CHALLENGES IN DRYING BIOACTIVE PROTEINS

Contributions: Preethi Jayaprakash, Laurine Rio, Elodie Beaupeux, Claire Gaiani, Audrey Maudhuit, Stéphane Desobry

CASE STUDY

PRESERVING BIOACTIVE INTEGRITY: OVERCOMING THE STABILITY CHALLENGES OF TRADITIONAL DRYING

The primary challenge in drying bioactive proteins lies in their **instability and sensitivity to environmental conditions**. Currently, encapsulation with drying is the preferred solution to overcome these challenges. Two technologies are well-known: **spray drying (SD)**, which enables high production rates but can damage bioactive compounds due to high temperatures, and **freeze drying (FD)**, which is superior for preserving sensitive molecules but is time- and energy-intensive due to its batch-system nature.

A new technology is emerging as a continuous alternative: **electrostatic drying (ESD)**. ESD operates continuously at lower temperatures than SD by utilizing an electrostatic charge. The choice of formulation, including the carrier, is also critical to ensure functionality, efficiency, and regulatory compliance.

Created in partnership with:

UNIVERSITÉ DE LORRAINE

ENZYME β-GALACTOSIDASE: COMPARISON OF THREE DRYING TECHNOLOGIES

Enzyme β-galactosidase was dried with three carriers (maltodextrin, skim milk, and shellac) and with three different processes: spray drying; freeze drying; and electrostatic drying. The enzyme activity was analyzed based on lactose hydrolysis and qualified using HPLC. Lactose degradation was linearized using first-order model. Operating conditions are as follows:

Operating Parameters				
Technologies	*Parameters*	*Details*		
Freeze Drying	Steps	Time (h)	Temperature (°C)	Pressure (mbar)
	Freezing	48	-52	0.3
Spray Drying	Inlet Temperature (°C)	170		
	Outlet Temperature (°C)	110		
	Oxygen Flowrate (Nm^3/h)	36		
Electrostatic Drying	Inlet Temperature (°C)	90		
	Outlet Temperature (°C)	44-46		
	Nitrogen Flowrate (Nm^3/h)	25		
	Voltage (kV)	3		

Figure 1. The feedstocks were prepared with a solids content of 27.5%, including 2.5% of enzyme.

LONG-TERM STABILITY ANALYSIS: 12-MONTH ACTIVITY RESULTS

The degradation rate was measured across all drying processes and carrier matrices immediately following production (0 month) and after a 12-month stability period at 21°C.

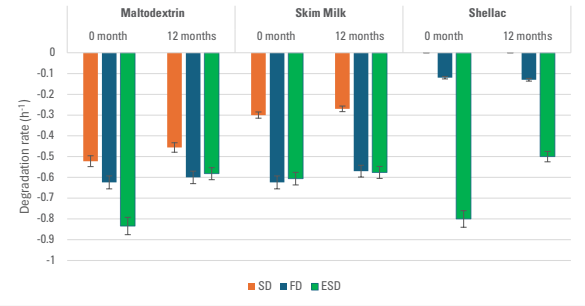

Figure 2. Impact of drying technology and carrier selection on the long-term degradation rate and stability of β-galactosidase.

KEY PERFORMANCE FINDINGS

- **Encapsulation Benefit:** Without a carrier, enzyme activity initially at -1.6 dropped to zero after 12 months, underscoring the absolute necessity of a protective matrix for long-term viability.
- **Superior Initial Activity:** At the 0-month mark, electrostatic drying (ESD) yielded the highest activity levels across all three tested matrices compared to traditional methods.
- **Thermal Impact:** Enzyme activity was consistently lowest with spray drying (SD) technology, a direct result of the high process temperatures required for this technology.
- **Operational Advantages:** For maltodextrin and skim milk, ESD mirrored the preservation performance of freeze drying (FD) while providing the distinct advantage of a continuous, time-efficient process.[1]
- **Formulation Choice:** In the case of shellac, ESD produced the highest recorded enzyme activity of all three technologies tested.

CONCLUSION

Enzyme β-galactosidase served as a critical control to evaluate the encapsulation efficiency of ESD technology on bioactive proteins. The results confirm that ESD is a highly promising solution for protecting bioactive integrity at room temperature, consistently maintaining superior enzyme activity levels at both the 0-month and 12-month intervals.

HIGHLIGHTS

High Activity
With ESD, the protein remains active.

Equivalent Quality
ESD and FD demonstrate equivalent bioactivity and stability.

Continuous Process
ESD offers a continuous and sustainable drying alternative.

Formulation Optimization
Strategic carrier selection is essential for success.

[1] J. Oxley, C. Castilla-Guiterrez, S. Collazos, C. Garza, E. Garza, K. Lange, M. Mamori and A. Zwiener, *Comparison of energy consumption and probiotic stability with pilot scale drying processes,* LWT, Vol 211, p 116937, 2024, doi: 10.1016/j.lwt.2024.116937

ISO 9001:2015 CERTIFIED

+1 630.665.5001
fluidairinfo@spray.com
fluidairinc.com

FLUID AIR
A Division of Spraying Systems Co.®