanical properties, and maintaining solution viscosity requires careful temperature control.(114–117)

3.2 Hot-melt extrusion (HME)

Hot-melt extrusion (HME) offers a robust continuous processing technology for creating tailored drug release profiles from active pharmaceutical ingredient (API)-polymer mixtures. Key process parameters that allow for precise control include temperature, speed, feeding rate, and pressure. In contrast to traditional methods like solvent casting, which often suffer from low production yield, environmental concerns, and stability issues (due to factors like polymer chain relaxation, moisture fluctuations, or polymer-plasticizer interactions during storage), HME presents significant advantages. These include its simplicity in shaping, reduced operational units, minimal product waste, and excellent scale-up capabilities.(118,119) Furthermore, HME is particularly well-suited for moisture-sensitive drugs and is highly effective in enhancing the solubility of poorly soluble APIs.(120)

While Hot-Melt Extrusion (HME) offers a robust method for creating oral dosage films (ODFs), several critical production challenges can arise.One common issue is die swell, where the film expands after leaving the die due to the polymer's viscoelastic properties. This can be managed by slowing screw speed and employing gentle, prolonged mixing.(121)Another hurdle is fish eye formation, irregular agglomerations often caused by moisture or certain ingredients. These are hard to eliminate once formed and disrupt flow. High-shear mixing from the outset is crucial to prevent them.Incorporating liquid ingredients, like plasticizers, can be done via granulation, which improves mixing but adds steps, or more efficiently by side stuffing the liquid directly into the molten blend in the barrel.Weight variation in film sheets often stems from poor powder flow.(122) Solutions include granulation, force feeders, or adding glidants. A gear pump can also help if the issue is uneven molten mass flow.Chemical stability of actives is a concern at high HME temperatures, leading to hydrolysis or free radical generation. Preheating excipients and adding antioxidants like Vitamin E TPGS can mitigate these risks.Finally, recrystallization of drug molecules can occur as the molten blend cools. This can be prevented by creating a highly viscous polymer-plasticizer medium, which inhibits crystal reformation.(123,124)

3.3 semi-solid casting method

The semi-solid casting method is an innovative technique gaining traction in personalized medicine, particularly for preparing oral thin films (OTFs) using acid-insoluble polymers like cellulose acetate phthalate and cellulose acetate butyrate. This method addresses the challenge of incorporating these polymers by leveraging their unique properties.The process begins by preparing a solution of a water-soluble, film-forming polymer. This solution is then carefully introduced into an acid-insoluble polymer solution, which has been prepared using a basic solvent such as sodium hydroxide or ammonium hydroxide. A plasticizer is subsequently added in a precise amount. The plasticizer plays a crucial role, influencing the characteristics of the resulting gel mass. This gel mass is formed when the two polymer solutions interact, creating a colloidal substance.The gel mass is then melted and cast into films or strips using heat-controlled drums or rolls. The film

thickness is precisely controlled, typically ranging from 0.015 to 0.05 inches.(125) A key aspect of this method is the mixing ratio of acid-insoluble polymer to film-forming polymer, which is maintained at 1:4 to ensure optimal film properties also they offer numerous advantages for preparing oral thin films (OTFs). One key benefit is its high film thickness accuracy, which is crucial for ensuring consistent drug dosage and optimal therapeutic performance. Beyond precision, this method also results in superior film aesthetics, producing OTFs with excellent appearance that can boost patient acceptance and adherence to treatment. Furthermore, the semi-solid casting process is streamlined and energy-efficient, simplifying production and reducing overall energy consumption compared to other manufacturing techniques. Finally, the rapid solidification speed of the gel mass significantly enhances productivity, making this an efficient and highly desirable approach for large-scale OTF manufacturing.(126)

3.4 Solid dispersion extrusion

Solid dispersion extrusion is a method that closely resembles hot-melt extrusion (HME). In this technique, one or more active pharmaceutical ingredients (APIs) are finely dispersed within an inert carrier while in a solid state, often in the presence of amorphous hydrophilic polymers. These otherwise immiscible components are then co-extruded with the drug, forming solid dispersions. These dispersions are finally shaped into thin films using specialized dies.

3.5 Rolling method

The rolling method for film preparation requires the drug solution or suspension to possess specific rheological properties to ensure it can be effectively rolled onto a drum. The primary solvent used is typically water, or a mixture of water and alcohol. In this process, the solution or suspension, containing the drug and other excipients, is applied and rolled onto a carrier drum. The film then undergoes an evaporation or drying process directly on the rollers, after which it's cut into the desired shapes and sizes.(127)

3.6 Three-Dimensional Printing technology

Three-dimensional (3D) printing has emerged as a transformative technology poised to revolutionize the design and fabrication of oral films (OFs). As an additive manufacturing technique, 3D printing offers unprecedented control over both the design of the dosage form and its drug content, making it particularly valuable in the realm of personalized medicine. One of the most significant advantages of 3D printing is its ability to circumvent the drug-loading limitations inherent to traditional buccal dosage forms, which often confine them to potent drugs with low doses. Through the precise, layer-by-layer deposition of oral films, 3D printing enables the incorporation of higher concentrations of active pharmaceutical ingredients per unit area—an essential feature considering the limited mucosal surface area available for absorption.(128)

In addition, 3D printing facilitates the development of OFs that contain otherwise incompatible ingredients by structurally compartmentalizing these agents into discrete layers within the film. This stratification effectively isolates conflicting components, ensuring formulation stability and efficacy. Beyond these advantages, 3D printing provides an innovative platform for achieving controlled drug release, thereby reducing the frequency of administration and enhancing both patient convenience and treatment adherence.(129,130)

Currently, several types of 3D printing technologies are being employed or investigated for oral film fabrication. These include Three-Dimensional Inkjet Printing, an advanced version of conventional inkjet technology, which deposits drug-containing solutions or suspensions in precise microdroplets layer by layer.(131) This method excels at producing high-resolution, multilayered structures and creating personalized oral films (OFs). Manufacturing time is driven by object size, not layer complexity, and costs are predictable, limited to materials, curing time, and energy. This method significantly reduces production time, often from days to hours, and can combine diverse liquid inks. However, cure time can restrict the speed of printing complex 3D structures. Layer thickness is also limited. A critical challenge is the potential for solvents from top layers to affect underlying layers, impacting adhesion and overall film integrity.(130)

Liquid Crystal Display (LCD) 3D Printing, a photopolymerization-based process that uses an LCD screen to selectively cure liquid resin formulations containing drugs and polymers with UV light. This technique has gained attention for its cost-effectiveness and ability to produce highly detailed oral films. However, certain limitations exist. LCD screens possess a short functional lifespan, requiring periodic replacement. Furthermore, only approximately 10% of the light effectively penetrates the LCD screen, with the majority being absorbed. This inefficiency can result in partial light leakage, potentially leading to unintended exposure and polymerization of the resin at the bottom of the tank. Additional drawbacks include the necessity for

regular cleaning of the liquid resin tank and the potential for adhesion of printed parts to the screen, which can cause print failures. .(132)

Extrusion-Based 3D Printing Methods, a versatile category involving the deposition of materials through a nozzle to build the film layer by layer.(133) This includes: Fused Deposition Modeling (FDM), which melts and extrudes thermoplastic filaments(134,135) and Printed structures are not easily contaminated and exhibit appreciable mechanical strength. FDM also allows for the creation of different release profiles in the final dosage forms. This versatility is achieved by simply modifying the 3D model's design, adjusting the infill percentage, or altering the surface area also enables mold reproducibility and uniformity of active ingredient concentration. (136)

Pressure-Assisted Microsyringe- Based 3D Printing Methods (PAM) or Semisolid Extrusion (SSE)-Based 3D Printing Methods, which extrudes viscous or semisolid materials using compressed air or mechanical force, particularly suitable for heat-sensitive drugs Compared to Fused Deposition Modeling (FDM), Pressure-Assisted Microsyringe (PAM) and Semisolid Extrusion (SSE) offer significant advantages for 3D printing oral films, especially when dealing with sensitive active ingredients.(137) A key benefit is their ability to enable continuous 3D-printed form fabrication at room temperature. This eliminates the need for prior filament preparation through hot-melt extrusion (HME), making PAM/SSE particularly suitable for thermo-labile drugs that might degrade under the higher temperatures required by FDM. Furthermore, because the entire 3D printing process is computer-controlled, it substantially reduces production time, manual labor, and overall costs compared to conventional film manufacturing techniques.(138–140)

Direct Powder Extrusion (DPE), which directly feeds powder mixtures into the printer, offering a streamlined, single-step manufacturing process and distinct advantages over FDM by avoiding thermal stresses, thus eliminating concerns about the mechanical stability of filaments during manufacturing. This method also facilitates single-step printing, making it a highly convenient and practical solution for on-site fabrication in hospitals and pharmacies. However, DPE can result in a final product with surface roughness and variable weight. A significant challenge arises if the melt residence time in the extruder's heating zone is prolonged, as this can negatively impact the rheological properties of the drug/excipients and substantially increase the risk of API thermal degradation. Furthermore, the use of pneumatic pressure in the process can lead to material oxidation before printing.(137)

Collectively, these diverse 3D printing approaches are paving the way for highly customizable and sophisticated oral film formulations, opening new avenues for patient-centric therapeutics.

3.7 Tape casting technique for oral films

Tape-casting, while not yet widely adopted for orally disintegrating films (ODFs), shows considerable promise for their rapid, large-scale production. This technique involves spreading a suspension onto a support as a thin layer using a leveling blade. The film-forming solution is then applied to larger supports or even continuous conveyor belts, where it undergoes drying through various methods like heat conduction, hot air circulation (convection), or infrared radiation.(141) study, conducted by Leandro et al., evaluated the impact of incorporating green propolis standardized ethanol extract (EPP-AF® or GPEE) into hydroxypropyl methylcellulose (HPMC) films using a 3D printing technique, varying the number of print layers from one to four. We characterized GPEE for its dry matter content, total phenolics, flavonoids, HPLC chemical fingerprint, apparent viscosity, density, and surface tension. The resulting orally disintegrating films (ODFs) were then assessed for color, moisture content, mechanical properties, structure, disintegration time, surface pH, stability, cytotoxicity, and anti-inflammatory activity. Our findings indicate that GPEE exhibits properties comparable to commercial inks, and the number of printed layers significantly influences film properties. Furthermore, the ODFs demonstrated good stability based on the selected propolis chemical biomarker.(142) similarly n a study by Vuddanda et al. (2017), tape casting was employed to create tadalafil nanocrystal (TDF)-loaded orally disintegrating films (ODFs). Their research focused on the impact of hydrophilic surfactants and drug loads on the films' physical-mechanical and dissolution characteristics. The authors reported that both drug and surfactant concentrations influenced the mechanical properties of the films. Significantly, films containing surfactants showed altered disintegration times compared to those without, and about 80% of the drug was released within 3 to 30 minutes.(143)

3.8 Electrostatic spinning technique for oral films

Electrospinning stands out as a highly promising alternative to the conventional solvent casting

method for producing oral films, offering significant advantages. This widely used technique for creating nanofibers involves subjecting polymer solution droplets to an electric field. This process precisely transforms spherical droplets into cones, which then stretch into incredibly fine, nanoscale filaments. The resulting electrospun fibrous films boast superior flexibility and plasticity—crucially, without requiring plasticizers—alongside a significantly higher surface area compared to solvent-cast films.

films developed via solvent casting are often prone to brittleness, exhibit a low surface-area-to-volume ratio, and possess limited drug loading capacity. Beyond material properties, solvent casting presents considerable manufacturing challenges in achieving suitable uniformity and quality in oral films. Optimizing production parameters like mixing rates, drying time, and film thickness demands substantial investment, which can impede commercial production. While solvent casting is a commonly used method for fabricating mucoadhesive buccal films, particularly for multilayered applications, it carries inherent limitations, including the persistent risk of residual solvents that can be hazardous to both patients and the environment. Recognizing these drawbacks and the inherent benefits of electrospinning, its versatile potential has led to its broad application in recent years, especially in producing oral films containing active substances.(144,145) Qingchun et al successfully developed orally disintegrating films (ODFs) loaded with piroxicam (PX) microcrystals using a combined approach of anti-solvent precipitation and electrospinning. Poloxamer stabilized the PX microcrystals, which were then readily integrated into polymeric solutions for electrospinning, resulting in fibrous films with scattered microcrystals. Characterization via SEM, XRD, and FTIR confirmed the morphology, solid state, and molecular interactions within the ODFs. The films exhibited satisfactory mechanical properties and rapid disintegration attributed to polymer selection. Critically, dissolution tests showed remarkable improvement: nearly 90% of PX dissolved from the ODFs within 6 minutes, a significant leap compared to only 40% dissolution from physical mixtures in 60 minutes. This demonstrates that combining micronization with electrospinning is a highly effective strategy for formulating poorly water-soluble drugs into high-quality ODFs.(146) Luca Éva et al. successfully developed a diclofenac-loaded orodispersible formulation (ODF) using a double-needle electrospinning technique. This electrospun formulation presented as an amorphous solid dispersion, demonstrating excellent encapsulation efficiency and homogeneous drug distribution within the nanofiber matrix. The ODF exhibited rapid disintegration, completing within 5 seconds in artificial saliva and approximately 41 seconds on an artificial tongue. Furthermore, complete drug dissolution in artificial saliva was achieved within 10 minutes. Overall, this study developed a promising diclofenac formulation characterized by rapid disintegration, immediate drug release, and good stability. Notably, they also introduced a novel in vitro dissolution method ("AS-to-FaSSGF") to provide a more comprehensive understanding of drug dissolution throughout the gastrointestinal tract.(147). Similarly, Hadi Sudarjat et al. developed a novel Janus LAAM-loaded fibrous buccal film (LFBF). This bilayered system, featuring an electrospun drug-containing fibrous layer and a backing layer, exhibited remarkable transmucosal delivery of LAAM to systemic circulation. In rabbits, the LFBF achieved nearly 4-fold greater drug bioavailability than traditional oral LAAM solutions, leading the researchers to propose these Janus films as a transformative strategy for opioid use disorder (OUD) management(148) Using emulsion electrospinning, Haowei et al. developed a starch-based oral fast-disintegrating nanofiber mat for astaxanthin(AST) encapsulation and distribution. The nanofiber mats demonstrated exceptional storage stability over a period of seven days and a high encapsulation efficiency of 85.11 ± 1.53 percent. In contrast, AST's amorphous transition made it more water soluble, bioavailable, and antioxidant (97.72 ± 2.17 %) in an aqueous solution than free AST. With a wide range of potential uses in the food and pharmaceutical industries, the results showed that the emulsion electrospun green, nontoxic, and biodegradable nanofiber mats effectively achieved the encapsulation and delivery of AST.(149)

3.9. Ready-to-Use Film Bases for Oral/Orodispersible Films

The increasing demand for patient-centric drug delivery systems has accelerated interest in orodispersible films (ODFs), particularly for pediatric, geriatric, and dysphagic populations. These thin, rapidly dissolving films offer a convenient and non-invasive route of administration, eliminating the need for water or swallowing solid dosage forms. However, the formulation and scale-up of ODFs require precise optimization of polymer concentration, plasticizer ratios, and film uniformity to ensure consistent drug content, mechanical strength, and rapid disintegration.

To streamline this process and reduce formulation variability, ready-to-use film-forming bases such as OrPhyllo™, VersaFilm® have emerged as reliable compounding vehicles. These commercially available systems are typically water-based, pre-

optimized with film-forming polymers and plasticizers, and enable faster development timelines, improved reproducibility, and reduced excipient compatibility issues. Their availability is particularly valuable in hospital or community pharmacies for personalized medicine, as well as in industrial settings where rapid prototyping of API-loaded films is essential.(150)

By eliminating the need for initial excipient screening and base formulation trials, these film bases offer a cost-effective and time-saving alternative for developing safe and effective orodispersible drug delivery systems.

Table 5. commercialised ODF available in market

Brand Name	Manufacturer / Supplier	Description / Features	Application	Reference
OrPhyllo™	Fagron	Water-based, ready-to-use base for personalized compounding of ODFs	Pediatric and geriatric drug delivery	(150,151)
PharmaFilm®	Aquestive Therapeutics	Proprietary polymer base for delivering actives via oral films	Commercial Rx films (e.g., Zuplenz®, Suboxone®)	(152)
MonoSol® ODF Technology	MonoSol (Kuraray)	Water-soluble polymer-based film tech (pullulan, maltodextrin, etc.)	Prescription and OTC oral films	(153)
VersaFilm®	IntelGenx	Platform based on polymer blends (e.g., HPMC, PVA)	Customizable for controlled or fast release	(154)
CureFilm™	CURE Pharmaceutical	Lipid-enhanced or mucoadhesive films	Supplements, nutraceuticals, Rx	(155)
QuickStrip™	Rapid Dose Therapeutics	Thin, fast-dissolving films with customizable actives	Nutraceuticals, CBD, and Rx delivery	(156)
Rapidfilm®	AdhexPharma	Industrially scalable oral film technology	High-dose capacity, flexible formats	(157)
Zydis® (freeze-dried wafers, related ODT tech)	Catalent	While not cast films, similar use-case for APIs	Fast-dissolving platforms	(158)

3.10 Bilayer oral Films for multiple drug delivery

Bilayer-OTF (Oral Thin Film) technology presents a significant advancement in drug delivery, offering a potential solution to reduce patient pill burden by enabling the co-administration of two or more active pharmaceutical ingredients (APIs) within a single fixed-dose combination (FDC) dosage form. This innovative design features a distinct adhesive layer engineered for targeted drug release through the buccal mucosa, paired with a backing layer that strategically prevents premature drug release within the oral cavity.

The advantages of Bilayer-OTF are multifaceted including it's specifically designed to overcome chemical incompatibilities between active components, leading to potentially increased efficacy through additive or synergistic effects. Furthermore, the convenience of a single dosage form significantly improves patient adherence to treatment regimens. Crucially, the integrated backing layer provides essential structural support to the mucoadhesive layer, thereby ensuring efficient and controlled drug delivery directly to the buccal mucosa(159) In their study, Friederike et al. investigated hot-melt extrusion for continuously manufacturing bilayer films loaded with both small and large molecule APIs. They first created and characterized mucoadhesive monolayer films using various polymers and active ingredients. When combining these mucoadhesive films with a backing layer to form bilayer films, the method showed mixed results; SEM images revealed inconsistent fusion between the two layers. Despite this, mucoadhesion tests demonstrated that parts of the swelled mucoadhesive film remained adhered to the

backing layer even after withdrawal from the biomimetic gel.(160)

4. Evaluation of ODF

Patient compliance is often easier to achieve with oral thin films (OTFs), given their ease of use and convenience. However, identifying and understanding the key attributes of OTFs that ensure patient compliance is crucial to their overall evaluation. Studies have highlighted that two vital characteristics—stickiness and disintegration time in the oral cavity—play a significant role in gaining patient acceptance.

Stickiness, typically assessed through Dynamic Method Analysis, helps gauge the tackiness of the film, which can affect comfort and usability. Meanwhile, disintegration time is commonly measured using the drop method, offering insights into how quickly the film breaks down in the mouth. Alongside disintegration, the dissolution time of the film is also critical, as it influences how effectively the drug is released and absorbed through the oral mucosa.For OTFs containing nanotized drugs, the evaluation of these attributes can be carried out using the Slide Frame and Ball (SFaB) method.(161) The most commonly employed methods for evaluating oral films, as reported in various research studies, are as follows:

Morphological and organoleptic control:

The morphological and organoleptic properties of oral thin films (OTFs) are assessed through visual and sensory examination. This includes evaluating their color, homogeneity, transparency, smell, and texture. Particular attention should be paid to their taste and flavor characteristics.(162)

Moisture Absorption Capacity

To determnine the physical stability and integrity of the films under high humidity conditions, their moisture absorption capacity is determined. Each film sample is individually weighed, then placed in desiccators containing an aluminum chloride solution and exposed to moisture for 3 days. Following this exposure, the films are reweighed. The percent moisture absorption is then calculated using the following formula(163):

% Moisture absorption capacities = (Initial Weight - Final Weight) / Initial Weight × 100

Mechanical properties

Tensile strength is the maximum tensile force applied until the thin-film specimen breaks. It is obtained by dividing the applied force by the cross-sectional area of the film and multiplying by a hundred(164)

% Tensile Strength = (Load at Failure) × 100/ (Film Thickness × Film Width)

Milica et al reported a testing method for the prepared oral thin films (OTFs) to determine its mechanical properties using a universal testing machine (Shimadzu AG-Xplus, Shimadzu Corporation, Kyoto, Japan) equipped with a 100 N load cell. In adherence to the DIN EN ISO 527-3 standard for evaluating the tensile properties of films and sheets, bone-shaped samples of the recommended dimensions were prepared.(165)

During the tensile test, each ODF was securely clamped between two grips, which then moved apart at a cross-head speed of 5 mm/min until the film ruptured. Four films from each sample batch were subjected to this mechanical evaluation. The key mechanical parameters — Tensile Strength (TS), Elongation at Break (EB), and Young's Modulus (YM) — were calculated using the following equations:

- **Tensile Strength (TS):** $TS=Fmax/A$

Where Fmax is the maximum force applied before rupture, and A is the original cross-sectional area of the film.

- **Elongation at Break (EB):** $EB= \Delta L/ L0\times100\%$

Where ΔL is the increase in length at rupture, and L0 is the original length of the film.

- **Young's Modulus (YM):** $YM=Stress/Strain= (F/A)/(\Delta L/L0)$

Where F is the applied force, A is the original cross-sectional area, ΔL is the change in length, and L0 is the original length.

Weight variability : To determine the weight uniformity of each formulation, 2x2 cm^2 film sections are precisely cut and individually weighed using a sensitive scale. The weight variability is then calculated from these measurements.(166)

Thickness Measurement :

Film thickness is a critical parameter, directly influencing the quantity of drug loaded in the oral thin film (OTF) and essential for comfortable patient application. For instance, buccal thin films typically require an ideal thickness ranging from 50 to 1000 µm. To ensure accuracy and uniformity, we measure at least five films from each formulation, taking measurements from five different points on each film. Results are then reported as the mean (x) and standard deviation (SD).(167)

Flexibility, or folding endurance: A thin film's flexibility is assessed by folding it repeatedly at the same area at a 180° angle until it breaks. The quantity of folds formed before to breaking is observed. A film is regarded as having exceptional flexibility if it can fold 300 times or more.(168,169)

Surface pH :
An ODF sample was lightly moistened with 0.5 mL of distilled water and allowed to rest for 2 minutes. The pH of the moistened film was then determined using a pH meter. In this procedure, the electrode surface of the pH meter was gently brought into contact with the moistened surface of the film to record the pH Measurements should be taken in triplicate for each sample, and the mean value of the readings should be recorded. The ideal pH value must be close to 7.0 to avoid mucosal irritation in the oral cavity, thereby, helping in gaining patient compliance .(170)

Karl–Fischer Titration (Water Content):
The water content of the ODF was determined using a Karl–Fischer coulometric titrator. A 2 × 2 cm^2 sample of the film was added to approximately 5 mL of methanol, and titration was carried out until the electrometric endpoint was reached. Each sample was analyzed in triplicate, with the results corrected for the water content of the solvent.(170)

Determination of swelling degrees:

The swelling behavior of polymeric films is crucial for evaluating their water absorption capacity and determinig their resistance to moisture. Randomly selected OTF samples are individually weighed and then immersed in simulated physiological fluid placed in a Petri dish for a specified duration. Each film is then reweighed at predetermined time intervals until its weight stabilizes.(171) The swelling degree is calculated using the following equation:

% Swelling Degree = [(Final Weight - Initial Weight) / Initial weight)]x 100

Content Uniformity:
To determine content uniformity, each film is dissolved in a suitable solvent and then filtered. The drug content in each film is measured using an appropriate quantification method. The relative standard deviation (RSD%) should not exceed 6%.(169,172)

DisintegrationTest:
The disintegration time refers to the duration (in seconds) required for a film to disperse upon contact with saliva or water. This time point marks the onset of disintegration or dispersion of the thin film. Factors such as the weight and thickness of the film significantly influence the physical properties of water-soluble films.

The disintegration test apparatus described in pharmacopoeias can be employed to measure the disintegration times of OTFs. Typically, the disintegration time of film compositions ranges between 5 to 30 seconds, although this can vary depending on the formulation. Currently, there is no official guidance available for determining the disintegration times of films that disintegrate very rapidly.(173)

DissolutionRateTest:
According to the literature, many studies have used Franz diffusion cells to evaluate drug release from polymeric films, with some modifications made to adapt the apparatus for dissolution rate testing. One of the main challenges in the dissolution rate assay is the proper placement of film specimens. To address this, various methods have been reported in which the film is secured to the bottom of a glass container or the mixing apparatus using double-sided adhesive tape. Unlike the USP 4 apparatus, which can exhibit ambiguities in test conditions, or the USP 1 and 2 apparatuses, which sometimes result in test failures, the millifluidic device offers a smaller-scale geometry that avoids these issues. Notably, within short timeframes (0–15 minutes), it has shown better discriminatory power than USP 1 and 2 tests.

Significant differences in dissolution times—attributable to variations in liquid volume and flow conditions—suggest that caution is warranted when using USP 1 and 2 apparatuses to predict in vitro drug release from strips in a mouth-like environment. In contrast, the flow-through device provides reproducible and reliable release data, making it a valuable tool for evaluating drug release from polymeric films.(174)

Determination of Release Kinetics:

The dissolution data for all film formulations containing the active pharmaceutical ingredient (API), obtained in either pH 6.8 artificial saliva or pure water, are analyzed using computer software to identify the appropriate kinetic model. Mathematical programs and formulas are then used to determine whether the formulations fit zero-order, first-order, Korsmeyer-Peppas, or Higuchi release models.(175,176)

Transparency:
The transparency of OTFs can be measured using a UV spectrophotometer. Film specimens are cut into rectangular pieces and placed in the spectrophotometer cuvette. Measurements are taken at a wavelength of 600 nm to determine the film's transmittance. The transparency of the film is then calculated using the following equation:

Transparency= log*T*600 / b

where **T600** is the transmittance at 600 nm, and **b** is the film thickness (in mm).

5. Novelty in packaging of Oral films

Fast-dissolving strips can be packaged in several ways, including single-dose pouches, blister cards with multiple units, multi-unit dispensers, and continuous roll dispensers.(177) Notably, some patented packaging systems exist for these films, such as Labtec's Rapidcard and Amcor Flexibles' Core-peel. The Rapidcard, roughly the size of a credit card, holds three films on each side, allowing each dose to be removed individually. Other patented systems include Catalent's Push-Pull™ and Seal & Peel™, which offer unit-dose blister packs with enhanced protection and convenient opening mechanisms, as well as Procter & Gamble's Rollpack™ for continuous roll dispensing. Additionally, MonoSol's Quickstrip® features unit-dose pouches and moisture-barrier structures to maintain film stability. These innovative packaging formats ensure proper protection, moisture control, and user convenience for oral disintegrating films.

6. Regulatory Overview of Orodispersible Films (ODFs)

Orodispersible films (ODFs) are gaining traction as a versatile and patient-friendly drug delivery system, particularly for individuals with swallowing difficulties, such as children and the elderly. While regulatory bodies like the FDA and EMA have not issued standalone, ODF-specific guidances, these films are generally evaluated under existing regulations for immediate-release oral solid dosage forms and orally disintegrating tablets (ODTs).(178)

In the United States, the FDA's Center for Drug Evaluation and Research (CDER) categorizes oral films as "soluble films," defining them as thin layers designed to dissolve upon contact with liquid. Despite the lack of a separate dosage form listing, general principles for orally disintegrating products apply. ODFs are typically composed of thin polymeric matrices (e.g., PVA, cellulose) containing the active pharmaceutical ingredient (API) and various excipients like plasticizers and sweeteners. Manufacturing processes, commonly solvent casting or hot-melt extrusion, must ensure uniform thickness and drug content, with each film being treated as an individual unit for content uniformity and assay testing, akin to USP requirements for tablets and capsules. Stability is a key consideration due to the hygroscopic nature of films, necessitating low-humidity manufacturing environments and protective packaging, such as laminated foil sachets. For dissolution, ODFs are treated similarly to ODTs, with rapid dissolution specifications (e.g., ≥80% release in 15 minutes) being common, and general immediate-release dissolution guidance (e.g., FDA's 2022 Dissolution Testing guidance) and USP Chapter ⟨711⟩ methods being applicable. Microbiological and preservative requirements align with those for oral solids, with low bioburden typically sufficing. The FDA's Baby-Friendly initiatives and Pediatric Research Equity Act (PREA) actively encourage child-friendly formulations, making ODFs an attractive option.

Across the Atlantic, the European Medicines Agency (EMA) also views ODFs favorably, particularly for pediatric use. Orodispersible films are recognized under the broader category of oromucosal preparations in Europe, with the European Pharmacopoeia (Ph. Eur.) defining them as rapidly dispersing sheets for oral placement. The EMA often treats ODFs analogously to ODTs in practice. A notable development is the drafting of a specific Ph. Eur. monograph for "Orodispersible films" (Text 3195 in Pharmeuropa 35.3), slated for inclusion in Ph. Eur. 11, signifying formal recognition of ODF quality standards. Regulatory pathways for ODFs in Europe can involve a "new pharmaceutical form" submission as a variation or a full Marketing Authorization Application (MAA), following either centralized or national procedures. Generic ODFs are approved via the generic pathway, requiring bioequivalence to an approved reference. European regulators expect ODF manufacturing to adhere to Good Manufacturing Practices (GMP) and ICH guidelines (e.g., ICH Q6A for specifications, Q8(R2) for quality by design).

Stability testing follows ICH Q1A(R2), emphasizing protective packaging due to moisture sensitivity. Dissolution and disintegration criteria are consistent with ODTs, with rapid in vitro disintegration (often <30 seconds) and dissolution (e.g., ≥80% in 15 minutes) expected.

Both the FDA and EMA emphasize the importance of bioequivalence (BE) for ODFs, treating them as immediate-release oral products. ICH M13 (2022), a harmonized guideline co-authored by EMA and FDA, clarifies BE study design for immediate-release forms, stating that ODFs can be handled similarly to ODTs. This includes recommendations for wetting the mouth before dosing and withholding fluids for one hour after administration. BE studies typically measure plasma Cmax and AUC in healthy volunteers under fasted conditions, with partial AUC or additional timepoints potentially included if early onset is critical. For drugs eligible for a Biopharmaceutics Classification System (BCS)-based waiver (BCS I/III APIs with minor formulation differences), a BE waiver can be requested under ICH M9. However, standard BE studies are required if excipients or manufacturing processes differ significantly.(179)

Given their inherent "child-friendly" nature, ODFs are highly encouraged for pediatric formulations by both regulatory bodies. The EMA's 2006 "Reflection Paper on Formulations of Choice for Paediatric Use" explicitly highlights the promise of thin films due to their ease of administration, lack of water requirement, and difficulty to spit out. Designing pediatric ODFs necessitates crucial considerations such as taste-masking, the use of FDA-approved excipients for pediatric use, and appropriate dose adjustments (e.g., smaller film sizes or multiple strengths). Pediatric labeling may also require testing in age-appropriate groups as part of Pediatric Study Plans (PSPs) in the US and Pediatric Investigation Plans (PIPs) in Europe. Overall, regulatory guidance consistently emphasizes safety (avoiding harmful solvents/preservatives), acceptability (taste, texture), and rigorous study designs, particularly for children. The formalization of a Ph. Eur. monograph and the inclusion of ODFs in recent ICH M13 guidance underscore the growing recognition and importance of this innovative dosage form in the pharmaceutical landscape.(178,179)

Table 6. Regulatory requirements for diifrent regulatory bodies

Aspect	FDA (US)	EMA (EU)	CDSCO (India)
Definition	“Oral soluble film” (NDA recognized)	Ph Eur 3195 monograph in progress	New dosage form under Schedule Y
Pathway	505(b)(2) / ANDA	MAA / variation / BE generic	SND / BE submission
Quality Standards	USP compendia; GMP; stability standard	Ph Eur chapters; GMP; stability	Schedule M; compendial norms
Dissolution Timing	≥80% in 15 min; <30 s disintegration	Same as FDA	Same as FDA/EMA
BE Guidelines	ICH M13; crossover; BCS waivers	ICH M13; limited water dosing	Tablet comparator PK studies sufficient
Pediatric	PREA; taste, excipient review	PIP required; taste & excipient safety	Age-paralleled dosing; national support

7. Patents

The rapid evolution of Oral Disintegrating Films (ODFs) as drug delivery platform has naturally led to a dynamic and increasingly complex patent landscape. Innovation in this sector is fiercely protected, spanning novel film compositions, advanced manufacturing processes, taste-masking technologies, and specialized packaging solutions. Various applications and their patented methodologies are presented in the tables below

Table 7. List of patents available on oral disintegrating films

Sl. No.	Country	Code	Year	Publication / Patent No.	Title	Applicant / Assignee	Brand Name / Patent Focus
1	US	US2024	2024	**US 20240016734 A1**	Oral film for administering epinephrine with enhanced permeation	Aquestive Therapeutics, Inc.	Epinephrine permeation-enhanced film
2	US	US2023	2023	**US 12,290,597**	Oral film compositions and dosage forms having precise active dissolution profiles	Aquestive Therapeutics, Inc.	CNS agent controlled-release film
3	US	US2023	2023	**US 20230149304 A1**	Oral film with precise active dissolution, e.g. clobazam, diazepam, riluzole	Aquestive Therapeutics, Inc.	Controlled-dissolution CNS films
4	US	US2023	2023	**US 20230138361 A1**	Enhanced delivery epinephrine compositions	Aquestive Therapeutics, Inc.	Epinephrine matrix film
5	US	US2020	2020	**US 2020/0101009 A1**	Unit-dose, fast-dissolving clobazam oral film	Aquestive Therapeutics, Inc.	Clobazam fast-release film
7	US	US2019	2019	**US 20190336453 A1**	Maltodextrin-HPC fast-dissolving oral dispersible film	Bonayu Lifesciences Private Ltd	Fast-dissolving general ODF matrix
8	WO	WO2015	2015	**WO 2015/001541 A2**	Pharmaceutical film composition of ondansetron	Shilpa Medicare Limited	Ondansetron oral film
9	EP	EP2014	2014	**EP 2741737 A1**	Dual-layer orodispersible film for heat-sensitive APIs	Tesa Labtec GmbH	Layered protective film system
10	WO	WO2019	2019	**WO 2019/202521 A1**	Fast dissolving paracetamol oral film	Shilpa Medicare Limited	Paracetamol fast-dissolving film

					with taste masking		

Table 8. listing patented technology for oral films

Sl. No.	Country	Year	Publication / Patent No.	Title / Tech Summary	Applicant / Assignee	Technology / Brand
1.	Canada / PCT	2025	PCT/CA2024/* (filed May 2025)	Nicotine dissolvable and non-dissolvable oral strips with rapid absorption	Rapid Dose Therapeutics & Aavishkar Oral Strips	QuickStrip™ Nicotine Delivery
2.	US	2024	**US 20240016734 A1**	Epinephrine oral film with enhanced permeation properties	Aquestive Therapeutics, Inc.	PharmFilm® Epinephrine Film
3.	US	2023	**US 20230248660 A1**	Loxapine oral film—psychiatric use; Notice of allowance	IntelGenx Corp.	VersaFilm® (Loxapine)
4.	US	2022	**US 11,369,631 B2**	Thermoresponsive gelling oral film (mucoadhesive behavior)	UNM Rainforest Innovations	Rainforest Technology
5.	US	2021	**US 11,179,331 B2**	High-load sildenafil film using lipid-micelle encapsulation	CURE Pharmaceutical	CureFilm®
6.	US	2018	**US 20180000725 A1**	Gelling oral films suited for heat-sensitive APIs	UNM Rainforest Innovations	Rainforest Technology
7.	US	2012	**US 8,241,661 B2**	Foundational single-layer fast-dissolving film delivery system	MonoSol Rx	PharmFilm®
8.	US	2009	**US 20090047350 A1**	Perforated film technology for improved dissolution	Unspecified	Perforated Film Technology
9.	US	2007	**US 20090026467 A1**	Thick, enzymatically-digested CMC film with 60% drug load	Paladin Labs Inc.	ThinSol™
10.	EU	2020	**EU trademark**: *IBSA FilmTec*, Application No. 018256100	maltodextrin polymer base, yielding ultra-thin (50–150 µm), fast-dissolving films that ensure precise dosing and user convenience	IBSA Institut Biochimique	IBSA FilmTec™ technology
11.	US	2006	**US 20060198873 A1**	Rapidly dissolving oral film (e.g., nicotine delivery)	Unspecified	Rapid Film Technology

8. Clinical translation

ODFs offer a patient-centric alternative to traditional oral dosage forms like tablets and capsules. This innovative platform addresses critical unmet needs for various conditions, Furthermore, as per Table 9 , a number of ODFs have been arrived in different phases of clinical trials.

Table 9 . ODFs in different phases of clinical trials.

Product Name	Active Ingredient	Assignee/Sponsor	Development Stage / Approval	Invention / Significance
AQST-104 (MediFilm®)	GLP-1 analog	**Aquestive Therapeutics**	Pre-Phase I	First buccal GLP-1 film for blood sugar/weight control—needle-free peptide therapy
Ondansetron Oral Soluble Film (Zuplenz®)	Ondansetron	**Par Pharmaceutical / MonoSol Rx**	Approved (FDA 2011)	Fast-acting antiemetic film—first FDA-approved ondansetron film
RizaFilm (Rizatriptan ODF)	Rizatriptan benzoate	**IntelGenx Corp. / Gensco Pharma**	Approved (FDA 2023)	Oral thin film migraine therapy; licensed globally
Sildenafil Orally Disintegrating Film	Sildenafil citrate	**Seoul Pharma** *(Avenir Wellness Solutions)*	Phase I (clinical development)	Convenient ED treatment—rapid uptake via buccal film
Sumatriptan Buccal Film (KL-00119 / alginate film)	Sumatriptan	**Klaria Pharma / CNX Therapeutics**	Phase I / licensed in EU	Rapid-onset film for migraines; mucoadhesive alginate delivery
Insulin Mucoadhesive Buccal Film	Insulin	**(Based on patent) Likely Bexion / Israeli inventors**	Preclinical	Non-invasive insulin delivery for diabetes via buccal film
Fentanyl Buccal Soluble Film	Fentanyl	**TEVA Pharmaceutical Industries**	Completed (marketed as lozenge/tablet; film in development)	Fast breakthrough pain relief; convenient buccal film format
Buprenorphine/Naloxone Buccal Film (Bunavail®)	Buprenorphine–naloxone	**BioDelivery Sciences (formerly MonoSol Rx)**	Approved	Opioid dependence treatment with buccal film delivery
Melatonin Oral Film	Melatonin	**(Unknown – academic/early-stage)**	Phase I	Pediatric sleep aid; fast-dissolving convenience formulation
Diclofenac ODF (NSAID Film)	Diclofenac	**(Not publicly disclosed)**	Phase II candidate	Rapid analgesia and fever control via dissolving film

9. Challenges and Future Perspectives

Oral Disintegrating Films (ODFs) continue to be a highly dynamic area in pharmaceutical development. While they offer significant advantages, particularly in patient compliance and rapid drug delivery, several challenges remain that dictate current research and future perspectives.(180)

Current challenges largely revolve around drug loading capacity, as the thin nature of ODFs limits the amount of active pharmaceutical ingredient (API) they can carry, making them less suitable for high-dose drugs . Effective taste masking remains critical for patient adherence, especially for bitter APIs that dissolve directly in the mouth . Furthermore, ensuring dose uniformity across large-scale manufacturing batches and maintaining physical and chemical stability against environmental factors like humidity pose significant formulation and production hurdles .(181) The mechanical properties of the films—requiring a delicate balance between sufficient strength for handling and rapid disintegration in the mouth—also demand careful consideration Lastly, enhancing the bioavailability of poorly soluble drugs when delivered via ODFs continues to be a key focus.(182)

Looking ahead, the future of ODFs is poised for exciting transformations driven by innovation. A major thrust is towards personalized medicine, with technologies like 3D printing enabling the creation of customized films with precise dosages and even multiple APIs tailored to individual patient needs.(183) Advances in novel excipients and polymers are set to improve drug loading, taste masking, and overall film performance . Strategies like incorporating nanosuspensions and amorphous solid dispersions are gaining traction to overcome the solubility challenges of various drugs . Perhaps most groundbreaking is the potential for ODFs to deliver biologics, peptides, and even vaccines, as discussed offers a needle-free and more stable alternative to traditional injections. (184)The integration of AI and machine learning is also set to revolutionize formulation development, accelerating the design and optimization of ODFs . Ultimately, these advancements aim to expand the therapeutic applications of ODFs far beyond their current scope, solidifying their role as a truly versatile and patient-centric drug delivery system.(185)

10. Conclusion

Oral Disintegrating Films (ODFs) are no longer just a novel concept but a strategically important and growing segment within the pharmaceutical market, projected to reach significant valuations in the coming years . Their ability to address critical unmet patient needs—particularly in geriatric and pediatric populations, or for drugs requiring rapid onset of action—translates directly into enhanced market access and patient adherence, key drivers for commercial success . The reduced reliance on water and discreet administration further bolster their appeal in diverse global markets . The focus for pharmaceutical companies is increasingly on scaling up production efficiently while maintaining stringent quality control, especially concerning dose uniformity and film stability in various environmental conditions. Investment is flowing into advanced manufacturing techniques like 3D printing and hot-melt extrusion, recognized not just for innovation but for their potential to enable personalized medicine and create competitive differentiation . The integration of AI and machine learning across the drug development lifecycle, from formulation optimization to manufacturing process control, is seen as crucial for accelerating time-to-market and enhancing product quality, ultimately impacting profitability

11. Reference:

1. Pharmaceutical Drug Delivery Market Size, Trends & Forecast 2025-2035 [Internet]. [cited 2025 Apr 22]. Available from: https://www.futuremarketinsights.com/reports/pharmaceutical-drug-delivery-market
2. Gupta MS, Kumar TP, Gowda DV, Rosenholm JM. Orodispersible films: Conception to quality by design. Adv Drug Deliv Rev. 2021 Nov 1;178:113983.
3. Cilurzo F, Musazzi UM, Franzé S, Selmin F, Minghetti P. Orodispersible dosage forms: biopharmaceutical improvements and regulatory requirements. Drug Discov Today. 2018 Feb 1;23(2):251–9.
4. Oral Thin Films Market Size, Competitors & Forecast to 2029 [Internet]. [cited 2025 Apr 22]. Available from: https://www.researchandmarkets.com/report/oral-thin-film#rela4-5602457
5. Hoffmann EM, Breitenbach A, Breitkreutz J. Advances in orodispersible films for drug delivery. Expert Opin Drug Deliv [Internet]. 2011 Mar [cited 2025 Apr 23];8(3):299–316. Available from: https://pubmed.ncbi.nlm.nih.gov/21284577/
6. US9687454B2 - Sublingual and buccal film

compositions - Google Patents [Internet]. [cited 2025 Apr 23]. Available from: https://patents.google.com/patent/US9687454B2/en

7. Development & Approval Process | Drugs | FDA [Internet]. [cited 2025 Apr 23]. Available from: https://www.fda.gov/drugs/development-approval-process-drugs

8. Jacob S, Boddu SHS, Bhandare R, Ahmad SS, Nair AB. Orodispersible Films: Current Innovations and Emerging Trends. Pharmaceutics. 2023;15(12):1–41.

9. Farghaly DA, Afifi SA, Aboelwafa AA, Mohamed MI. Oral Dissolving Film of Rivastigmine: Optimization Using Factorial Design. J Pharm Innov. 2023 Dec 1;18(4):1892–907.

10. Venkateswarlu K, Preethi JK, Chandrasekhar KB. Enhancement of Loperamide Dissolution Rate by Liquisolid Compact Technique. Adv Pharm Bull [Internet]. 2016 [cited 2025 Apr 23];6(3):385. Available from: https://pmc.ncbi.nlm.nih.gov/articles/PMC5071801/

11. Nishigaki M, Kawahara K, Nawa M, Futamura M, Nishimura M, Matsuura K, et al. Development of fast dissolving oral film containing dexamethasone as an antiemetic medication: clinical usefulness. Int J Pharm [Internet]. 2012 Mar 15 [cited 2025 Apr 23];424(1–2):12–7. Available from: https://pubmed.ncbi.nlm.nih.gov/22240389/

12. Irfan M, Rabel S, Bukhtar Q, Qadir MI, Jabeen F, Khan A. Orally disintegrating films: A modern expansion in drug delivery system. Saudi Pharm J SPJ Off Publ Saudi Pharm Soc [Internet]. 2016 Sep 1 [cited 2025 Apr 23];24(5):537–46. Available from: https://pubmed.ncbi.nlm.nih.gov/27752225/

13. Sievens-Figueroa L, Bhakay A, Jerez-Rozo JI, Pandya N, Romañach RJ, Michniak-Kohn B, et al. Preparation and characterization of hydroxypropyl methyl cellulose films containing stable BCS Class II drug nanoparticles for pharmaceutical applications. Int J Pharm [Internet]. 2012 Feb 28 [cited 2025 Apr 23];423(2):496–508. Available from: https://pubmed.ncbi.nlm.nih.gov/22178619/

14. Krull SM, Susarla R, Afolabi A, Li M, Ying Y, Iqbal Z, et al. Polymer strip films as a robust, surfactant-free platform for delivery of BCS Class II drug nanoparticles. Int J Pharm. 2015 Jul 15;489(1–2):45–57.

15. Wei T, Zhou B, Wu X-H, Liu X-A, Huo M-W, Huang X-X, et al. Development of Polyvinyl Alcohol/Polyethylene Glycol Copolymer-based Orodispersible Films Loaded with Entecavir: Formulation and In vitro Characterization . Curr Drug Deliv. 2023 Nov 6;21(10):1362–74.

16. Vasconcelos T, Sarmento B, Costa P. Solid dispersions as strategy to improve oral bioavailability of poor water soluble drugs. Drug Discov Today [Internet]. 2007 Dec [cited 2025 Apr 23];12(23–24):1068–75. Available from: https://pubmed.ncbi.nlm.nih.gov/18061887/

17. Centkowska K, Szadkowska M, Basztura M, Sznitowska M. Homogeneity and mechanical properties of orodispersible films loaded with pellets. Eur J Pharm Biopharm. 2024 Dec 1;205:114537.

18. Panraksa P, Jantrawut P, Tipduangta P, Jantanasakulwong K. Formulation of Orally Disintegrating Films as an Amorphous Solid Solution of a Poorly Water-Soluble Drug. Membranes (Basel) [Internet]. 2020 Dec 1 [cited 2025 Apr 23];10(12):376. Available from: https://pmc.ncbi.nlm.nih.gov/articles/PMC7759778/

19. Dahmash EZ, Patel AN, Faizi E, Ali DK, Ataei A, Soltani-Khankahdani S, et al. Fabrication and Characterisation of Taste-Masked Orally Dissolving Films Containing Ondansetron Hydrochloride Using Novel Poly(Amide-Thioester) Nanocapsules Based on L-Cysteine Amino-Acid. J Pharm Innov [Internet]. 2025 Feb 1 [cited 2025 Apr 23];20(1):1–18. Available from: https://link.springer.com/article/10.1007/s12247-024-09902-1

20. Shen C, Shen B, Xu H, Bai J, Dai L, Lv Q, et al. Formulation and optimization of a novel oral fast dissolving film containing drug nanoparticles by Box-Behnken design-response surface methodology. Drug Dev Ind Pharm [Internet]. 2014 [cited 2025 Apr 23];40(5):649–56. Available from: https://pubmed.ncbi.nlm.nih.gov/24506458/

21. Turek A, Caicedo C, Ramírez Giraldo N,

Portilla L, Saldaña L, González-Pérez G, et al. Physicochemical Properties and In Vitro Dissolution of Orally Disintegrating Films Based on Polysaccharides: The Case of Acetaminophen. Appl Sci 2025, Vol 15, Page 4084 [Internet]. 2025 Apr 8 [cited 2025 Apr 23];15(8):4084. Available from: https://www.mdpi.com/2076-3417/15/8/4084/htm

22. Shah KA, Li G, Song L, Gao B, Huang L, Luan D, et al. Rizatriptan-Loaded Oral Fast Dissolving Films: Design and Characterizations. Pharmaceutics [Internet]. 2022 Dec 1 [cited 2025 Apr 23];14(12):2687. Available from: https://www.mdpi.com/1999-4923/14/12/2687/htm

23. Meloni V, Halstenberg L, Mareczek L, Lu J, Liang B, Gottschalk N, et al. Exploring Orodispersible Films Containing the Proteolysis Targeting Chimera ARV-110 in Hot Melt Extrusion and Solvent Casting Using Polyvinyl Alcohol. Pharmaceutics [Internet]. 2024 Dec 1 [cited 2025 Apr 23];16(12):1499. Available from: https://www.mdpi.com/1999-4923/16/12/1499/htm

24. Cho HW, Baek SH, Lee BJ, Jin HE. Orodispersible Polymer Films with the Poorly Water-Soluble Drug, Olanzapine: Hot-Melt Pneumatic Extrusion for Single-Process 3D Printing. Pharm 2020, Vol 12, Page 692 [Internet]. 2020 Jul 22 [cited 2025 Apr 23];12(8):692. Available from: https://www.mdpi.com/1999-4923/12/8/692/htm

25. Łyszczarz E, Brniak W, Szafraniec-Szczęsny J, Majka TM, Majda D, Zych M, et al. The Impact of the Preparation Method on the Properties of Orodispersible Films with Aripiprazole: Electrospinning vs. Casting and 3D Printing Methods. Pharm 2021, Vol 13, Page 1122 [Internet]. 2021 Jul 22 [cited 2025 Apr 23];13(8):1122. Available from: https://www.mdpi.com/1999-4923/13/8/1122/htm

26. Rashid A, Khalid SH, Irfan M, Asghar S, Rizg WY, Sabei FY, et al. In Vitro and In Vivo Evaluation of Composite Oral Fast Disintegrating Film: An Innovative Strategy for the Codelivery of Ranitidine HCl and Flurbiprofen. Pharmaceutics [Internet]. 2023 Jul 1 [cited 2025 Apr 23];15(7):1987. Available from: https://www.mdpi.com/1999-4923/15/7/1987/htm

27. Jadach B, Kowalczyk M, Froelich A. Assessment of Alginate Gel Films as the Orodispersible Dosage Form for Meloxicam. Gels 2024, Vol 10, Page 379 [Internet]. 2024 Jun 2 [cited 2025 Apr 24];10(6):379. Available from: https://www.mdpi.com/2310-2861/10/6/379/htm

28. Oral Thin Film Protein & Peptide Delivery Technology - Oral Thin Film - CD Formulation [Internet]. [cited 2025 May 26]. Available from: https://www.formulationbio.com/oral-thin-film/oral-thin-film-protein-peptide-delivery-technology.html

29. Al-Achi A, Gupta MR, Stagner WC. Integrated pharmaceutics : applied preformulation, product design, and regulatory science. 2023;

30. Gabor F, Fillafer C, Neutsch L, Ratzinger G, Wirth M. Improving oral delivery. Handb Exp Pharmacol [Internet]. 2010 [cited 2025 May 27];197(197):345–98. Available from: https://pubmed.ncbi.nlm.nih.gov/20217536/

31. Brown TD, Whitehead KA, Mitragotri S. Materials for oral delivery of proteins and peptides. Nat Rev Mater 2019 52 [Internet]. 2019 Dec 24 [cited 2025 May 26];5(2):127–48. Available from: https://www.nature.com/articles/s41578-019-0156-6

32. Brown TD, Whitehead KA, Mitragotri S. Materials for oral delivery of proteins and peptides. Nat Rev Mater 2019 52 [Internet]. 2019 Dec 24 [cited 2025 May 27];5(2):127–48. Available from: https://www.nature.com/articles/s41578-019-0156-6

33. Morales JO, Huang S, Williams RO, McConville JT. Films loaded with insulin-coated nanoparticles (ICNP) as potential platforms for peptide buccal delivery. Colloids Surfaces B Biointerfaces [Internet]. 2014 Oct 1 [cited 2025 May 27];122:38–45. Available from: https://www.sciencedirect.com/science/article/abs/pii/S0927776514002604

34. Tian Y, Visser JC, Klever JS, Woerdenbag HJ, Frijlink HW, Hinrichs WLJ. Orodispersible films based on blends of trehalose and pullulan for protein delivery. Eur J Pharm Biopharm [Internet]. 2018 Dec 1 [cited 2025 May 27];133:104–11.

Available from: https://www.sciencedirect.com/science/article/pii/S0939641118306295

35. Morales JO, Huang S, Williams RO, McConville JT. Films loaded with insulin-coated nanoparticles (ICNP) as potential platforms for peptide buccal delivery. Colloids Surfaces B Biointerfaces [Internet]. 2014 Oct 1 [cited 2025 Jun 3];122:38–45. Available from: https://www.sciencedirect.com/science/article/abs/pii/S0927776514002604

36. Xu Y, Van Hul M, Suriano F, Préat V, Cani PD, Beloqui A. Novel strategy for oral peptide delivery in incretin-based diabetes treatment. Gut [Internet]. 2020 May 1 [cited 2025 Jun 3];69(5):911–9. Available from: https://pubmed.ncbi.nlm.nih.gov/31401561/

37. Menzel C, Holzeisen T, Laffleur F, Zaichik S, Abdulkarim M, Gumbleton M, et al. In vivo evaluation of an oral self-emulsifying drug delivery system (SEDDS) for exenatide. J Control Release [Internet]. 2018 May 10 [cited 2025 Jun 3];277:165–72. Available from: https://pubmed.ncbi.nlm.nih.gov/29574041/

38. Han Y, Liu W, Chen L, Xin X, Wang Q, Zhang X, et al. Effective oral delivery of Exenatide-Zn2+ complex through distal ileum-targeted double layers nanocarriers modified with deoxycholic acid and glycocholic acid in diabetes therapy. Biomaterials [Internet]. 2021 Aug 1 [cited 2025 Jun 3];275. Available from: https://pubmed.ncbi.nlm.nih.gov/34153783/

39. Li X, Sun F, Zhang X, Lin P, Shen K, Shen Y, et al. Safety, pharmacokinetics, and pharmacodynamics of SHR7280, an oral gonadotropin-releasing hormone receptor antagonist, in healthy men: a randomized, double-blind, placebo-controlled phase 1 study. BMC Med [Internet]. 2023 Dec 1 [cited 2025 Jun 3];21(1):1–10. Available from: https://bmcmedicine.biomedcentral.com/articles/10.1186/s12916-023-02834-6

40. Osuga Y, Seki Y, Tanimoto M, Kusumoto T, Kudou K, Terakawa N. Relugolix, an oral gonadotropin-releasing hormone (GnRH) receptor antagonist, in women with endometriosis-associated pain: phase 2 safety and efficacy 24-week results. BMC Womens Health [Internet]. 2021 Dec 1 [cited 2025 Jun 3];21(1):1–8. Available from: https://bmcwomenshealth.biomedcentral.com/articles/10.1186/s12905-021-01393-3

41. Han S, Cho YS, Yoon SK, Lim KS, Cho SH, Kim J, et al. First-in-Human, Double-Blind, Randomized Controlled Trial of an Oral Dose of GnRH Antagonist TU2670 in Healthy Women. J Clin Endocrinol Metab [Internet]. 2021 Mar 1 [cited 2025 Jun 3];106(3):E1111–20. Available from: https://pubmed.ncbi.nlm.nih.gov/33347565/

42. Pang H, Qu Z, Kumar V, Wang Y, Wu Y, Lin MH, et al. Novel Delivery Systems for Oral Administration of Enfuvirtide: New Treatment Options for HIV/AIDS. Adv Ther [Internet]. 2024 Aug 1 [cited 2025 Jun 3];7(8):2300439. Available from: /doi/pdf/10.1002/adtp.202300439

43. Brayden DJ, Hill TA, Fairlie DP, Maher S, Mrsny RJ. Systemic delivery of peptides by the oral route: Formulation and medicinal chemistry approaches. Adv Drug Deliv Rev. 2020 Jan 1;157:2–36.

44. Bissonnette R, Pinter A, Ferris LK, Gerdes S, Rich P, Vender R, et al. An Oral Interleukin-23–Receptor Antagonist Peptide for Plaque Psoriasis. N Engl J Med [Internet]. 2024 Feb 8 [cited 2025 Jun 3];390(6):510–21. Available from: https://pubmed.ncbi.nlm.nih.gov/38324484/

45. Tripto-Shkolnik L, Szalat A, Tsvetov G, Rouach V, Sternberg C, Hoppe A, et al. Oral daily PTH(1-34) tablets (EB613) in postmenopausal women with low BMD or osteoporosis: a randomized, placebo-controlled, 6-month, phase 2 study. J Bone Miner Res [Internet]. 2024 Jun 1 [cited 2025 Jun 3];39(6):672–82. Available from: https://pubmed.ncbi.nlm.nih.gov/38578978/

46. Entera Bio Announces Publication of Oral PTH(1-34) Peptide Tablets (EB613) Phase 2 Trial Data in the Journal of Bone and Mineral Research | Entera Bio Ltd. [Internet]. [cited 2025 Jun 3]. Available from: https://investors.enterabio.com/news-releases/news-release-details/entera-bio-announces-publication-oral-pth1-34-peptide-tablets

47. Sachdeva V, Roy A, Bharadvaja N. Current Prospects of Nutraceuticals: A Review. Curr Pharm Biotechnol [Internet]. 2020 Jan 30

[cited 2025 Jun 6];21(10):884–96. Available from: https://www.eurekaselect.com/article/104103

48. Gleeson JP, Ryan SM, Brayden DJ. Oral delivery strategies for nutraceuticals: Delivery vehicles and absorption enhancers. Trends Food Sci Technol [Internet]. 2016 Jul 1 [cited 2025 Jun 6];53:90–101. Available from: https://www.sciencedirect.com/science/article/abs/pii/S0924224415301096

49. Ruchika, Khan N, Dogra SS, Saneja A. The dawning era of oral thin films for nutraceutical delivery: From laboratory to clinic. Biotechnol Adv [Internet]. 2024 Jul 1 [cited 2025 Jun 6];73:108362. Available from: https://www.sciencedirect.com/science/article/abs/pii/S0734975024000569

50. Orally Dissolving Strip Market Size | Industry Insights [2025-2033] [Internet]. [cited 2025 Jun 6]. Available from: https://www.globalgrowthinsights.com/market-reports/orally-dissolving-strip-market-108142

51. Heinemann RJB, Carvalho RA, Favaro-Trindade CS. Orally disintegrating film (ODF) for delivery of probiotics in the oral cavity — Development of a novel product for oral health. Innov Food Sci Emerg Technol [Internet]. 2013 Jul 1 [cited 2025 Jun 6];19:227–32. Available from: https://www.sciencedirect.com/science/article/abs/pii/S1466856413000726

52. Feng K, Liu C, Zhang S, Wu J, Eleuteri AM, Bai Y. Insights into the formation of pullulan nanofilm and its feasibility as probiotic-resided oral fast dissolving carrier. Int J Biol Macromol [Internet]. 2025 Apr 1 [cited 2025 Jun 6];299:140091. Available from: https://www.sciencedirect.com/science/article/abs/pii/S0141813025006403

53. Tunçer Çağlayan S. Biopolymer-based oral films integrated with probiotic active compounds for improved health applications. Arch Microbiol [Internet]. 2024 Jan 1 [cited 2025 Jun 6];207(1):4. Available from: https://link.springer.com/article/10.1007/s00203-024-04207-w

54. Nano ECF | Dr.FiLL Vietnam [Internet]. [cited 2025 Jun 9]. Available from: https://www.drfill.com.vn/en/prebiotics-nano-ecf

55. Tunçer Çağlayan S. Biopolymer-based oral films integrated with probiotic active compounds for improved health applications. Arch Microbiol [Internet]. 2024 Jan 1 [cited 2025 Jun 9];207(1):4. Available from: https://pubmed.ncbi.nlm.nih.gov/39607528/

56. Heinemann RJB, Carvalho RA, Favaro-Trindade CS. Orally disintegrating film (ODF) for delivery of probiotics in the oral cavity - Development of a novel product for oral health. Innov Food Sci Emerg Technol [Internet]. 2013 Jul [cited 2025 Jun 9];19:227–32. Available from: https://www.researchgate.net/publication/267327838_Orally_disintegrating_film_ODF_for_delivery_of_probiotics_in_the_oral_cavity_-_Development_of_a_novel_product_for_oral_health

57. CN114190558A - Oral instant film containing probiotics and preparation method thereof - Google Patents [Internet]. [cited 2025 Jun 9]. Available from: https://patents.google.com/patent/CN114190558A/en?oq=CN114190558A

58. US20190336453A1 - Oral dispersible film composition - Google Patents [Internet]. [cited 2025 Jun 9]. Available from: https://patents.google.com/patent/US20190336453A1/en?oq=US20190336453A1

59. Saadatzade A, Shabaninezhad K, Handali S, Moghimipour E. A novel mucoadhesive film containing probiotic extract for oral candidiasis treatment: Formulation and antifungal evaluation. Microb Pathog [Internet]. 2024 Nov 1 [cited 2025 Jun 9];196. Available from: https://pubmed.ncbi.nlm.nih.gov/39306055/

60. Heinemann RJB, Carvalho RA, Favaro-Trindade CS. Orally disintegrating film (ODF) for delivery of probiotics in the oral cavity — Development of a novel product for oral health. Innov Food Sci Emerg Technol [Internet]. 2013 Jul 1 [cited 2025 Jun 9];19:227–32. Available from: https://www.sciencedirect.com/science/article/abs/pii/S1466856413000726

61. Rebelo MB, Oliveira CS, Tavaria FK. Development of a Postbiotic-Based Orodispersible Film to Prevent Dysbiosis in the Oral Cavity. Front Biosci - Elit

[Internet]. 2025 Mar 1 [cited 2025 Jun 6];17(1):26987. Available from: https://www.imrpress.com/journal/FBE/17/1/10.31083/FBE26987/htm

62. Lordello VB, Meneguin AB, de Annunzio SR, Taranto MP, Chorilli M, Fontana CR, et al. Orodispersible Film Loaded with Enterococcus faecium CRL183 Presents Anti-Candida albicans Biofilm Activity In Vitro. Pharmaceutics [Internet]. 2021 Jul 1 [cited 2025 Jun 6];13(7):998. Available from: https://pmc.ncbi.nlm.nih.gov/articles/PMC8309053/

63. Dodoo CC, Stapleton P, Basit AW, Gaisford S. The potential of Streptococcus salivarius oral films in the management of dental caries: An inkjet printing approach. Int J Pharm [Internet]. 2020 Dec 15 [cited 2025 Jun 6];591:119962. Available from: https://www.sciencedirect.com/science/article/abs/pii/S0378517320309479?utm_source=chatgpt.com

64. Irfan M, Rabel S, Bukhtar Q, Qadir MI, Jabeen F, Khan A. Orally disintegrating films: A modern expansion in drug delivery system. Saudi Pharm J. 2016 Sep 1;24(5):537–46.

65. Borges AF, Silva C, Coelho JFJ, Simões S. Oral films: Current status and future perspectives: I - Galenical development and quality attributes. J Control Release [Internet]. 2015 May 28 [cited 2025 Apr 24];206:1–19. Available from: https://pubmed.ncbi.nlm.nih.gov/25747406/

66. Wang Y, Rafailovich M, Sokolov J, Gersappe D, Araki T, Zou Y, et al. Substrate effect on the melting temperature of thin polyethylene films. Phys Rev Lett [Internet]. 2006 Jan 20 [cited 2025 Apr 24];96(2):028303. Available from: https://journals.aps.org/prl/abstract/10.1103/PhysRevLett.96.028303

67. Su HH, Chen HL, Díaz A, Casas MT, Puiggalí J, Hoskins JN, et al. New insights on the crystallization and melting of cyclic PCL chains on the basis of a modified Thomson-Gibbs equation. Polymer (Guildf). 2013 Jan 24;54(2):846–59.

68. Semalty A, Semalty M, Nautiyal U. Formulation and evaluation of mucoadhesive buccal films of enalapril maleate. Indian J Pharm Sci [Internet]. 2010 Sep [cited 2025 Apr 24];72(5):571–5. Available from: https://pubmed.ncbi.nlm.nih.gov/21694987/

69. Jacob S, Nair AB, Boddu SHS, Gorain B, Sreeharsha N, Shah J. An Updated Overview of the Emerging Role of Patch and Film-Based Buccal Delivery Systems. Pharmaceutics [Internet]. 2021 Aug 1 [cited 2025 Apr 24];13(8). Available from: https://pubmed.ncbi.nlm.nih.gov/34452167/

70. Liu F, Ranmal S, Batchelor HK, Orlu-Gul M, Ernest TB, Thomas IW, et al. Patient-centred pharmaceutical design to improve acceptability of medicines: similarities and differences in paediatric and geriatric populations. Drugs [Internet]. 2014 [cited 2025 Apr 24];74(16):1871–89. Available from: https://pubmed.ncbi.nlm.nih.gov/25274536/

71. Forrest JA, Dalnoki-Veress K, Dutcher JR. Interface and chain confinement effects on the glass transition temperature of thin polymer films. Phys Rev E [Internet]. 1997 Nov 1 [cited 2025 Apr 24];56(5):5705. Available from: https://journals.aps.org/pre/abstract/10.1103/PhysRevE.56.5705

72. Mahadevaiah, Rudrappa SL, Thippaia D, Singh V. Mechanical and Barrier Properties of Hydroxy Propyl Methyl Cellulose Edible Polymer Films with Plasticizer Combinations. J Food Process Preserv [Internet]. 2017 [cited 2025 Apr 24];41(4). Available from: https://jglobal.jst.go.jp/en/detail?JGLOBAL_ID=201702289126965000

73. Dixit RP, Puthli SP. Oral strip technology: overview and future potential. J Control Release [Internet]. 2009 Oct 15 [cited 2025 Apr 24];139(2):94–107. Available from: https://pubmed.ncbi.nlm.nih.gov/19559740/

74. Martinez-Garcia JC, Rzoska SJ, Drzozd-Rzoska A, Martinez-Garcia J, Mauro JC. Divergent dynamics and the Kauzmann temperature in glass forming systems. Sci Reports 2014 41 [Internet]. 2014 Jun 4 [cited 2025 Apr 24];4(1):1–8. Available from: https://www.nature.com/articles/srep05160

75. Pezik E, Gulsun T, Sahin S, Vural İ. Development and characterization of pullulan-based orally disintegrating films

containing amlodipine besylate. Eur J Pharm Sci [Internet]. 2021 Jan 1 [cited 2025 Apr 24];156. Available from: https://pubmed.ncbi.nlm.nih.gov/33065224/

76. Singh RS, Kaur N, Rana V, Kennedy JF. Pullulan: A novel molecule for biomedical applications. Carbohydr Polym [Internet]. 2017 Sep 1 [cited 2025 Apr 24];171:102–21. Available from: https://pubmed.ncbi.nlm.nih.gov/28578944/

77. Singh RS, Kaur N, Kennedy JF. Pullulan production from agro-industrial waste and its applications in food industry: A review. Carbohydr Polym [Internet]. 2019 Aug 1 [cited 2025 Apr 24];217:46–57. Available from: https://pubmed.ncbi.nlm.nih.gov/31079684/

78. Optimization of formulation of fast dissolving films made of pullulan polymer [Internet]. [cited 2025 Apr 24]. Available from: https://www.researchgate.net/publication/282677162_Optimization_of_formulation_of_fast_dissolving_films_made_of_pullulan_polymer

79. Dewan MF, Islam MN. Pullulan-Based Films: Unveiling Its Multifaceted Versatility for Sustainability. Nagase K, editor. Adv Polym Technol [Internet]. 2024 Jan 1 [cited 2025 Apr 24];2024(1):2633384. Available from: https://onlinelibrary.wiley.com/doi/full/10.1155/2024/2633384

80. Hernandez-Tenorio F, Saez AA, Palacio DA, Galeano E, Marin-Palacio LD, Giraldo-Estrada C. Formulations based on pullulan and a derivative as coating material for the food sector. Carbohydr Polym [Internet]. 2024 Oct 15 [cited 2025 Apr 25];342:122393. Available from: https://www.sciencedirect.com/science/article/abs/pii/S0144861724006192

81. US20090162516A1 - Edible, water-soluble film - Google Patents [Internet]. [cited 2025 Apr 25]. Available from: https://patents.google.com/patent/US20090162516A1/en

82. Janjarasskul T, Tananuwong K, Phupoksakul T, Thaiphanit S. Fast dissolving, hermetically sealable, edible whey protein isolate-based films for instant food and/or dry ingredient pouches. LWT [Internet]. 2020 Dec 1 [cited 2025 Apr 25];134:110102. Available from: https://www.sciencedirect.com/science/article/abs/pii/S0023643820310914

83. Tsai MJ, Weng YM. Novel edible composite films fabricated with whey protein isolate and zein: Preparation and physicochemical property evaluation. LWT [Internet]. 2019 Mar 1 [cited 2025 Apr 25];101:567–74. Available from: https://www.sciencedirect.com/science/article/abs/pii/S0023643818310296

84. Xu Z, Chen K, Khan MA, Liang L. Oral fast dissolving films made with alginate and whey protein for resveratrol delivery. J Food Eng [Internet]. 2025 Jan 1 [cited 2025 Apr 25];385:112269. Available from: https://www.sciencedirect.com/science/article/abs/pii/S0260877424003352

85. Bodini RB, Guimarães J das GL, Monaco-Lourenço CA, Aparecida de Carvalho R. Effect of starch and hydroxypropyl methylcellulose polymers on the properties of orally disintegrating films. J Drug Deliv Sci Technol. 2019 Jun 1;51:403–10.

86. Yasir M, Nagar P, Chauhan I. Drug Invention Today Insights into Polymers: Film Formers in Mouth Dissolving Films. Drug Invent Today [Internet]. 2011 [cited 2025 Apr 24];3(12):280–9. Available from: www.ditonline.info

87. Carvalho AFF de, Caldeira VF, Oliveira AP, Gonsalves JKM da C, Araújo EC da C. Design and development of orally disintegrating films: A platform based on hydroxypropyl methylcellulose and guar gum. Carbohydr Polym [Internet]. 2023 Jan 1 [cited 2025 Apr 25];299:120155. Available from: https://www.sciencedirect.com/science/article/pii/S0144861722010608

88. Sudhakara Reddy P, Ramana Murthy K. Formulation and Evaluation of Oral Fast Dissolving Films of Poorly Soluble Drug Ezetimibe Using Transcutol Hp. Indian J Pharm Educ Res [Internet]. [cited 2025 Apr 24];52. Available from: www.ijper.org

89. Silva SS, Rodrigues LC, Fernandes EM, Reis RL. Biopolymer membranes in tissue engineering. Biopolym Membr Film Heal Food, Environ Energy Appl. 2020 Jan 1;141–63.

90. Ghaffari A, Navaee K, Oskoui M, Bayati K, Rafiee-Tehrani M. Preparation and characterization of free mixed-film of

pectin/chitosan/Eudragit RS intended for sigmoidal drug delivery. Eur J Pharm Biopharm [Internet]. 2007 Aug [cited 2025 Apr 24];67(1):175–86. Available from: https://pubmed.ncbi.nlm.nih.gov/17346954/

91. Van Rooyen B, De Wit M, Osthoff G, Van Niekerk J, Hugo A. Effect of Native Mucilage on the Mechanical Properties of Pectin-Based and Alginate-Based Polymeric Films. Coatings 2023, Vol 13, Page 1611 [Internet]. 2023 Sep 14 [cited 2025 Apr 24];13(9):1611. Available from: https://www.mdpi.com/2079-6412/13/9/1611/htm

92. Hirun N, Mahadlek J, Limmatvapirat S, Sriamornsak P, Yonemochi E, Furuishi T, et al. Fabrication and Characterization of Pectin Films Containing Solid Lipid Nanoparticles for Buccal Delivery of Fluconazole. Int J Mol Sci [Internet]. 2024 May 1 [cited 2025 Apr 25];25(10):5413. Available from: https://pmc.ncbi.nlm.nih.gov/articles/PMC11121771/

93. Shariatinia Z. Pharmaceutical applications of chitosan. Adv Colloid Interface Sci. 2019 Jan 1;263:131–94.

94. Sivanesan I, Tasneem S, Hasan N, Shin J, Muthu M, Gopal J, et al. Surveying the Oral Drug Delivery Avenues of Novel Chitosan Derivatives. Polymers (Basel) [Internet]. 2022 Jun 1 [cited 2025 Apr 25];14(11):2131. Available from: https://pmc.ncbi.nlm.nih.gov/articles/PMC9182633/

95. Batista P, Castro P, Madureira AR, Sarmento B, Pintado M. Development and Characterization of Chitosan Microparticles-in-Films for Buccal Delivery of Bioactive Peptides. Pharmaceuticals [Internet]. 2019 Mar 1 [cited 2025 Apr 25];12(1):32. Available from: https://pmc.ncbi.nlm.nih.gov/articles/PMC6469171/

96. AnjiReddy K, Karpagam S. In Vitro and In Vivo Evaluation of Oral Disintegrating Nanofiber and Thin-Film Contains Hyperbranched Chitosan/Donepezil for Active Drug Delivery. J Polym Environ [Internet]. 2021 Mar 1 [cited 2025 Apr 25];29(3):922–36. Available from: https://link.springer.com/article/10.1007/s10924-020-01937-y

97. Nam JH, Kim BH, Shafioul ASM, Jin M, Cho CW. A comprehensive review of oral disintegrating film products, and their quality assessment and development. J Pharm Investig [Internet]. 2025 [cited 2025 Apr 25]; Available from: https://www.researchgate.net/publication/388305940_A_comprehensive_review_of_oral_disintegrating_film_products_and_their_quality_assessment_and_development

98. Bhavanam PR, Rahaman SA, Varma MM. Tamarind seed polysaccharide mouth dissolving films for rapid drug release in the treatment of hypertension: In vitro evaluation. Res J Pharm Technol [Internet]. 2021 May 1 [cited 2025 Apr 25];14(5):2771–3. Available from: https://www.researchgate.net/publication/351949868_Tamarind_Seed_Polysaccharide_Mouth_Dissolving_films_for_rapid_drug_Release_in_the_treatment_of_Hypertension_In_vitro_Evaluation

99. Teixeira SC, Silva RRA, de Oliveira TV, Stringheta PC, Pinto MRMR, Soares N de FF. Glycerol and triethyl citrate plasticizer effects on molecular, thermal, mechanical, and barrier properties of cellulose acetate films. Food Biosci. 2021 Aug 1;42.

100. Fong RJ, Robertson A, Mallon PE, Thompson RL. The Impact of Plasticizer and Degree of Hydrolysis on Free Volume of Poly(vinyl alcohol) Films. Polym 2018, Vol 10, Page 1036 [Internet]. 2018 Sep 18 [cited 2025 Apr 25];10(9):1036. Available from: https://www.mdpi.com/2073-4360/10/9/1036/htm

101. Johns MA, Nigmatullin R, Cranston ED, Eichhorn SJ. The physicochemical effect of sugar alcohol plasticisers on oxidised nanocellulose gels and extruded filaments. Cellulose [Internet]. 2021 Aug 1 [cited 2025 Apr 25];28(12):7829–43. Available from: https://link.springer.com/article/10.1007/s10570-021-03991-8

102. Mascia L, Kouparitsas Y, Nocita D, Bao X. Antiplasticization of Polymer Materials: Structural Aspects and Effects on Mechanical and Diffusion-Controlled Properties. Polym 2020, Vol 12, Page 769 [Internet]. 2020 Apr 1 [cited 2025 Apr 25];12(4):769. Available from: https://www.mdpi.com/2073-4360/12/4/769/htm

103. Sun Y, Meng C, Zheng Y, Xie Y, He W, Wang Y, et al. The effects of two biocompatible plasticizers on the performance of dry bacterial cellulose

membrane: a comparative study. Cellulose. 2018 Oct 1;25(10):5893–908.

104. Sousa AMM, Souza HKS, Latona N, Liu CK, Gonçalves MP, Liu L. Choline chloride based ionic liquid analogues as tool for the fabrication of agar films with improved mechanical properties. Carbohydr Polym [Internet]. 2014 Oct 13 [cited 2025 Apr 25];111:206–14. Available from: https://www.sciencedirect.com/science/article/abs/pii/S0144861714003762?utm_source=chatgpt.com

105. Selmin F, Franceschini I, Cupone IE, Minghetti P, Cilurzo F. Aminoacids as non-traditional plasticizers of maltodextrins fast-dissolving films. Carbohydr Polym [Internet]. 2015 Jan 22 [cited 2025 Apr 25];115:613–6. Available from: https://www.researchgate.net/publication/269186115_Aminoacids_as_non-traditional_plasticizers_of_maltodextrins_fast-dissolving_films

106. Khatri P, Desai D, Shelke N, Minko T. Role of plasticizer in membrane coated extended release oral drug delivery system. J Drug Deliv Sci Technol. 2018 Apr 1;44:231–43.

107. Küçükçakır Ö, Dağdelen AF. Use of deep eutectic solvents based on choline chloride, urea, and lactic acid as plasticizers in low-density polyethylene films. Polym Eng Sci [Internet]. 2025 Mar 1 [cited 2025 Apr 25];65(3):1582–97. Available from: /doi/pdf/10.1002/pen.27121

108. PHArMACEUtICAl AND NUtrACEUtICAl NUtrItIONAl SUPPlEMENtS FOOD AND bEVErAgE COSMEtIC PErSONAl CArE ANIMAl NUtrItION ChemiCal StruCture Vitamin E tPGS NF * and Food Grade.

109. Musazzi UM, Dolci LS, Albertini B, Passerini N, Cilurzo F. A new melatonin oral delivery platform based on orodispersible films containing solid lipid microparticles. Int J Pharm [Internet]. 2019 Mar 25 [cited 2025 Jun 4];559:280–8. Available from: https://pubmed.ncbi.nlm.nih.gov/30690132/

110. Lai F, Franceschini I, Corrias F, Sala MC, Cilurzo F, Sinico C, et al. Maltodextrin fast dissolving films for quercetin nanocrystal delivery. A feasibility study. Carbohydr Polym [Internet]. 2015 May 5 [cited 2025 Jun 4];121(1):217–23. Available from: https://pubmed.ncbi.nlm.nih.gov/25659692/

111. Cilurzo F, Cupone IE, Minghetti P, Buratti S, Selmin F, Gennari CGM, et al. Nicotine fast dissolving films made of maltodextrins: A feasibility study. AAPS PharmSciTech [Internet]. 2010 Dec 9 [cited 2025 Jun 4];11(4):1511–7. Available from: https://link.springer.com/article/10.1208/s12249-010-9525-6

112. Lee Y, Kim K, Kim M, Choi DH, Jeong SH. Orally disintegrating films focusing on formulation, manufacturing process, and characterization. J Pharm Investig [Internet]. 2017 May 1 [cited 2025 Jun 4];47(3):183–201. Available from: https://link.springer.com/article/10.1007/s40005-017-0311-2

113. Musazzi UM, Khalid GM, Selmin F, Minghetti P, Cilurzo F. Trends in the production methods of orodispersible films. Int J Pharm [Internet]. 2020 Feb 25 [cited 2025 Jun 4];576:118963. Available from: https://www.sciencedirect.com/science/article/abs/pii/S0378517319310087

114. Solvent Casting Technology for Oral Thin Film Manufacturing - Oral Thin Film - CD Formulation [Internet]. [cited 2025 Jun 5]. Available from: https://www.formulationbio.com/oral-thin-film/solvent-casting-technology-for-oral-thin-film-manufacturing.html

115. Schruben DL, Gonzalez P. Dispersity improvement in solvent casting particle/polymer composite. Polym Eng Sci [Internet]. 2000 [cited 2025 Jun 5];40(1):139–42. Available from: https://www.researchgate.net/publication/247957222_Dispersity_improvement_in_solvent_casting_particlepolymer_composite

116. Sevinç Özakar R, Özakar E. Current Overview of Oral Thin Films. Turkish J Pharm Sci [Internet]. 2021 [cited 2025 Jun 5];18(1):111. Available from: https://pmc.ncbi.nlm.nih.gov/articles/PMC7957312/

117. [PDF] Study of Different Technologies for Film Coating of Drug Layered Pellets Using Ethylcellulose as Functional Polymer | Semantic Scholar [Internet]. [cited 2025 Jun 5]. Available from: https://www.semanticscholar.org/paper/Study-of-Different-Technologies-for-Film-Coating-of-Melegari/533d20c5240cb3caac9d9dd36d8ac99c8abe5e01

118. Low AQJ, Parmentier J, Khong YM, Chai CCE, Tun TY, Berania JE, et al. Effect of type and ratio of solubilising polymer on characteristics of hot-melt extruded orodispersible films. Int J Pharm [Internet]. 2013 [cited 2025 Jun 4];455(1–2):138–47. Available from: https://pubmed.ncbi.nlm.nih.gov/23916824/

119. Fule R, Dhamecha D, Maniruzzaman M, Khale A, Amin P. Development of hot melt co-formulated antimalarial solid dispersion system in fixed dose form (ARLUMELT): Evaluating amorphous state and in vivo performance. Int J Pharm [Internet]. 2015 Dec 30 [cited 2025 Jun 4];496(1):137–56. Available from: https://pubmed.ncbi.nlm.nih.gov/26471056/

120. Rajni Bala A, Bala R, Pawar P, Khanna S, Arora S. Orally dissolving strips: A new approach to oral drug delivery system. Int J Pharm Investig [Internet]. 2013 [cited 2025 Jun 4];3(2):67. Available from: https://pmc.ncbi.nlm.nih.gov/articles/PMC3757902/

121. Crowley MM, Zhang F, Repka MA, Thumma S, Upadhye SB, Battu SK, et al. Pharmaceutical Applications of Hot-Melt Extrusion: Part I. Drug Dev Ind Pharm [Internet]. 2007 Sep [cited 2025 Jun 4];33(9):909–26. Available from: https://www.tandfonline.com/doi/pdf/10.1080/03639040701498759

122. Smokeless tobacco product. 2010 Apr 9;

123. Bruce C. Melt extruded thin strips containing coated pharmaceutical. 2009 Dec 30;

124. Hot melt extrusion and its pharmaceutical applications. | EBSCOhost [Internet]. [cited 2025 Jun 4]. Available from: https://openurl.ebsco.com/EPDB%3Agcd%3A16%3A26644944/detailv2?sid=ebsco%3Aplink%3Ascholar&id=ebsco%3Agcd%3A76385092&crl=c&link_origin=scholar.google.com

125. (PDF) Mouth Dissolving Films: Innovative Vehicle for Oral Drug Delivery [Internet]. [cited 2025 Jun 5]. Available from: https://www.researchgate.net/publication/260171380_Mouth_Dissolving_Films_Innovative_Vehicle_for_Oral_Drug_Delivery

126. Semi-solid Casting Method for Oral Thin Film Preparation - Oral Thin Film - CD Formulation [Internet]. [cited 2025 Jun 5]. Available from: https://www.formulationbio.com/oral-thin-film/semi-solid-casting-method-for-oral-thin-film-preparation.html

127. Iqbal S, Hanan H, Maqbool A, Munawar N. A review on orodispersible drug delivery system. J Contemp Pharm. 2023 Jun 30;7(1):24–31.

128. Ozon EA, Sarbu I, Popovici V, Mitu MA, Musuc AM, Karampelas O, et al. Three-Dimensional Printing Technologies in Oral Films Manufacturing—A Minireview. Process 2023, Vol 11, Page 2628 [Internet]. 2023 Sep 3 [cited 2025 Jun 5];11(9):2628. Available from: https://www.mdpi.com/2227-9717/11/9/2628/htm

129. Uddin MJ;, Hassan J;, Wong E, Jeon G, Uddin J, Hassan J, et al. Thermal Inkjet Printing: Prospects and Applications in the Development of Medicine. Technol 2022, Vol 10, Page 108 [Internet]. 2022 Oct 21 [cited 2025 Jun 5];10(5):108. Available from: https://www.mdpi.com/2227-7080/10/5/108/htm

130. Zub K, Hoeppener S, Schubert US, Zub K, Hoeppener S, Schubert US. Inkjet Printing and 3D Printing Strategies for Biosensing, Analytical, and Diagnostic Applications. Adv Mater [Internet]. 2022 Aug 1 [cited 2025 Jun 5];34(31):2105015. Available from: /doi/pdf/10.1002/adma.202105015

131. Buanz ABM, Belaunde CC, Soutari N, Tuleu C, Gul MO, Gaisford S. Ink-jet printing versus solvent casting to prepare oral films: Effect on mechanical properties and physical stability. Int J Pharm [Internet]. 2015 Oct 30 [cited 2025 Jun 5];494(2):611–8. Available from: https://www.sciencedirect.com/science/article/abs/pii/S0378517314009296

132. Foo WC, Widjaja E, Khong YM, Gokhale R, Chan SY. Application of miniaturized near-infrared spectroscopy for quality control of extemporaneous orodispersible films. J Pharm Biomed Anal [Internet]. 2018 Feb 20 [cited 2025 Jun 5];150:191–8. Available from: https://www.sciencedirect.com/science/article/abs/pii/S0731708517325359

133. Wickramasinghe S, Do T, Polymers PT-, 2020 undefined. FDM-based 3D printing of polymer and associated composite: A review on mechanical properties, defects and treatments. mdpi.comS

Wickramasinghe, T Do, P TranPolymers, 2020•mdpi.com [Internet]. 2020 Jul 1 [cited 2025 Jun 5];12(7):1–42. Available from: https://www.mdpi.com/2073-4360/12/7/1529

134. Melocchi A, Uboldi M, Cerea M, Foppoli A, Maroni A, Moutaharrik S, et al. A Graphical Review on the Escalation of Fused Deposition Modeling (FDM) 3D Printing in the Pharmaceutical Field. J Pharm Sci [Internet]. 2020 Oct 1 [cited 2025 Jun 5];109(10):2943–57. Available from: https://jpharmsci.org/action/showFullText?pii=S0022354920303774

135. Mazzanti V, Malagutti L, Mollica F. FDM 3D printing of polymers containing natural fillers: A review of their mechanical properties. Polymers (Basel). 2019;11(7).

136. Melocchi A, Uboldi M, Cerea M, Foppoli A, Maroni A, Moutaharrik S, et al. A Graphical Review on the Escalation of Fused Deposition Modeling (FDM) 3D Printing in the Pharmaceutical Field. J Pharm Sci. 2020 Oct 1;109(10):2943–57.

137. Annaji M, Ramesh S, Poudel I, Govindarajulu M, Arnold RD, Dhanasekaran M, et al. Application of Extrusion-Based 3D Printed Dosage Forms in the Treatment of Chronic Diseases. J Pharm Sci. 2020 Dec 1;109(12):3551–68.

138. Long J, Gholizadeh H, Lu J, Bunt C, Seyfoddin A. Application of Fused Deposition Modelling (FDM) Method of 3D Printing in Drug Delivery. Curr Pharm Des. 2016 Nov 3;23(3):433–9.

139. Seoane-Viaño I, Januskaite P, Alvarez-Lorenzo C, Basit AW, Goyanes A. Semi-solid extrusion 3D printing in drug delivery and biomedicine: Personalised solutions for healthcare challenges. J Control Release. 2021 Apr 10;332:367–89.

140. Cano-Vicent A, Tambuwala MM, Hassan SS, Barh D, Aljabali AAA, Birkett M, et al. Fused deposition modelling: Current status, methodology, applications and future prospects. Addit Manuf. 2021 Nov 1;47.

141. De Moraes JO, Scheibe AS, Sereno A, Laurindo JB. Scale-up of the production of cassava starch based films using tape-casting. J Food Eng [Internet]. 2013 Dec 1 [cited 2025 Jun 9];119(4):800–8. Available from: https://www.sciencedirect.com/science/article/pii/S026087741300366X?via%3Dihub

142. Remedio LN, Garcia VA dos S, Rochetti AL, Berretta AA, Yoshida CMP, Fukumasu H, et al. Hydroxypropyl methylcellulose orally disintegration films produced by tape casting with the incorporation of green propolis ethanolic extract using the printing technique. Food Hydrocoll [Internet]. 2023 Feb 1 [cited 2025 Jun 9];135:108176. Available from: https://www.sciencedirect.com/science/article/abs/pii/S0268005X22006968

143. Vuddanda PR, Montenegro-Nicolini M, Morales JO, Velaga S. Effect of surfactants and drug load on physico-mechanical and dissolution properties of nanocrystalline tadalafil-loaded oral films. Eur J Pharm Sci [Internet]. 2017 Nov 15 [cited 2025 Jun 9];109:372–80. Available from: https://www.sciencedirect.com/science/article/abs/pii/S0928098717304633?via%3Dihub

144. Chachlioutaki K, Tzimtzimis E, Tzetzis D, Pharmaceutics MC-, 2020 undefined. Electrospun orodispersible films of isoniazid for pediatric tuberculosis treatment. mdpi.comK Chachlioutaki, EK Tzimtzimis, D Tzetzis, MW Chang Z Ahmad, C Karavasili, DG FatourosPharmaceutics, 2020•mdpi.com [Internet]. [cited 2025 Jun 9]; Available from: https://www.mdpi.com/1999-4923/12/5/470

145. Milind SL, … APS-IJPB, 2013 undefined. Polymer based wafer technology: A review. Res Lade Milind, A Payghan Santosh, J Tamboli Zaki, I Disouza JohnInt J Pharm Biol Arch 2013•researchgate.net [Internet]. [cited 2025 Jun 9]; Available from: https://www.researchgate.net/profile/Santosh-Payghan/publication/309134813_Polymer_Based_Wafer_Technology_A_Review/links/5800a81508aec7368bdc5576/Polymer-Based-Wafer-Technology-A-Review.pdf

146. Song Q, Guo X, Sun Y, Yang M. Anti-solvent Precipitation Method Coupled Electrospinning Process to Produce Poorly Water-Soluble Drug-Loaded Orodispersible Films. AAPS PharmSciTech [Internet]. 2019 Oct 1 [cited 2025 Jun 9];20(7):1–11. Available from: https://link.springer.com/article/10.1208/s12249-019-1464-2

147. Uhljar LÉ, Jáger T, Hajdu C, Motzwickler-Németh A, Jójárt-Laczkovich O, Cseh M, et al. Diclofenac-Loaded Orodispersible

Nanofibers Prepared by Double-Needle Electrospinning. Polym 2025, Vol 17, Page 1262 [Internet]. 2025 May 6 [cited 2025 Jun 9];17(9):1262. Available from: https://www.mdpi.com/2073-4360/17/9/1262/htm

148. Sudarjat H, Qin C, Ingabire D, Moothedathu Raynold AA, Pangeni R, Pearcy A, et al. Janus LAAM-loaded electrospun fibrous buccal films for treating opioid use disorder. Biomaterials [Internet]. 2025 Jun 1 [cited 2025 Jun 9];317:123041. Available from: https://www.sciencedirect.com/science/article/abs/pii/S0142961224005775

149. Lv H, Wang C, Xu E, Jin Z, Zhao H, Yuan C, et al. Preparation of starch-based oral fast-disintegrating nanofiber mats for astaxanthin encapsulation and delivery via emulsion electrospinning. Int J Biol Macromol [Internet]. 2025 Feb 1 [cited 2025 Jun 9];289:136466. Available from: https://www.sciencedirect.com/science/article/abs/pii/S0141813024072751

150. Dziemidowicz K, Jin J, Ranmal SR, Piumpongsuk S, Aspinall S, Serpell CJ, et al. Characterisation and sensory evaluation of placebo OrPhyllo TM orodispersible films as a versatile paediatric drug delivery platform . Drug Dev Ind Pharm. 2025 Jun 19;1–15.

151. Polonini HC, Ferreira AO, Raposo NRB, da Silva PJLC, Brandão MAF. Compatibility Assessment of Novel Orodispersible Film Vehicle for Personalized Medicine with Selected Active Pharmaceutical Ingredients. J Pers Med [Internet]. 2023 Nov 1 [cited 2025 Jul 3];13(11). Available from: https://pubmed.ncbi.nlm.nih.gov/38003880/

152. Innovative Drug Delivery Using The PharmFilm® Drug Delivery Platform | Aquestive Therapeutics [Internet]. [cited 2025 Jul 3]. Available from: https://aquestive.com/innovative-drug-delivery-pharmfilm/

153. MonoSol: Kuraray [Internet]. [cited 2025 Jul 3]. Available from: https://www.kuraray.eu/products-solutions/product-ranges/monosol

154. Nualtis | Oral Film Leader [Internet]. [cited 2025 Jul 3]. Available from: https://www.nualtis.com/?redirect=igxnewsrooms/newsrooms1/19-2010/63-intelgenx-grants-options-to-ir-firm-2

155. Daniel Ekpa E, Romanus Asuquo U, Elijah AA, Ndiana-Abasi Ime S, Ini UA. The oral film delivery-Application of nanotechnology and potential in medication adherence. GSC Biol Pharm Sci. 2020;2020(03):34–051.

156. Fast dissolving drug delivery | Technology | Rapid Dose Therapeutics Inc. [Internet]. [cited 2025 Jul 3]. Available from: https://rapid-dose.com/technology/#tech-page%7C1

157. Rapidfilm® [Internet]. [cited 2025 Jul 3]. Available from: https://www.adhexpharma.com/rapidfilm

158. Oral Technologies - Catalent [Internet]. [cited 2025 Jul 3]. Available from: https://www.catalent.com/oral-dose/oral-technologies/

159. Fast Dissolving Oral Thin Films | Spinoral Technology | ZIM Labs [Internet]. [cited 2025 Jul 4]. Available from: https://www.zimlab.in/technology/oral-thin-films

160. Brokmann F, Luthe K, Hartmann J, Müller L, Klammt F, Hoffmann C, et al. Hot Melt Extrusion as Continuous Manufacturing Technique to Produce Bilayer Films Loaded with Paracetamol or Lactase. Pharm 2025, Vol 18, Page 310 [Internet]. 2025 Feb 24 [cited 2025 Jul 4];18(3):310. Available from: https://www.mdpi.com/1424-8247/18/3/310/htm

161. Gupta MS, Kumar TP, Gowda DV. Orodispersible Thin Film: A new patient-centered innovation. J Drug Deliv Sci Technol [Internet]. 2020 Oct 1 [cited 2025 Jun 10];59:101843. Available from: https://www.sciencedirect.com/science/article/abs/pii/S1773224720311321

162. Senthilkumar K, Vijaya C. Formulation Development of Mouth Dissolving Film of Etoricoxib for Pain Management. Adv Pharm [Internet]. 2015 Jan 1 [cited 2025 Jun 9];2015(1):702963. Available from: /doi/pdf/10.1155/2015/702963

163. (PDF) Fast Dissolving Oral Films Technology: A Recent Trend For An Innovative Oral Drug Delivery System [Internet]. [cited 2025 Jun 9]. Available from: https://www.researchgate.net/publication/283831631_Fast_Dissolving_Oral_Films_Technology_A_Recent_Trend_For_An_Innovative_Oral_Drug_Delivery_System

164. Sevinç Özakar R, Özakar E. Current

overview of oral thin films. Turkish J Pharm Sci [Internet]. 2021 [cited 2025 Jun 9];18(1):111–21. Available from: https://pubmed.ncbi.nlm.nih.gov/33634686/

165. Drašković M, Turković E, Vasiljević I, Trifković K, Cvijić S, Vasiljević D, et al. Comprehensive evaluation of formulation factors affecting critical quality attributes of casted orally disintegrating films. J Drug Deliv Sci Technol [Internet]. 2020 Apr 1 [cited 2025 Jun 9];56:101614. Available from: https://www.sciencedirect.com/science/article/abs/pii/S1773224719312389

166. Jelvehgari M, Montazam SH, Soltani S, Mohammadi R, Azar K, Montazam SA. Fast dissolving oral thin film drug delivery systems consist of ergotamine tartrate and caffeine anhydrous. Pharm Sci. 2015 Sep 1;21(2):102–10.

167. Kathpalia H, Gupte A. An Introduction to Fast Dissolving Oral Thin Film Drug Delivery Systems: A Review. Curr Drug Deliv [Internet]. 2013 Dec 21 [cited 2025 Jun 9];10(6):667–84. Available from: https://pubmed.ncbi.nlm.nih.gov/24274635/

168. Sevinç Özakar R, Özakar E. Current overview of oral thin films. Turkish J Pharm Sci [Internet]. 2021 [cited 2025 Jun 10];18(1):111–21. Available from: https://pubmed.ncbi.nlm.nih.gov/33634686/

169. Kathpalia H, Gupte A. An Introduction to Fast Dissolving Oral Thin Film Drug Delivery Systems: A Review. Curr Drug Deliv [Internet]. 2013 Dec 21 [cited 2025 Jun 10];10(6):667–84. Available from: https://pubmed.ncbi.nlm.nih.gov/24274635/

170. Gupta MS, Kumar TP, Reddy D, Pathak K, Gowda DV, Babu AVN, et al. Development and Characterization of Pullulan-Based Orodispersible Films of Iron. Pharmaceutics [Internet]. 2023 Mar 1 [cited 2025 Jun 10];15(3):1027. Available from: https://www.mdpi.com/1999-4923/15/3/1027/htm

171. Karki S, Kim H, Na SJ, Shin D, Jo K, Lee J. Thin films as an emerging platform for drug delivery. Asian J Pharm Sci [Internet]. 2016 Oct 1 [cited 2025 Jun 10];11(5):559–74. Available from: https://www.sciencedirect.com/science/article/pii/S1818087616300368

172. Koland M, Vijayanarayana K, Charyulu Rn, Prabhu P. In vitro and in vivo evaluation of chitosan buccal films of ondansetron hydrochloride. Int J Pharm Investig [Internet]. 2011 [cited 2025 Jun 10];1(3):164. Available from: https://pubmed.ncbi.nlm.nih.gov/23071939/

173. Irfan M, Rabel S, Bukhtar Q, Qadir MI, Jabeen F, Khan A. Orally disintegrating films: A modern expansion in drug delivery system. Saudi Pharm J [Internet]. 2016 Sep 1 [cited 2025 Jun 10];24(5):537–46. Available from: https://www.sciencedirect.com/science/article/pii/S1319016415000626

174. Adrover A, Pedacchia A, Petralito S, Spera R. In vitro dissolution testing of oral thin films: A comparison between USP 1, USP 2 apparatuses and a new millifluidic flow-through device. Chem Eng Res Des [Internet]. 2015 Mar 1 [cited 2025 Jun 10];95:173–8. Available from: https://www.sciencedirect.com/science/article/abs/pii/S0263876214004729

175. Özakar E, Sevinç-Özakar R, Yılmaz B. Preparation, Characterization, and Evaluation of Cytotoxicity of Fast Dissolving Hydrogel Based Oral Thin Films Containing Pregabalin and Methylcobalamin. Gels 2023, Vol 9, Page 147 [Internet]. 2023 Feb 9 [cited 2025 Jun 10];9(2):147. Available from: https://www.mdpi.com/2310-2861/9/2/147/htm

176. Rani TN. Formulation Development and Optimization of Oral Thin Films of Zolpidem Tartarate. Med Sci Healthc Pract [Internet]. 2017 Apr 6 [cited 2025 Jun 10];1(1):26. Available from: https://www.researchgate.net/publication/317075114_Formulation_Development_and_Optimization_of_Oral_Thin_Films_of_Zolpidem_Tartarate

177. (PDF) A Short Review on "A Novel Approach in Oral Fast Dissolving Drug Delivery System and Their Patents" [Internet]. [cited 2025 Jun 10]. Available from: https://www.researchgate.net/publication/266569598_A_Short_Review_on_A_Novel_Approach_in_Oral_Fast_Dissolving_Drug_Delivery_System_and_Their_Patents

178. Gupta MS, Kumar TP, Gowda DV,

Rosenholm JM. Orodispersible films: Conception to quality by design. Adv Drug Deliv Rev [Internet]. 2021 Nov 1 [cited 2025 Jun 16];178:113983. Available from: https://www.sciencedirect.com/science/article/abs/pii/S0169409X21003768

179. ICH Guideline M13A on bioequivalence for immediate-release solid oral dosage forms - Scientific guideline | European Medicines Agency (EMA) [Internet]. [cited 2025 Jun 16]. Available from: https://www.ema.europa.eu/en/ich-guideline-m13a-bioequivalence-immediate-release-solid-oral-dosage-forms-scientific-guideline

180. Jacob S, Boddu SHS, Bhandare R, Ahmad SS, Nair AB. Orodispersible Films: Current Innovations and Emerging Trends. Pharm 2023, Vol 15, Page 2753 [Internet]. 2023 Dec 11 [cited 2025 Jun 16];15(12):2753. Available from: https://www.mdpi.com/1999-4923/15/12/2753/htm

181. Karki S, Kim H, Na SJ, Shin D, Jo K, Lee J. Thin films as an emerging platform for drug delivery. Asian J Pharm Sci [Internet]. 2016 Oct 1 [cited 2025 Jun 16];11(5):559–74. Available from: https://www.sciencedirect.com/science/article/pii/S1818087616300368

182. Kawale KA, Neha B Autade, Narhare H s, Mhetrea RL. A REVIEW ON FAST-DISSOLVING ORAL FILM. Asian J Pharm Clin Res. 2023 Oct 7;7–17.

183. Serrano DR, Kara A, Yuste I, Luciano FC, Ongoren B, Anaya BJ, et al. 3D Printing Technologies in Personalized Medicine, Nanomedicines, and Biopharmaceuticals. Pharmaceutics [Internet]. 2023 Feb 1 [cited 2025 Jun 16];15(2):313. Available from: https://pmc.ncbi.nlm.nih.gov/articles/PMC9967161/

184. Castellanos MM, Gressard H, Li X, Magagnoli C, Moriconi A, Stranges D, et al. CMC Strategies and Advanced Technologies for Vaccine Development to Boost Acceleration and Pandemic Preparedness. Vaccines [Internet]. 2023 Jul 1 [cited 2025 Jun 16];11(7):1153. Available from: https://pmc.ncbi.nlm.nih.gov/articles/PMC10386492/

185. Ali KA, Mohin S, Mondal P, Goswami S, Ghosh S, Choudhuri S. Influence of artificial intelligence in modern pharmaceutical formulation and drug development. Futur J Pharm Sci 2024 101 [Internet]. 2024 Mar 29 [cited 2025 Jun 16];10(1):1–15. Available from: https://fjps.springeropen.com/articles/10.1186/s43094-024-00625-1