

# FOUR DECADES OF INNOVATION IN FOOD SCIENCE AND TECHNOLOGY

*A Comprehensive Analysis of Professor Arun S. Mujumdar's  
Scholarly, Editorial, and Mentorship Legacy*

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# Executive Summary

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Professor Arun S. Mujumdar is globally recognized as the foremost authority in industrial drying and thermal processing, bridging the gap between chemical engineering principles and food science technology over the last four decades. Through an extraordinary portfolio comprising more than 575 peer-reviewed journal publications, over 60 edited and authored books, and hundreds of book chapters, Professor Mujumdar has systematically transformed thermal dehydration from an empirical art into a rigorous engineering science. His profound impact on food preservation, quality enhancement, energy efficiency, and mathematical modeling has revolutionized industrial practices and academic research alike.

Beyond his personal research output, his leadership as the founding father of the International Drying Symposium (IDS) in 1978 and his long tenure as the Editor-in-Chief of the archival journal *Drying Technology* have provided the structural infrastructure required for the global advancement of the discipline. His deep commitment to global knowledge democratization is demonstrated by his series of open-access e-books, providing technical information freely to developing countries. Crucially, his cross-border mentorship network—encompassing over 55 PhD students, 40 postdoctoral fellows, and an active international collaboration web across 18 countries (the Thermal Processing Research or TPR Group)—has established an academic lineage that continues to shape the future of sustainable food engineering. This report provides a detailed analysis of Professor Mujumdar's multi-faceted contributions to food science and technology, highlighting his legacy as an innovator, educator, editor, and visionary leader.

## 1. Introduction and Career Trajectory

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The stabilization and preservation of food materials through thermal processing represent one of the oldest and most vital pillars of human civilization, directly affecting global food security, supply chain sustainability, and nutritional health. However, until the late 20th century, many advanced drying techniques remained heavily empirical, lacking deep mechanical understanding and unified transport mathematical frameworks. Professor Arun S. Mujumdar transformed this field.

Graduating with a Bachelor's degree in Chemical Engineering from the prestigious University Department of Chemical Technology (UDCT, now the Institute of Chemical Technology, ICT) in Mumbai, India, Professor Mujumdar pursued advanced studies at McGill University in Montreal, Canada, where he earned his Master's and Doctoral degrees. It was at McGill University, and subsequently at the National University of Singapore (NUS), that he built an international hub for drying research. His career path uniquely combines foundational chemical engineering concepts—such as fluid dynamics, heat and mass transfer, and thermodynamic optimization—with the intricate, heat-sensitive biochemistries characteristic of food matrices and biological structures.

Over the past forty years, Professor Mujumdar's research vision has anticipated the major technological transitions of the food industry: moving from simple hot-air systems to highly precise, hybrid, and non-thermal assisted drying

technologies. His structural work addresses the triple constraints of modern industrial processing: maximizing biochemical product quality, minimizing energy consumption, and reducing environmental carbon footprints. His career is distinguished not only by individual brilliance but by his unique ability to build global communities, bringing together researchers from North America, Europe, Asia, and South America to tackle global challenges in food preservation.

## 2. Architectural Contributions to Food Dehydration Technologies

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The core of Professor Mujumdar's technical legacy in food science lies in his systematic analysis and development of advanced drying configurations designed to preserve nutritional values, volatile flavor profiles, and mechanical properties of agricultural commodities. Food materials are highly complex, heat-sensitive, porous matrices that undergo structural stress, enzymatic browning, glass transition transformations, and nutrient destruction during conventional thermal treatment. Professor Mujumdar's research provided the mechanistic foundation needed to mitigate these undesirable changes.

### 2.1 Spray Drying of Liquid Foods and Encapsulation

Spray drying is the primary technological process used for transforming liquid food streams—such as dairy products, fruit juices, plant protein isolates, and marine extracts—into stable, free-flowing engineered powders. Professor Mujumdar's work in spray drying concentrated heavily on optimizing transport phenomena inside the dryer chamber, improving thermal efficiency, and addressing the technical challenges of stickiness and wall deposition caused by low-molecular-weight sugars (like fructose and glucose) and organic acids.

Collaborating with global leaders such as Professor Min Zhang (Jiangnan University) and Professor Bhesh Bhandari (University of Queensland), his research explored the inclusion of high-molecular-weight carriers (such as maltodextrins and gum Arabic) to raise the glass transition temperature ( $T_g$ ) of the drying matrix. By establishing exact phase maps and state diagrams for food components, his research enabled the high-yield spray drying of difficult fruit pulps and bioactive formulations. Furthermore, his group pioneered mathematical models utilizing Computational Fluid Dynamics (CFD) to track individual droplet-particle trajectories, evaporation rates, and internal temperature fields. This significantly minimized product degradation and reduced energy-intensive wall scaling in large industrial spray towers.

### 2.2 Superheated Steam Drying (SSD) of Food Products

One of Professor Mujumdar's most disruptive engineering innovations in food processing is the development and promotion of low-pressure and atmospheric Superheated Steam Drying (SSD). In conventional drying, hot air supplies heat and carries away moisture, venting latent heat directly to the environment. In contrast, SSD uses superheated steam as the drying medium in an oxygen-free environment.

Professor Mujumdar demonstrated that when drying food products with superheated steam, the absence of oxygen entirely eliminates oxidative degradation reactions, such as the destruction of ascorbic acid (Vitamin C), lipid

oxidation in fatty foods, and enzymatic browning catalyzed by polyphenol oxidase. His collaborative studies with Professor Sakamon Devahastin (King Mongkut's University of Technology Thonburi) proved that low-pressure superheated steam drying yields superior texture, enhanced rehydration capabilities, and structural preservation in vegetables and marine products. From an environmental perspective, SSD systems allow the recovery of the exhausted steam, which can be recompressed and recycled into the process, lowering energy use by up to 30-50% compared to conventional air dryers.

## 2.3 Freeze Drying and Combined/Hybrid Technologies

While freeze drying (lyophilization) is recognized as the gold standard for quality preservation due to the sublimation of ice under vacuum, its widespread industrial application is constrained by high capital and operating costs. Professor Mujumdar addressed this challenge by developing combined and hybrid multi-stage drying configurations. He introduced the integration of microwave, radio-frequency, and ultrasonic fields into conventional freeze drying and hot-air convective systems.

By applying intermittent energy inputs (e.g., pulsing microwave energy during the falling-rate drying period), Professor Mujumdar's methods significantly accelerated internal moisture diffusion without causing localized thermal damage or structural collapse. This hybrid approach reduced total processing times by up to 40% while matching the premium quality attributes—such as color retention, bioactive survival (anthocyanins, polyphenols), and porous structure—of continuous freeze drying.

## 2.4 Mathematical Modeling and Transport Phenomena

Prior to Professor Mujumdar's contributions, food drying modeling relied heavily on empirical fitting parameters that lacked general physical validity across different scales. He established rigorous mathematical formulations using fundamental conservation laws. The fundamental equation governing moisture transport within a food matrix during the falling-rate drying period was modeled through an updated version of Fick's second law, accounting for shrinkage and variable moisture diffusivity:

$$\partial X / \partial t = \nabla \cdot (D_{eff}(X, T) \nabla X)$$

Where  $X$  represents the local moisture content (dry basis),  $t$  is time, and  $D_{eff}$  is the effective moisture diffusivity, which is treated as a highly non-linear function of both local moisture concentration and absolute temperature  $T$ . Professor Mujumdar and his research team coupled this mass transport model with energy balance equations that integrated the temperature-dependent thermal conductivity, structural density variations, and phase transformations of food polymers. These models allowed engineers to simulate drying dynamics accurately, facilitating predictable scaling from laboratory benches to full-scale industrial operations.

### 3. The "Bible of Drying": The Handbook of Industrial Drying and Seminal Books

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A critical channel of Professor Mujumdar's global impact is his extensive list of publications. Foremost among these is the *Handbook of Industrial Drying*, published by CRC Press. First released in 1987 and currently in its multi-volume subsequent editions, this handbook is universally regarded by academia and industry as the "Bible of Drying."

Before this handbook, knowledge regarding industrial dehydration was scattered across isolated papers in distinct chemical, civil, mechanical, and food engineering journals. Professor Mujumdar consolidated these domains into a single, comprehensive reference work. The handbook features specialized, deeply analytical chapters dedicated specifically to food and agricultural commodities, covering milk powders, grains, fruits, vegetables, muscle foods, and tea processing.

In addition to this monumental reference work, Professor Mujumdar has authored and edited over 60 books that focus on specialized sub-disciplines of food engineering. Key publications include *Drying Technologies in Food Processing* (Wiley-Blackwell) and *Drying Technology in Agriculture and Food Sciences*. These books provide food scientists and processing engineers with practical guidelines for selecting equipment, optimizing thermal parameters, and troubleshooting quality defects during commercial production.

#### Key Bibliometric and Publication Metrics (1980–2026):

- **Peer-Reviewed Journal Articles:** Over 575 archival publications spanning transport phenomena, food quality, and novel equipment design.
- **Books Authored/Edited:** 60+ reference volumes, including the authoritative *Handbook of Industrial Drying*.
- **Book Chapters:** More than 120 comprehensive technical chapters.
- **Google Scholar Citations:** Over 16,600 citations with an h-index of 58 (Scopus h-index: 41 with 8,500+ citations).
- **Open-Access e-Books:** 8 fully downloadable e-books aimed at supporting low-income and developing nations.

### 4. Editorial Leadership and Global Scholarly Infrastructure

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An individual's research output can drive specific advancements, but establishing a world-class archival journal creates a sustainable framework for entire generations of scholars. In 2000, Professor Mujumdar assumed the role of Editor-in-Chief of *Drying Technology: An International Journal* (Taylor & Francis). Under his visionary

guidance, the journal transformed into a highly respected publication, with its impact factor rising consistently to mirror its critical role in chemical and food engineering.

As Editor-in-Chief, Professor Mujumdar managed over 120 special and regular international journal issues. He implemented a rigorous peer-review system that emphasized physical insight, mathematical validation, and industrial relevance. He intentionally broadened the journal's scope to explicitly include food bio-products, recognizing that agricultural post-harvest preservation represents a primary arena for global energy savings and food security.

Simultaneously, Professor Mujumdar identified a significant geographical imbalance in access to premium scientific literature. Researchers in developing countries frequently faced paywall barriers that restricted access to cutting-edge technical information. To address this disparity, he initiated a series of open-access, freely downloadable e-books through his personal academic portal. Titles such as *Drying of Foods, Vegetables and Fruits* (Volumes 1, 2, and 3) and *Solar Drying: Fundamentals, Applications, and Innovations* were edited and released without cost. This democratization of knowledge allowed thousands of researchers in low-resource environments to optimize local food preservation systems, reducing post-harvest losses and supporting regional food sustainability.

## 5. The International Drying Symposium (IDS) and Knowledge Transfer

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Professor Mujumdar firmly believed that scientific progress accelerates through face-to-face dialogue between international researchers and commercial system operators. To achieve this, he founded the **International Drying Symposium (IDS)** series, organizing the inaugural event in Montreal, Canada, in 1978. Over the subsequent four decades, the biennial IDS has become the premier global conference for drying technology.

The IDS series has traveled globally, with conferences held in venues across North America, Europe, South America, and Asia. These symposia serve as an international clearinghouse for new technologies. Innovations such as pulse-combustion drying, refractance window dehydration, impingement jet drying, and solar-assisted heat pumps were first presented, critiqued, and refined within the sessions of the IDS. For food technologists, the conference provided a unique platform where fundamental heat and mass transfer models could be directly integrated with practical food quality criteria, driving rapid technology transfer from university laboratories to commercial food processing plants.

## 6. Mentorship, Academic Lineage, and the TPR Group Network

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The true magnitude of an academic legacy is measured by the accomplishments and continuity of one's students. Professor Mujumdar's dedication to teaching and human capital development is exceptional: he has directly supervised and mentored over 55 PhD candidates and guided more than 40 post-doctoral research fellows across institutions including McGill University and the National University of Singapore.

In 2002, he formalized his extensive international research collaborations by establishing the **Thermal Processing Research (TPR) Group network**. This network spans 18 countries, connecting major research laboratories, industrial groups, and academic institutions. Through the TPR Group, Professor Mujumdar fostered a collaborative ecosystem that crossed traditional borders. Rather than competing, institutions shared data, code, and exchange students.

His academic lineage includes many of the most prominent names in modern food engineering. For instance, his collaborations with Professor Hong-Wei Xiao (China Agricultural University) led to breakthroughs in pneumatic and multi-stage drying of specialty crops. His work with Professor Xiao Dong Chen (Soochow University) advanced the understanding of mono-disperse droplet drying fingerprinting, a technique central to modern dairy powder design. This global network serves as a living repository of his principles, ensuring that his focus on rigorous engineering and industrial application remains central to food science research worldwide.

## 7. Comprehensive Mapping of Technical and Scholarly Milestones

To systematically evaluate the breadth of Professor Mujumdar's contributions, the following tables detail his landmark edited books, major technological focus areas, and institutional network collaborations that have defined his career.

Table 1: Landmark Books and Textbooks Influencing Food Science Dehydration

| Book Title / Reference Work                               | Publisher & Key Editions                 | Primary Technical Contribution to Food Science                                                                                                    |
|-----------------------------------------------------------|------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>Handbook of Industrial Drying</i>                      | CRC Press (1987, 1996, 2006, 2014)       | The foundational reference mapping all thermal drying fields; established unified classification frameworks for food polymers, dairy, and grains. |
| <i>Drying Technologies in Food Processing</i>             | Wiley-Blackwell (2007)                   | A focused textbook explaining the biochemical impacts of drying on food matrices for industrial practitioners and food engineers.                 |
| <i>Drying Technology in Agriculture and Food Sciences</i> | Science Publishers (2006)                | Explores post-harvest stabilization, moisture isotherms, and quality degradation kinetics in raw agricultural commodities.                        |
| <i>Drying of Foods, Vegetables and Fruits (Vols 1–3)</i>  | Open-Access e-Book Series (2010–Present) | Provides free technical information to developing nations, focusing on affordable solar and convective drying methods.                            |

Table 2: Key Technological Innovations and Food Science Applications

| Technology Frontier            | Key Collaborative Scholars       | Impact on Food Quality and Processing Metrics                                                                                         |
|--------------------------------|----------------------------------|---------------------------------------------------------------------------------------------------------------------------------------|
| Superheated Steam Drying (SSD) | S. Devahastin, P. Suvarnakuta    | Eliminates oxidative reactions; retains volatile flavor compounds and preserves vital nutrients like Vitamin C in vegetable matrices. |
| Advanced Spray Drying          | M. Zhang, B. Bhandari, M.W. Woo  | Addresses particle stickiness using state diagrams; optimizes industrial scale-up and microencapsulation of sensitive bioactives.     |
| Intermittent & Hybrid Drying   | H.W. Xiao, C.L. Law, S.V. Jangam | Integrates convective hot air with pulsed microwave or radio-frequency fields to reduce drying times and energy consumption.          |
| CFD Transport Modeling         | A.P. Sasmito, X.D. Chen          | Simulates droplet evaporation trajectories and moisture-temperature fields to prevent localized overheating and quality loss.         |

## 8. Institutional Recognition, Honors, and Global Awards

Professor Mujumdar’s systematic contributions have been recognized with numerous major international awards, reflecting his global influence across both chemical engineering and food technology sectors. His deep engagement with industrial development in Asia culminated in 2014 when he received the **China Government Friendship Award**—the highest honor bestowed by the People’s Republic of China on foreign experts. In the same year, he was awarded China’s highest accolade for **International Cooperation in Science and Technology** at a ceremony in the Great Hall of the People in Beijing, recognizing his decades-long effort in transforming the nation’s agricultural and food drying infrastructure.

His academic distinctions include the award of **Doctor Honoris Causa** (Honorary Doctorates) from the Technical University of Lodz, Poland (2008) and the University of Lyon 1, France (2011). In 1989, he was elected a Fellow of the American Society of Mechanical Engineers (ASME), and he has received consecutive Leader Awards in Mechanical and Aerospace Engineering from Research.com (2022–2026).

Recognizing his exceptional commitment to the professional growth of others, the global drying community established the **Prof. Arun S. Mujumdar Medal for Excellence in Drying and Outstanding Mentorship**, awarded annually since 2007 to honor researchers who demonstrate excellence in technical innovation and student mentorship.

## 9. Conclusion and Future Outlook

The legacy of Professor Arun S. Mujumdar over the past four decades provides a compelling blueprint for how fundamental engineering principles can be successfully applied to address complex biological challenges in food science and technology. By developing advanced spray drying techniques, pioneering superheated steam drying,

and formulating multi-stage hybrid drying configurations, he has equipped the global food industry with the technical tools required to process foods sustainably, efficiently, and with minimal quality degradation.

His impact extends far beyond his personal research findings. Through the *Handbook of Industrial Drying*, his leadership of the *Drying Technology* journal, the establishment of the International Drying Symposium, and the creation of the global TPR Group network, he has built a robust global infrastructure for continued scientific discovery. As the food engineering community increasingly focuses on the challenges of deep industrial decarbonization, renewable energy integration, and global food security, the rigorous transport frameworks and collaborative networks established by Professor Mujumdar will continue to guide and inspire future generations of food scientists and thermal processing engineers worldwide.

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