



Recipharm

**FROM LATE-STAGE DEVELOPMENT TO LAUNCH:
A PREDICTIVE APPROACH TO
COMPLEX OSD CHALLENGES**

Introduction

Executive summary

The oral solid dosage (OSD) market is entering a new phase, one defined by increasing formulation complexity, tighter development timelines and greater pressure to achieve seamless scale-up into commercial manufacturing. As drug developers pursue more sophisticated molecules and products containing a combination of pharmaceutical ingredients (APIs), traditional trial-and-error development approaches are becoming increasingly insufficient.

This eBook explores these challenges and demonstrates how a predictive, data-driven approach can help pharmaceutical companies:

- ▶ Reduce technical and operational risk during development
- ▶ Minimise API consumption while accelerating formulation understanding
- ▶ Improve process robustness and repeatability at commercial scale
- ▶ Identify scale-up risks before they impact validation or manufacturing
- ▶ Accelerate timelines while maintaining scientific confidence and regulatory readiness

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Section 1

Challenges in OSD development

The global OSD market continues to evolve rapidly. While tablets and capsules remain the most widely used drug delivery formats worldwide¹, the nature of the products being developed is changing significantly.

Growth is increasingly being driven by higher-value, more technically demanding formulations, including modified-release products, highly potent APIs, poorly soluble compounds and patient-centric dosage forms. These therapies often require specialist technologies and advanced excipients to achieve the required performance characteristics.

The transition from developmental to commercial manufacturing is also becoming more complex. Processes that appear robust at small scale can encounter unexpected variability during scale-up; commercial-scale equipment can affect compound material behaviour in new ways; minor inconsistencies in material composition (particle size, moisture content, etc.) can become more apparent during upscaling/at a commercial scale.

These issues can lead to:

- ▶ Validation failures
- ▶ Delays to clinical supply or commercial launch
- ▶ Increased API consumption
- ▶ Additional formulation work
- ▶ Higher development costs
- ▶ Manufacturing inefficiencies

To avoid these outcomes, development programmes must be designed with scalability, repeatability and commercial manufacturing in mind from the earliest stages.

This requires pharmaceutical companies to adopt more preventative approaches that account for:

- ▶ Cost of goods (CoGs)
- ▶ Repeatability at large scale
- ▶ Equipment differences
- ▶ Material variability
- ▶ Process robustness
- ▶ Regulatory expectations

These risks must not only be identified early but also understood holistically.

Rather than treating formulation, analytical development and manufacturing as isolated activities, successful OSD development increasingly depends on understanding how critical material attributes (CMAs), critical process parameters (CPPs) and critical quality attributes (CQAs) interact throughout the entire process.

A predictive, data-driven approach enables development teams to move beyond traditional trial-and-error methodologies and instead build robust manufacturing processes through scientific understanding and modelling.

Section 2

API constraints

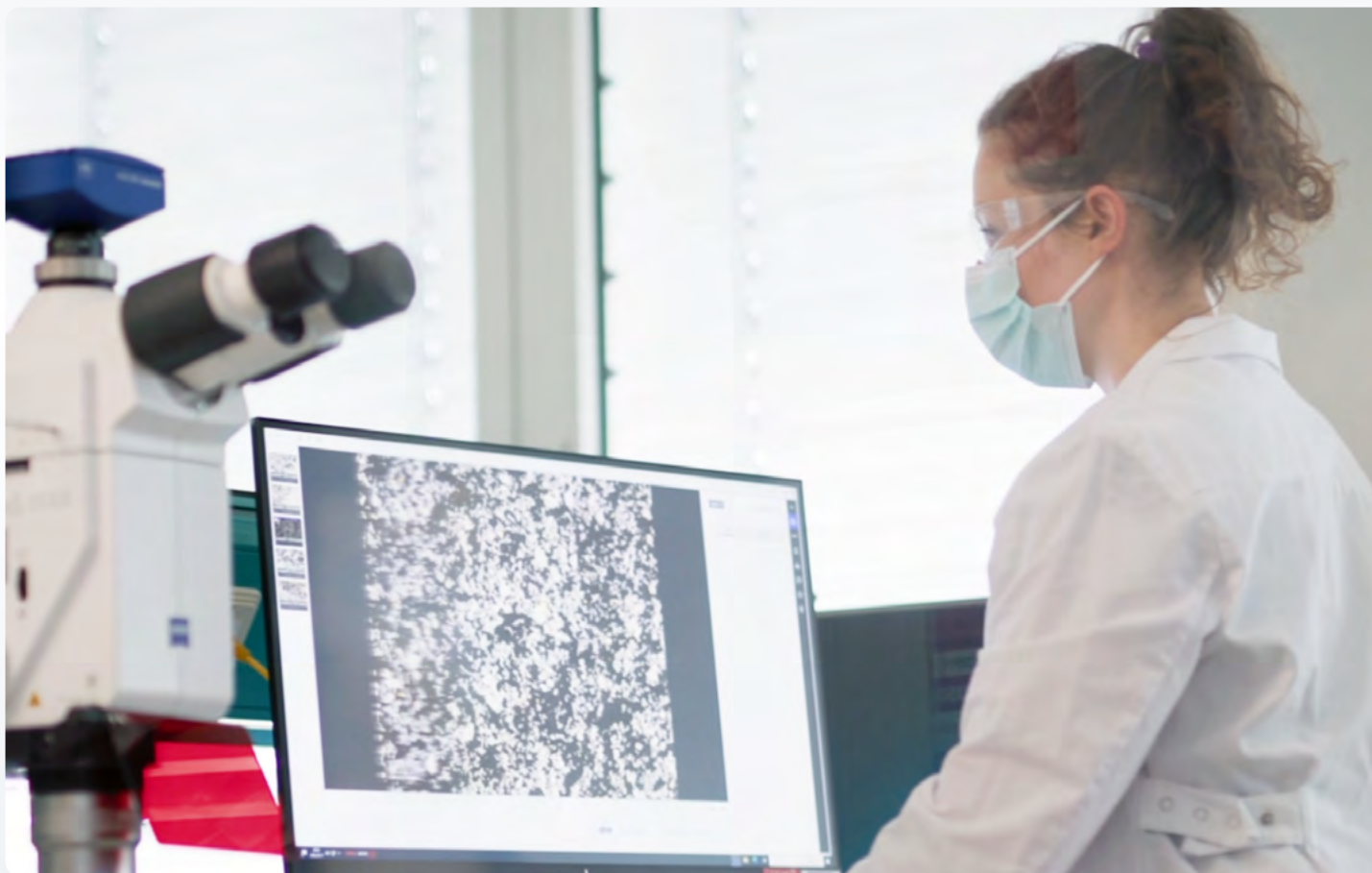
The challenge

Success at applying predictive development principles first depends on generating a detailed understanding across every stage of the OSD process. However, this becomes significantly more challenging when development teams are working with limited quantities of highly valuable API.

This frequent restriction places significant pressure on formulation teams to maximise every gram of material while still generating the process understanding needed for successful scale-up and commercialisation.

Compounding this issue of scarcity, much of the API data can be incomplete during development. Material characteristics such as flowability and particle behaviour may not yet be fully understood, for instance, making it difficult to predict how the formulation will behave during manufacturing.

Traditional development approaches can exacerbate this challenge. Repeated physical trials and scale-up iterations can consume large quantities of API while still failing to generate a sufficiently robust process understanding.



Section 2. API constraints

The solution

To address API constraints effectively, development programmes must be designed to generate maximum insight from minimal material. This begins with advanced material characterisation.

By understanding the physical properties of the API and excipients early, development teams can identify formulation strategies that improve flow, compressibility and blend uniformity while preserving limited API quantities.

At Recipharm, technologies such as the FT4 powder rheometer, BET specific surface area measurement and particle size measurement via laser diffraction are used to generate a detailed understanding of material behaviour.

The FT4 powder rheometer, for example, enables teams to evaluate:

- ▶ Flow behaviour
- ▶ Cohesion
- ▶ Compressibility
- ▶ Wall friction
- ▶ Bridging tendencies

These insights allow formulation scientists to compare formulations and determine which excipient combinations are most likely to perform successfully before committing scarce API to larger studies.

Based on these material characterisation data, Recipharm can create in silico prototype formulations that predict how a formulation is likely to behave during processing and manufacturing. Through the ReciPredict platform, material attributes are linked directly to process parameters and quality attributes, enabling developers to simulate process outcomes computationally and reduce the need for extensive physical experimentation. This predictive approach can reduce material consumption by up to 70%, while simultaneously improving process understanding and accelerating development timelines.

Importantly, the process is not purely virtual. Targeted physical trials are still conducted to calibrate and refine predictive models, ensuring that simulations remain grounded in real manufacturing behaviour.

By combining small-scale experimentation with modelling and statistical analysis, development teams can establish robust formulations and scalable processes using far less API than conventional approaches. This approach enables pharmaceutical companies to preserve valuable

API supplies while building the process robustness needed for reliable scale-up and commercial manufacturing.



Section 3

Complex formulations



The challenge

Modern OSD products are becoming increasingly complex. Drug developers are now routinely working with:

- ▶ Highly potent APIs
- ▶ Poorly soluble compounds
- ▶ Modified-release formulations
- ▶ Combination products
- ▶ Sensitive molecules requiring specialist handling

These formulations present significant development challenges.

Poorly soluble APIs, for instance, typically suffer from limited bioavailability and inconsistent dissolution performance. Highly potent compounds may require specialist containment strategies and highly controlled manufacturing environments. Modified-release products demand precise control over material behaviour and process conditions to achieve the desired release profile.

These unique formulation challenges add to the many standard considerations developers already face (achieving target bioavailability, ensuring scalability, meeting regulatory expectations, etc.) when scaling up production.

Without proper expertise and appropriate technologies, the combination of these sets of challenges could overwhelm a facility's team, leading to unstable or failing formulations.



Section 3. Complex formulations

The solution

Successfully developing complex OSD products requires both specialist expertise and systematic development methodologies. In many cases, the most important foundation remains adherence to the principles of Quality by Design (QbD) and Design of Experiments (DoE). These approaches allow development teams to move beyond isolated experimentation and instead build a structured understanding of how formulation and process variables interact.

At Recipharm, development programmes are built around understanding the relationship between CMAs, CPPs and CQAs. This creates a mathematical understanding of the product and manufacturing process that can be used to guide decision-making throughout development.

For poorly soluble APIs, for instance, specialist technologies and excipients can be evaluated systematically to identify solubilisation strategies

that are not only effective but scalable and commercially viable.

Rather than relying solely on empirical experimentation, modelling and risk assessment tools help identify which formulation and process combinations are most likely to deliver robust outcomes.

Importantly, development is approached as a continuous iteration of:

- ▶ Risk assessment
- ▶ Gap analysis
- ▶ Small-scale experimentation
- ▶ Model refinement

This allows scientific understanding to evolve progressively while minimising unnecessary experimentation.

Analytical development also plays a critical role. By developing analytical methods early and integrating analytical data directly into development models, teams can ensure that decisions are based on reliable, scientifically defensible data.

This integrated approach enables faster identification of formulation risks, improved understanding of process variability, reduced development iterations and, ultimately, greater confidence during scale-up.



Section 4

Scaling up

The challenge

Scale-up remains one of the most critical risk points in pharmaceutical development. Processes that appear successful during development can behave very differently when transferred to larger-scale manufacturing equipment. Differences in compaction behaviour, feeding dynamics, blending performance or equipment geometry can significantly impact product quality and process robustness.

Without robust planning, scale-up failures can lead to:

- ▶ Failed validation campaigns
- ▶ Rework and reformulation
- ▶ Delayed commercialisation
- ▶ Increased operational costs
- ▶ Manufacturing inefficiencies

Operators should therefore never assume that duplication will suffice. In reality, commercial manufacturing environments introduce new variables that must be understood and anticipated early.

The solution

Successful scale-up begins many steps before technology transfer. Development programmes should be designed from the outset with commercial manufacturing in mind.

At Recipharm, scale-up is approached as an integrated process involving formulation scientists, analytical teams, manufacturing experts and MSAT teams working collaboratively throughout development. The objective is to establish robust processes and design spaces early, reducing uncertainty during transfer into manufacturing.

Through ReciPredict, CMAs and CPPs are linked directly to CQAs, enabling teams to predict how the process is likely to behave at a larger scale. These insights allow developers to identify scale-dependent parameters and equipment differences before they become validation issues. Risk assessments, DoE studies and modelling tools are also used to define operating ranges and understand process robustness under varying manufacturing conditions.

Importantly, process parameters and the associated design space are established in advance of technology transfer and aligned through a structured agreement

between development teams, MSAT operations teams and the customer.

This alignment helps ensure seamless transfer into manufacturing, clear understanding of process expectations, reduced operational surprises and stronger commercial readiness.

Recipharm's development teams also focus on designing simplified, efficient manufacturing processes that minimise operational complexity while maintaining specification-conforming product quality.

This focus includes consideration of:

- ▶ Equipment capabilities
- ▶ Workforce requirements
- ▶ Excipient costs
- ▶ Manufacturing efficiency
- ▶ Long-term process sustainability

The result is a development strategy focused both on technical success and reliable commercial manufacturing.

Section 5

Timeline pressures

The challenge

The pressure to accelerate development timelines continues to intensify across the pharmaceutical industry². Drug developers face growing urgency to bring therapies to market quickly while still ensuring scientific rigour, regulatory compliance and manufacturing robustness.

The truncating of timelines can create risks. When process variability or formulation weaknesses are identified late, programmes can become trapped in cycles of repeated troubleshooting, additional experimentation and delayed validation.

Compounding these pressures, traditional one-variable-at-a-time troubleshooting approaches are also often too slow and insufficiently informative for modern OSD complexity.

Development teams, therefore, need faster ways to identify root causes, predict outcomes and make confident decisions.

The solution

Reducing development timelines requires both strategic planning and predictive scientific tools. At the beginning of a development partnership, project timelines, objectives and success criteria should be clearly aligned between all stakeholders. Structured governance processes, including stage gates, regular risk reviews and collaborative decision-making, can also be adopted to maintain alignment throughout the programme.

Recipharm's modelling tools and specialist expertise across OSD technologies can also contribute significantly to timeline acceleration. Experience with complex formulations, process behaviour and commercial manufacturing challenges enables our teams to anticipate risks early and implement more effective development strategies. Combined with predictive tools and integrated analytical development, this expertise helps reduce delays while improving overall development confidence.

Section 6

An OSD development case study

To illustrate how predictive, data-driven development strategies can practically overcome complex manufacturing challenges, we can look to a recent tablet development partnership.

The challenge

A Recipharm customer was experiencing significant process reproducibility issues with a tablet formulation. The primary challenge was poor granule formation during processing, which negatively impacted tableability and caused the product to fail critical quality specifications.

The formulation, however, could not be altered. Traditional troubleshooting approaches had failed to identify a sustainable solution, creating significant risk for validation and commercial manufacturing.

ReciPredict

The solution

Recipharm began the programme with a detailed risk assessment designed to identify the key process risks and knowledge gaps.

The team then performed a comprehensive physical characterisation of the API and linked the resulting material attributes directly to the process parameters associated with compaction and compression.

Using small-scale DoE studies, the development team evaluated the design space and investigated how variations in process conditions impacted CQAs. A mathematical model was then built linking material properties, such as compressibility to the required target quality attributes.

Through the ReciPredict platform, the interconnected relationships between material attributes, process parameters and product quality could then be analysed holistically.

This evaluation enabled the team to predict process behaviour and optimise the manufacturing strategy without relying on extensive experimentation.

The result

Using this systematic, predictive approach, Recipharm was able to:

- ▶ Reduce material consumption during testing
- ▶ Establish a robust manufacturing process
- ▶ Accelerate development timelines
- ▶ Achieve successful validation in just six months

Most importantly, the programme delivered seamless and uneventful commercial manufacturing for the customer.

This project demonstrates how predictive modelling, integrated process understanding and early risk mitigation can transform complex development challenges into scalable commercial success.

Section 7

A complex future made simpler with a predictive approach

The future of OSD development will be defined by complexity. As pharmaceutical companies pursue increasingly sophisticated therapies, development programmes must evolve beyond traditional trial-and-error methodologies.

Predictive development strategies that integrate modelling, material characterisation, QbD and manufacturing expertise are essential for this future, reducing risk in OSD development and ensuring successful commercialisation.

By understanding the interconnected relationships between material attributes, process parameters and product quality, pharmaceutical developers can establish robust processes earlier, thereby reducing unnecessary experimentation and accelerating pathways to market.

Recipharm's integrated development approach, supported by the ReciPredict platform, enables pharmaceutical companies to do just that, helping

partners to anticipate and overcome the most significant challenges in modern OSD development.

From API constraints and complex formulations to scale-up and timeline pressures, factors that could otherwise be challenges become useful data for Recipharm's predictive tools to deliver robust, scalable and commercially viable outcomes.

References

1. Grand View Research. "Oral Solid Dosage CDMO Market (2026 - 2033)." 2025. <https://www.grandviewresearch.com/industry-analysis/oral-solid-dosage-cdmo-market-report>
2. McKinsey & Company. "Charting the path to patients". 2025. <https://www.mckinsey.com/industries/life-sciences/our-insights/charting-the-path-to-patients>

Ready to de-risk your next OSD programme?

Whether you are managing complex formulations, limited API availability or challenging scale-up requirements, our teams can help you establish a confident path from development to launch.

Contact Recipharm to learn how a predictive approach can support your next OSD programme.

Contact us

The logo for Recipharm features the word "Recipharm" in a white, sans-serif font. The letter 'i' is stylized with a vertical stem and a small leaf-like shape at the top. The background is a teal gradient with a circular, textured pattern of white powder or granules in the center.

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