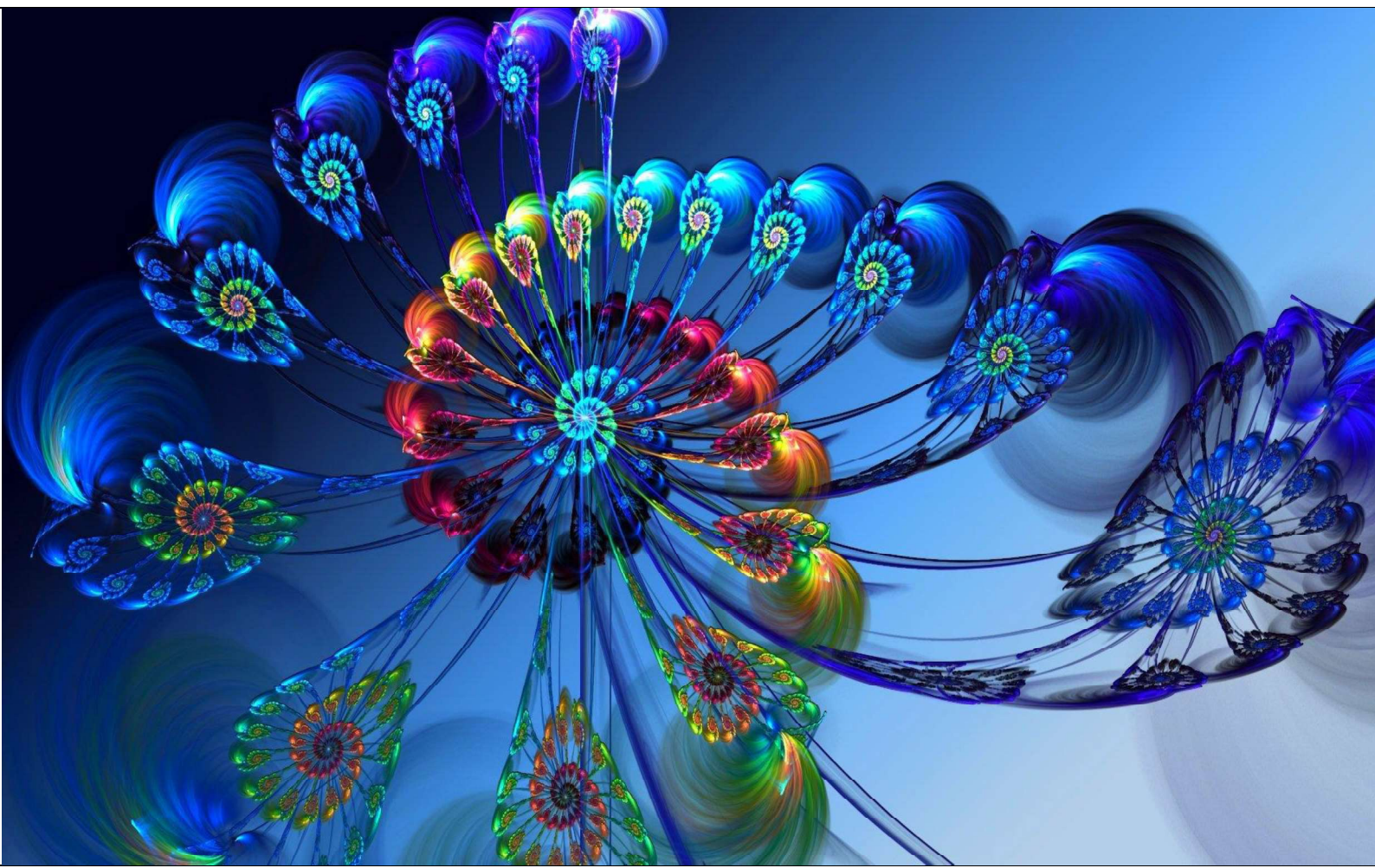


Selected Lectures Delivered at ADC2023

**Arun S. Mujumdar, Hong Wei Xiao,
and Shivanand S. Shirkole**



Preface

This concise e-book is a compilation of three Power Points presentations made by the authors at the 11th Asia Pacific Drying Conference (ADC2023) held in Kolkata on February 18th and 19th, 2023.

These lecture materials are detailed enough to be readable and understood by anyone in academia or interested in the field of drying technology. The only journal devoted to drying and dewatering, Drying Technology, has completed four decades of publication. The first chapters gives a concise summary of the ups and downs when entering a totally new area. The second chapters provide a summary of a highly successful and productive international collaboration lasting over two decades between Professor Min Zhang and Professor Arun Mujumdar. Finally, Professor Hong-Wei Xiao gives a fascinating overview of the role of drying technologies in human welfare.

We hope that this concise e-booklet will encourage readers to enhance research activity in drying science and technology.

Reader feedback is welcome as always.

Shivanand S. Shirkole, PhD

ICT-IOC Odisha Campus, Bhubaneswar, INDIA

[*shivanandshirkole@gmail.com*](mailto:shivanandshirkole@gmail.com)

February, 2023



Chapter – I

Four Decades of Drying Technology Journal Publication: Impact on Global Drying R&D

Plenary Talk





**FOUR DECADES OF DRYING
TECHNOLOGY JOURNAL
PUBLICATION**


...IMPACT ON GLOBAL DRYING R&D

ADC2023

Prof. Arun S. Mujumdar
McGill University, Montreal, Canada
www.arunmujumdar.com

Dr. Shivanand S. Shirkole
Institute of Chemical Technology Mumbai,
ICT-IOC Odisha Campus, Bhubaneswar





OUTLINE OF KEYNOTE LECTURE

- Drying Technology – An International Journal
- Innovative Ideas Devised by Professor Arun S. Mujumdar to Sustain Journal
- Global Journey of Drying Conferences
- A Concise Historical Account of Drying Technology
- 2022 Usage Figures for Drying Technology – An International Journal
- Some Interesting Stats/Facts About Drying
- Why Innovative Ideas are Slow to be Adopted...?
- Closing Remarks

FOUR DECADES OF LDRT PUBLICATION

.....Impact on Global Drying R&D

- This year marks the Ruby Anniversary of the premier archival journal – Drying Technology.
- A statistical snapshot will be presented here on how both the quality and quantity of publications.
- The success of the IDS series had a positive effect on the journal although initially authors preferred to publish their papers in book format.
- From a very modest start with just two small issues published in camera-ready format in 1982-83 to latest volume of 16 issues in large type-set format.
- Finally, some ideas are discussed about the future direction of drying R & D and how this journal can continue to accelerate impactful research with international networking.

PLENARY LECTURE

18/02/2023

3

DRYING TECHNOLOGY

– AN INTERNATIONAL JOURNAL



**225K annual
downloads/views**

Journal Metrics

- 3.556 (2021) Impact Factor
- Q2 Impact Factor Best Quartile
- 3.489 (2021) 5 Year IF
- 6.4 (2021) CiteScore (Scopus)
- Q1 (2021) CiteScore Best Quartile
- 1.324 (2021) SNIP
- 0.654 (2021) SJR

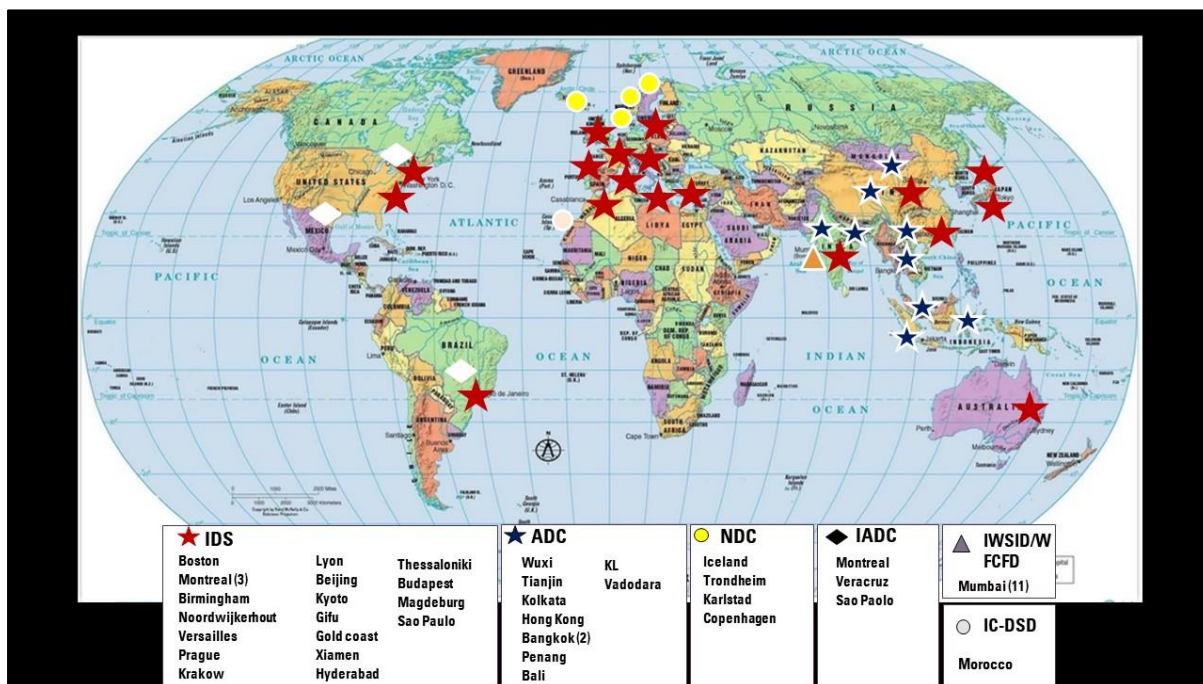
Speed/ Acceptance

- 0 days avg. from submission to first decision
- 48 days avg. from submission to first post-review decision
- 24 days avg. from acceptance to online publication
- 27% acceptance rate

PLENARY LECTURE

18/02/2023

4



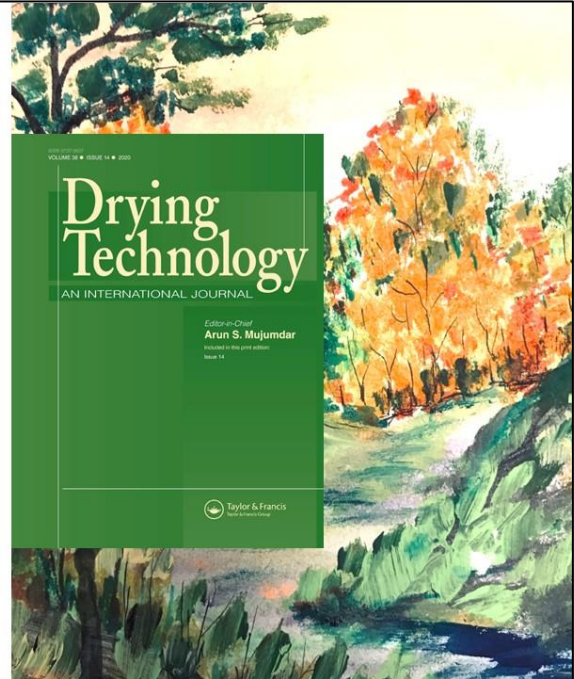
INNOVATIVE IDEAS

..... Devised by Professor Arun S. Mujumdar to Sustain Journal

- Initial shortage of manuscripts was offset by Issuing theme issues with guest editors in different industries
- An issue devoted to R&D needs and opportunities to encourage r and d and submissions to journal
- Revising/ Re-typing them in camera-ready format for authors from non-English speaking countries
- One issue devoted to translation of an acclaimed Japanese book on drying
- Publication of summaries of PhD Theses in drying from various countries
- Publication of book reviews from various countries- mainly Russian books
- Conference/Workshop reports / Snippets on Drying
- Concise biographies of Giants in Drying
- Bibliographies in various drying themes
- Guest Editorials Etc.,

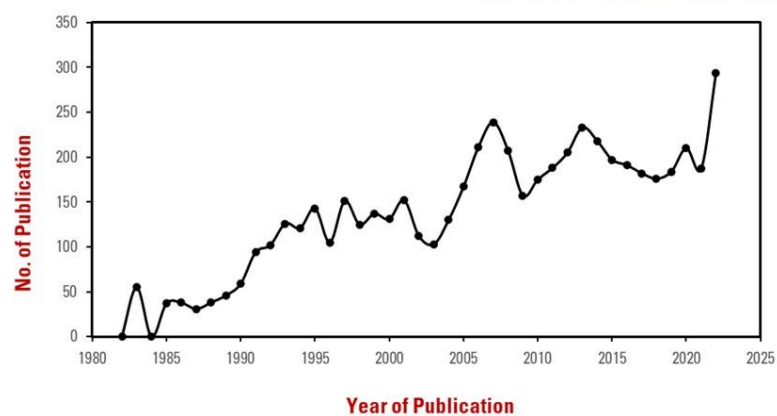
ADC2023

A Concise Historical Account of Drying Technology



A CONCISE HISTORICAL ACCOUNT OF LDRT

..... Year-wise Publications in LDRT



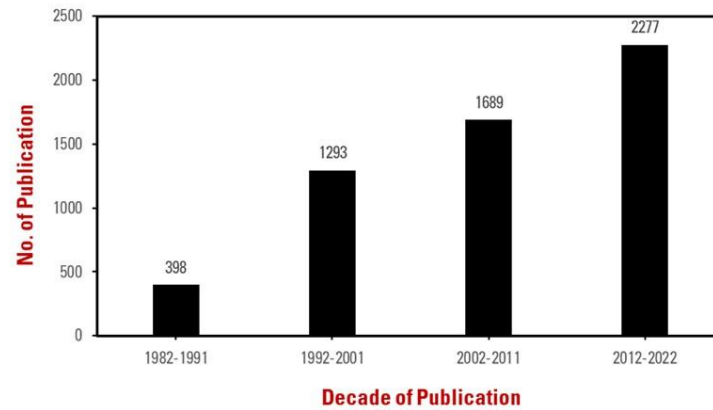
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8

A CONCISE HISTORICAL ACCOUNT OF LDRT

..... Decade-wise Publications in LDRT



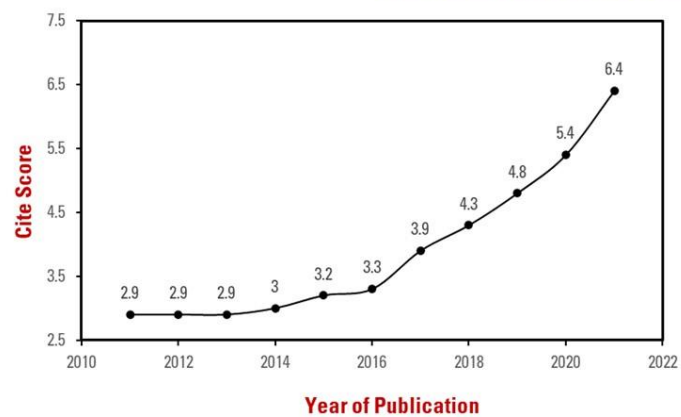
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9

A CONCISE HISTORICAL ACCOUNT OF LDRT

..... Cite Score of LDRT from 2011 to 2021



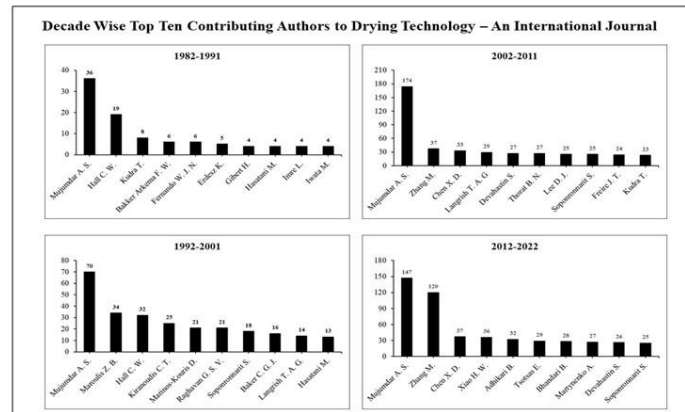
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10

A CONCISE HISTORICAL ACCOUNT OF LDRT

..... Decade-wise Top Ten Contributing Authors to LDRT



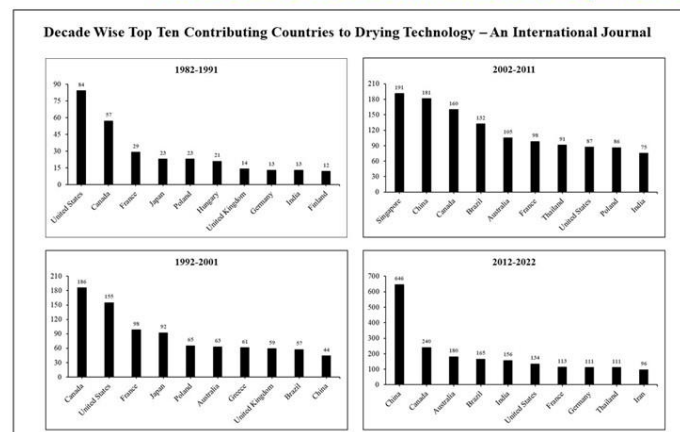
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A CONCISE HISTORICAL ACCOUNT OF LDRT

..... Decade-wise Contribution of Top Ten Countries to LDRT



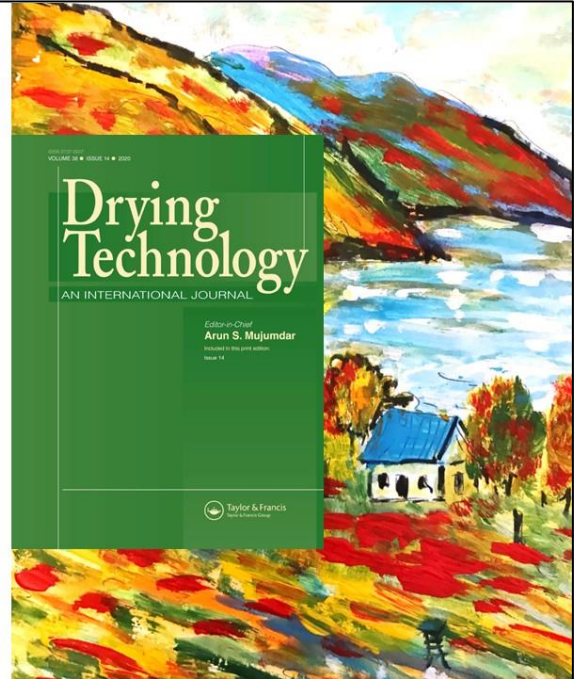
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12

ADC2023

2022 Usage Figures for Drying Technology



2022 USAGE FIGURES FOR DRYING TECHNOLOGY

..... Readership Numbers Compared



Drying Technology achieved 251045 downloads in 2022.

That's +61% compared to 2019's downloads.



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14

2022 USAGE FIGURES FOR DRYING TECHNOLOGY

..... Altmetric Data



40 mentions

In the past 12 months *Drying Technology* was mentioned **40** times on social media, such as Twitter, Facebook, and LinkedIn.



3 mentions

In the past 12 months *Drying Technology* was mentioned **3** times on news outlets and blogs.

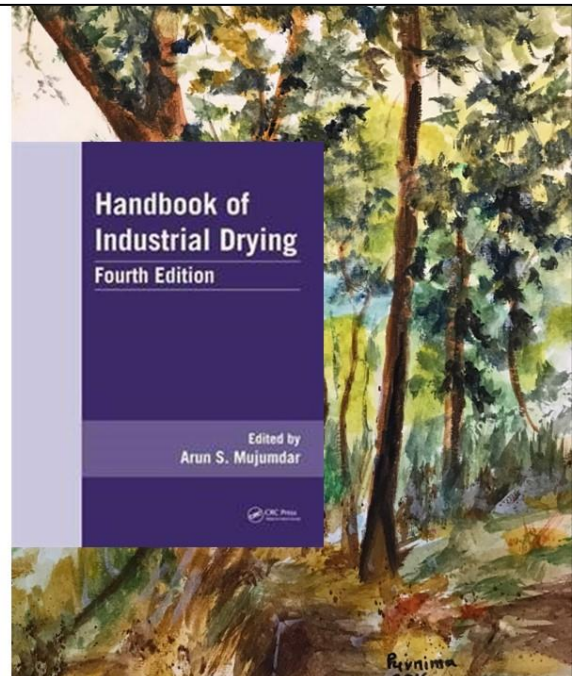
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15

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Interesting Stats/Facts About Drying



INTERESTING STATS/FACTS ABOUT DRYING

- Over 10,000 materials are dried at different scales to diverse specifications starting from liquid, suspension, sludge, particulate to large discrete sheets to continuous sheets hence the need for 100 dryer types.
- Operating ranges- supercritical to sub-zero temperature/pressure.
- Mechanism of heat input include conduction, convection, and radiation, continuous, hybrid, simultaneous or sequential.
- Continuous or batch modes of operation.

From above it is easy to see why a wide assortment of diverse dryers are needed.

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17

SELECTION OF RIGHT DRYER/DRYING SYSTEM

- Selection of right dryer/drying system is the most baffling problem in industry



Important Note

- **Novel dryers are not necessarily better.**
- New ideas need to be tested and validated.
- LCA is recommended when choosing a new dryer.

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18

INNOVATION

"Innovation is seeing what everybody has seen and thinking what nobody has thought."



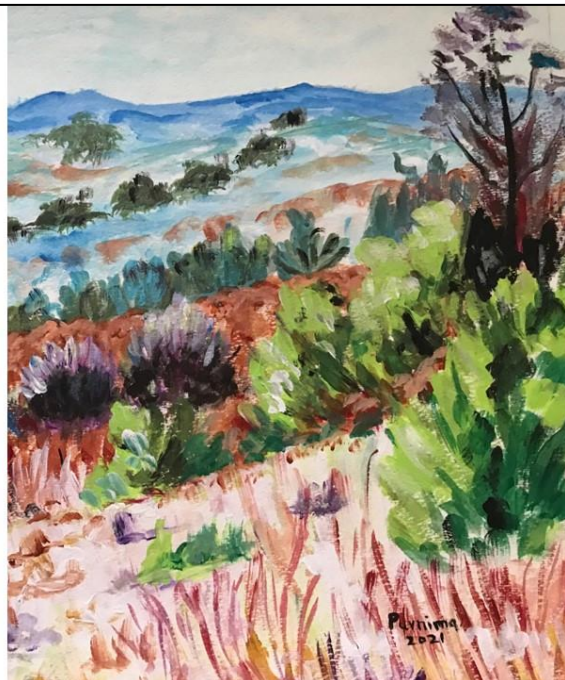
PLENARY LECTURE

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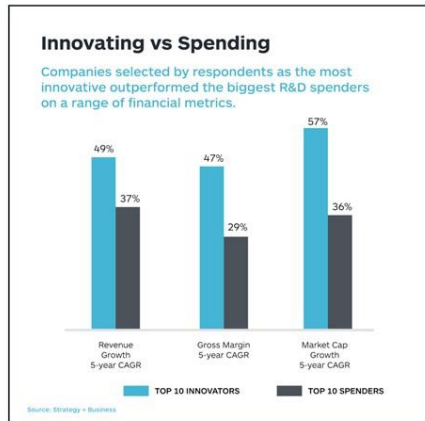
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**Innovation Versus R&D
Spending**



INNOVATION VERSUS R&D SPENDING



Innovation Ecosystems

	Innovation Ranking	R&D Expenditure as a % of Revenue
Apple	1	5%
amazon	2	13%
Alphabet	3	15%
Microsoft	4	14%
Google	5	12%
SAMSUNG	6	7%
Facebook	7	10%
GE	8	4%
Intel	9	21%
IBM	10	9%
Toyota	>10	4%
Oracle	>10	5%
Volkswagen	>10	6%
NOKIA	>10	21%
MERCK	>10	25%

Source: Strategy + Business

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21

TYPES OF INNOVATION

Incremental / Evolutionary

- Low cost of implementation
- Less risk
- More likely to be adopted

Examples:

- Superheated steam dryers
- Modified fluidized/spouted beds
- Hybrid dryers
- Adsorption dryer for grains (particulate drying)

Radical / Revolutionary

- High R&D cost
- Risky, although room for successful technologies is high

Examples:

- Pulse combustions dryers; Flame dryers
- Impinging jet superheated steam dryer for tissue/newsprint
- Microwave + Ultrasonic dryers, Swell drying (DIC)

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22

WHY INNOVATIVE DRYERS HAVE HIGHER RISK?

- Lack of reliable knowledge on the mechanisms of heat/mass transfer in drying
- Lack of “universal” model for drying or dryers
- High research & development costs - nonlinearity of scale-up of heat/mass transfer and quality attributes in scale-up from lab to pilot to full scale
- Optimal dryer design and selection of operating conditions offer major challenges etc etc.

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23

WHY ADOPTION RATES ARE LOW...

..... from Published Works to Industry...?

- Over 500 dryer types are reported in literature: most are based on lab scale reports from academia
- Pilot and full-scale reports are typically proprietary and not in public domain
- Research papers do not often provide enough information to allow scale-up by potential users.
- Often quality attributes cannot be scaled up reliably resulting in expensive testing and uncertainty
- Techno economics of the novel dryer concepts is largely unknown.
- Lack of close interaction between academia and industry is needed for introduction of innovations in practice

Results: close interaction between academia and industry is a pre-requisite for introduction of innovations.

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24

MOTIVATING FACTORS FOR INNOVATION

- New product or process
- Higher capacities than current technology permits
- Better quality than currently feasible
- Reduced overall cost
- Reduced environmental impact, sustainable
- Safer operation; more flexibility
- Better efficiency

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25

ON INNOVATION IN DRYING TECH

..... Why Slow...?

- Most innovative ideas in public domain come from academia; techno economic analysis conspicuous by absence
- Half-life /operating life of most dryer systems are long, discouraging need for replacement with better/innovative dryers.
- Developing economies are more likely to leapfrog to new Technology then established ones e g vacuum steam drying of timber.
- Buzz word research areas tend to attract major fraction of funding available; much less available for R&D in drying. Industrial funding has not taken up the slack for various reasons.

Solution: Make R&D cost-effective by sharing knowledge, ideas, resources globally and enhance industry-academia interaction.

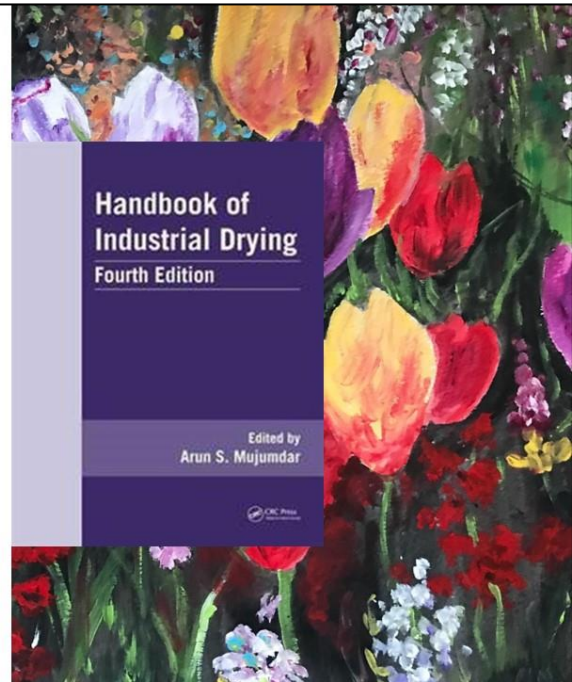
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26

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FUTURE R&D NEEDS



FUTURE R&D NEEDS

1. Applied vs Basic (fundamental, non targeted)

- Only 5 per cent of all. Engineering Research in 15 European countries is labelled Applied in a recent study. This is also true of IDS, LDT
- However, some Science oriented journals to look at some basic issues in Drying but at microscale. Difficult to use for design/optimization etc.
- Major problems : Drying materials are too complex; parameters are dynamic and hard to measure accurately, computationally very challenging etc.
- Funding for blue sky Research - like drying materials is shrinking everywhere !

FUTURE R&D NEEDS

2. Need to study microstructure and relate it through multi-scale modelling to drying kinetics, quality parameters etc.
 - Need to study microstructure and relate it through multi-scale modelling to drying kinetics, quality parameters etc.
3. Innovative dryers - miniaturized, smart , optimized with low carbon footprint etc.
 - Expensive computationally and experimentally. Needs advanced instrumentation like NMR, AFM, SCM, TEM, XRD, X-ray tomography, etc etc. Even such measurements do not often suffice to provide validation of models.

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29

FUTURE R&D NEEDS

- Basic research including multiscale modeling, molecular dynamic simulation along with advanced CFD modelling and computation of stress/strain development in drying solids.
- Innovative dryers that are significantly smaller with low physical and carbon footprint capable of coupling renewable energy with fossil fuels as needed.
- Use AI to design smart dryers for high quality products. Are these needed?
- Re-evaluate current drying technologies in paper, wood, ceramics industries which have not shown trend to innovate in recent decades.

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30

HOW TO ENHANCE BASIC RESEARCH IN DRYING?

- Currently most drying research is multi and interdisciplinary between applied sciences engineering. New paradigm requires cooperation with pure sciences (chemistry, biochemistry, physics and mathematics).
- Publish in applied and pure science journals - already happening in limited areas such as colloids/suspensions/nanotechnology areas. Drying problems need to be made known to Science communities.
- Large industrial communities can offer grants to study science of drying to pursue so-called Blue-Sky Research. Long term research is currently missing.
- Lack of truly novel ideas will hamper future innovation.

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31

ROLE OF INDUSTRY-ACADEMIA COLLABORATION

1. Tangible support and collaboration by industry- users of dryers and vendors- is key to innovative drying technology in practice.
2. Both incremental and radical innovations that disrupt current practice are possible only through such collaboration.
3. Minimization of R&D costs requires sharing human and capital resources via institutional cooperation and international networking.
4. Design innovation via reliable math modeling is cost-effective but much research is needed to improve design and scale up of new dryers.
5. Reduction of carbon footprint while enhancing dried product quality is the goal of innovation.

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32

WHY INNOVATIVE IDEAS ARE....

..... **Slow to be Adopted...**?

- Generally key incremental/ evolutionary ideas are adopted more readily-less risk but small advantage.
- Radical/revolutionary ideas are risky, need scale up and pilot testing which are expensive steps.
- Gestation time from first report to adoption can take 20-50 years.
- Small companies can not afford R&D needed.
- Users have no appetite for risk despite potential big benefits.
- Drying is highly nonlinear process so scale up is difficult, risky and expensive

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33

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Closing Remarks



CLOSING REMARKS

- Much has been achieved directly and indirectly on a global scale in 4 decades - inter and multidisciplinary theme of Drying Science and Technology has advanced significantly despite major barriers.
- A key accomplishment has been to bring awareness of the importance of the subject to industry and academia in most sectors.
- International networking and active collaboration has resulted in a high degree of innovation and generation of new ideas.
- Future R&D should be driven by basic sciences working with applied sciences and engineering with proactive industry participation

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35

CLOSING REMARKS

- Advances in analytical, visualization and computational tools should be applied to advance basic knowledge of drying. This can also lead to cost effective innovation.
- Design and scale-up of drying systems should increasingly be based on basic knowledge and less on knowhow.
- Competing of research funds and human talent to this field will remain a challenge requiring multiple innovative solutions which may vary with country.
- Industry participation is essential to effective technology transfer leading to more efficient and cost effective industrial drying systems.

PLENARY LECTURE

18/02/2023

36

ACKNOWLEDGEMENTS

Authors gratefully acknowledge assistance of Dr. Sachin V. Jangam, NUS, in preparation of this PowerPoint presentation.

Members of the Transport Processes Research Group and the editorial team of *Drying Technology Journal* have provided valuable service leading to the success of the journal as well as the global drying R&D community in academia and in industry.

Special thanks are extended to Prof. Parag Sutar and to Mr. Nishant Garg for their extraordinary effort in ensuring success of ADC2023.



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18/02/2023

37



THANK YOU

Arun S Mujumdar | arunmujumdar123@gmail.com | www.arunmujumdar.com


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46


Chapter – II

Brief Look at Success Story at International Networking and Collaboration – A Case Study




A Brief Look at Success Story at International Networking and Collaboration – A Case Study






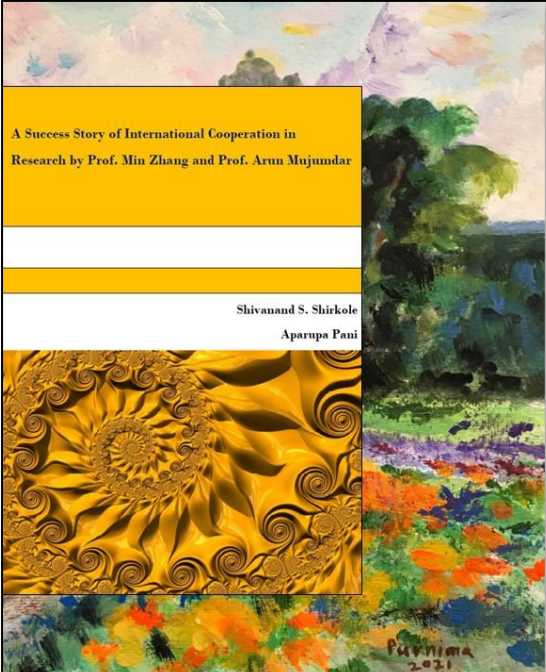
Professor Min Zhang
Jiangnan University, Wuxi, China



11th ASIA PACIFIC DRYING
CONFERENCE 2023 INDIA
---INNOVATIONS, HIGH VALUE PRODUCTS, SUSTAINABILITY---



Professor Arun S. Mujumdar
McGill University, Canada



Concise History

2002: Prof Min Zhang, JU, invited Prof Mujumdar to JU

2002-2022 : Numerous visits to JU and some other universities by ASM

Now the network has grown to include faculty from Australia, Thailand, Malaysia, and Canada...

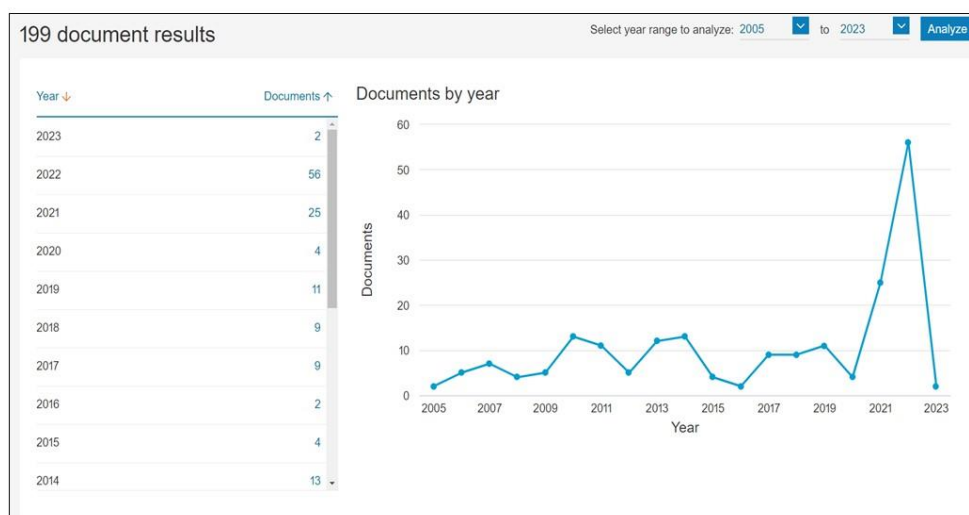


Success Story at International Networking and Collaboration

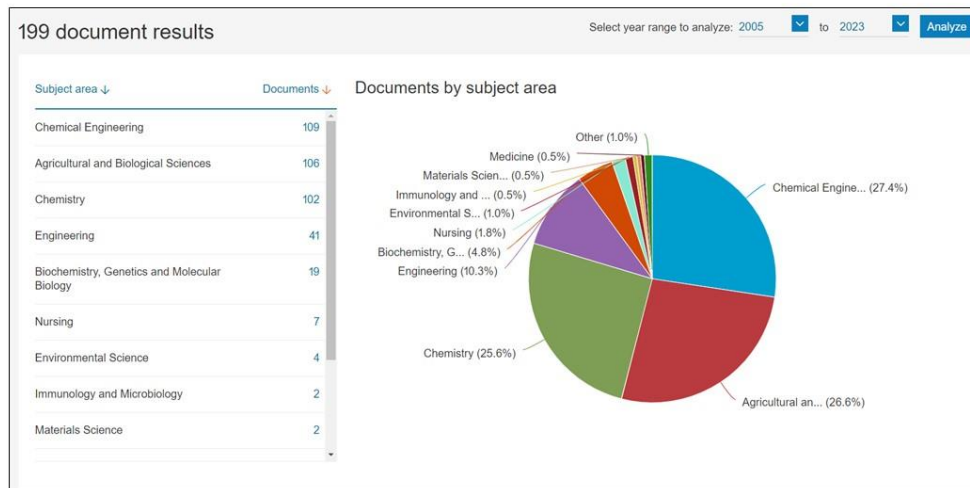
Publications Statistics

Documents by Year:

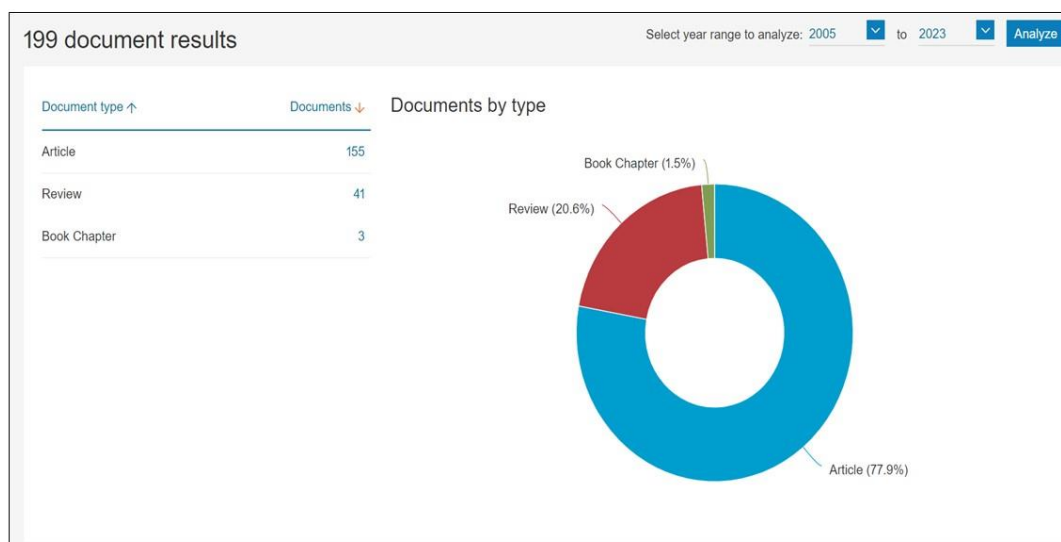
Source: Scopus Database Accessed on December 15, 2022



Documents by Subject Area:



Documents by Type:



Outcomes

Over 200 journal papers

One award winning book in Chinese

One CRC series book by Prof Zhang and ASM

Numerous book chapters

An ADC conference in Wuxi

Numerous industry visits

Support by PepsiCo R&D, USA, for 3 years

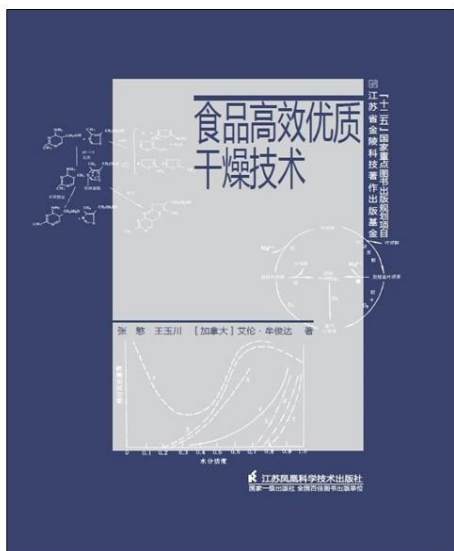
Reviewed numerous area of industry interest

Led to two National awards as well as provincial awards to ASM

Prof Zhang is now top author of Drying Technology journal;

Conferred Prof Mujumdar Medal for outstanding research

Numerous awards



Book

**Book in Chinese via-authored by
Professor Min Zhang and Professor
Arun S. Mujumdar Entitled High-
Efficiency Hybrid Dryers.**

**Won a National Award in China in
2019**



牟俊达 教授首次在无锡轻工大学（现江南大学）讲学（2002 年初）
7-1 The first time Prof. Mujumdar took the lecture in college of Wuxi light industry (Jiangnan University) (The Beginning of 2002)

Some exchange records of both sides during the international collaboration

The first time Prof. Mujumdar took the lecture in college of Wuxi light industry (Jiangnan University) the beginning of 2002

Some exchange records of both sides during the international collaboration





Some exchange records of both sides during the international collaboration

Some exchange records of both sides during the international collaboration



Prof. Mujumdar conducted technical exchanges in the cooperative enterprises of Yechun Food Co., Shanghai Nestle R & D Center and Zhejiang Xingcai Food Co.



Some exchange records of both sides during the international collaboration



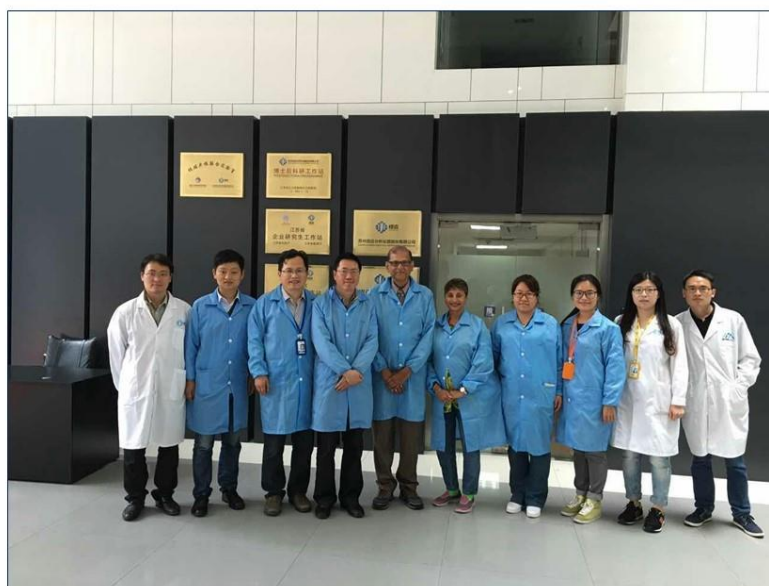
Some exchange records of both sides during the international collaboration

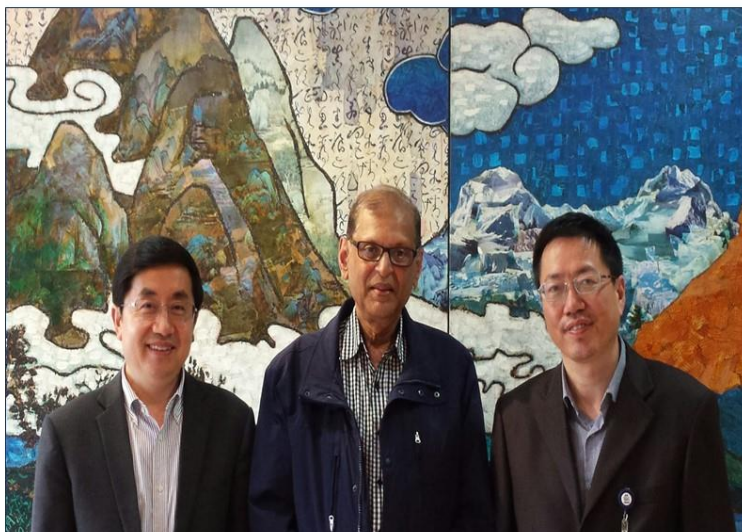


Some exchange records of both sides during the international collaboration

Prof. Min Zhang's group and Prof. Mujumdar organized the 9th ADC, 2017, Wuxi, China

Some exchange records of both sides during the international collaboration





Some exchange records of both sides during the international collaboration



Some exchange records of both sides during the international collaboration

(一) 合作期间牟俊达教授荣获国家及省级国际合作奖项及相关报道

Prof Mujumdar won national and provincial international cooperation awards and related reports during the collaboration



Arun S Mujumdar 教授荣获中华人民共和国国际科技合作奖 (2013) 及中国政府友谊奖 (2014)
Professor Arun S Mujumdar won the international science and Technology Cooperation Award of the people's Republic of China (2013) and the Friendship Award of the Chinese government (2014)

Some exchange records of both sides during the international collaboration

Prof. Mujumdar won national and provincial international cooperation awards and related reports during the collaboration

Some exchange records of both sides during the international collaboration





牟俊达教授荣获江苏省国际科技合作奖的获奖介绍及获奖证书（2012年度）
The introduction and certificate of Jiangsu Province International Science and Technology Cooperation Award (2012 Year)

The introduction and certificate of Jiangsu Province International Science and Technology Cooperation Award (2012 Year)

Some exchange records of both sides during the international collaboration



Some exchange records of both sides during the international collaboration

Some exchange records of both sides during the international collaboration



《Drying Technology》39 卷第 9 期“江南大学干燥研发”特刊封面及报道
Cover and report of the special issue “drying research and development of Jiangnan University”, Volume 39, No. 9, 《Drying Technology》

Cover and report of the special issue “drying research and development of Jiangnan University”, Volume 39, No. 9 (LDRT)



Some exchange records of both sides during the international collaboration

Group photo of representations at the kick-off meeting of national key R&D project led by Professor Min Zhang

Some exchange records of both sides during the international collaboration



张愍教授团队的果蔬食品干燥项目荣获国家科技进步二等奖（2012 年度）
The project of fruits & vegetables drying led by Prof Min Zhang awarded the China National Award for Scientific and Technological Progress (2012 Year)

Prof. Min Zhang's food drying group awarded the national award and DRT top ten contributor award and report of the 13th five year national key R&D plan project on the fruit and vegetable drying the collaboration



张愍教授牵头的国家重点研发计划项目中期检查会代表合影
Group photo of representatives at the mid-term inspection meeting of national key R & D plan projects led by Professor Min Zhang

Some exchange records of both sides during the international collaboration

Group photo of representatives at the mid term inspection meeting of national key R&D plan projects led by Prof. Min Zhang

Some exchange records of both sides during the international collaboration



Advantages of Networking

- Over 20 co-advised PhDs
- **Very valuable for cost-effective research by sharing laboratory facilities**
- Human resources enhanced for creativity, innovation, and shared knowledge
- **Globalization of outcomes to benefit whoever wants to access the results**
- IDS2024 to be held in Wuxi, China in October 2024
- **China now provides highest number of papers to IDS, LDRT**
- China now has the largest dryer manufacturers exporting to over 140 countries!
- **Also, most number of active drying researchers in most number of universities**

Closing Remarks



Closing Remarks

International cooperation can be a powerful process for cost-effective and innovative research

Entire drying community benefits from the resulted a peer reviewed publications

Effective industry support and collaboration can lead to major economic benefits

Highly recommended to researchers at all levels!

-- Prof. Arun Mujumdar / Prof. Min Zhang



Thank You

Arun S. Mujumdar | arunmujumdar123@gmail.com | www.arunmujumdar.com

Chapter – III

Importance of Drying in Support of Human Welfare



中國農業大學
China Agricultural University

11th ASIA PACIFIC DRYING
CONFERENCE 2023

Importance of drying in support of human welfare

Prof. Hong-Wei Xiao

China Agricultural University

Associate Editor of Drying Technology

E-mail: xhwcaugxy@163.com

February 18, 2023

Worst of times VS Best of times!

It was the worst of times, it was the best of times!
It was the season of darkness, it was the season of light!
It was the winter of despair, it was the spring of hope!
We had nothing before us, we had everything before us!

-From Charles Dickens' "A Tale of Two Cities" with some modification

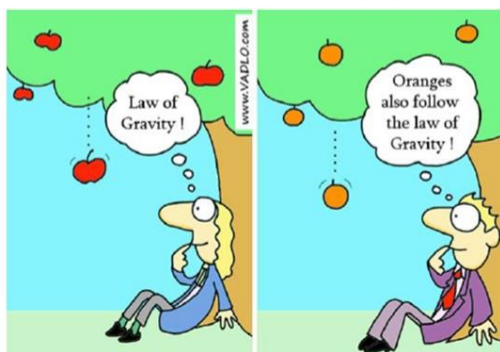
Is it true for drying research?

Innovation and funding applications in the drying field are becoming more and more difficult

- ❑ Almost all drying related technical systems have been established! For what we can do is making some cosmetic changes! What's you can think has already been done by others.
 - Freeze dryer was invented over 100 year ago, and there are more than 11 400 papers
 - Spray dryer was invented 100 years ago and now there are more than 8 800 papers about spray drying.
 - Microwave dryer was invented over 70 years ago and there are over 3 400 papers about microwave drying!
 - Infrared dryer was invented over 80 years ago and there are 1599 papers about infrared drying.
 - ❑ Innovations in the drying field are becoming more and more difficult.
- We are using more and more indicators and more and more advanced characterization techniques to express a conclusion that has been consistently proven for decades that one drying technique is superior to other drying methods. It is rare to see the birth of new ideas.
- ❑ Research funding in the field of drying are becoming more and more difficult to apply, and many scholars turn to other research fields, especially in the United States.

Editor's confusion

Most of the published papers are "Me too" imitation papers or "sandwich papers"!

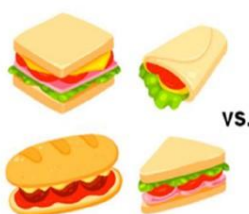


High Impact Paper

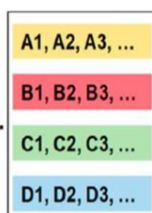
Low Impact Paper

Original and imitative research!

meToo



vs.



ACS
Energy
LETTERS

<http://pubs.acs.org/journal/energ>

Fewer Sandwich Papers, Please

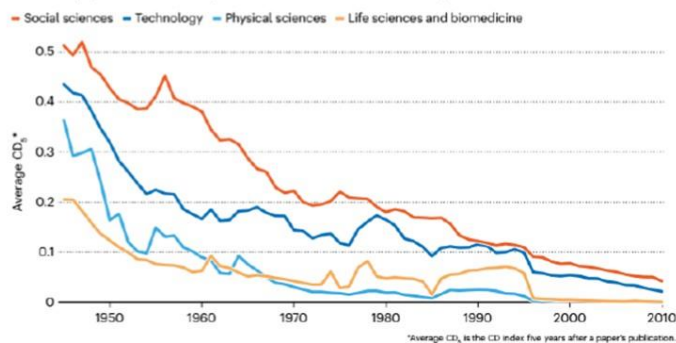
Cite This: ACS Energy Lett. 2022, 7, 3727–3728

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DISRUPTIVE SCIENCE DWINDLES

To quantify how much a paper shakes up a field, researchers used a metric called a CD index, which ranges from 1 for the most disruptive papers to -1 for the least disruptive. Analysis of millions of papers shows that disruptiveness has fallen over time in all analysed fields.



**‘Disruptive’ science has declined –
and no one knows why**

For detail information you can read: *Nature* 2023, **613**:225; *Nature* 2023, **614**: 7-8

Let's rethink the importance of drying to human well-being

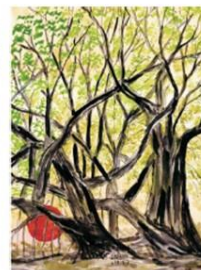
Section I: Drying and the origin of life

Section II: Drying and food security

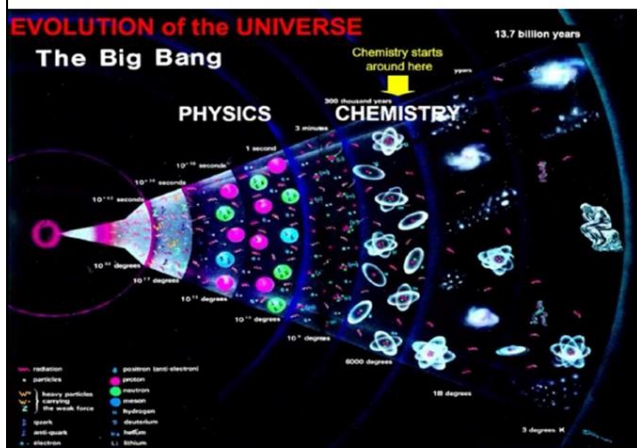
Section III: Drying and human health

Section IV: Drying and Climate change

Section I: Drying and the origin of life

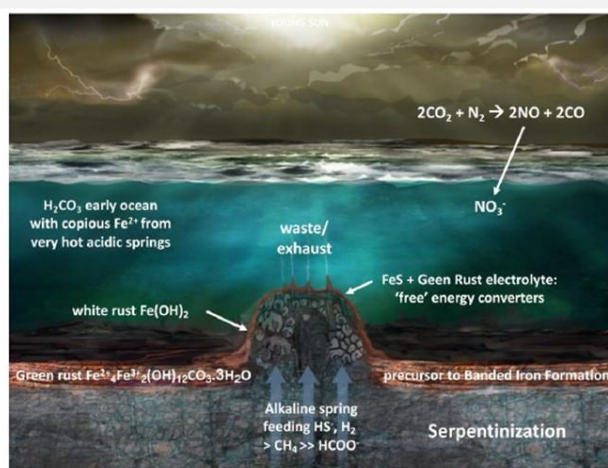
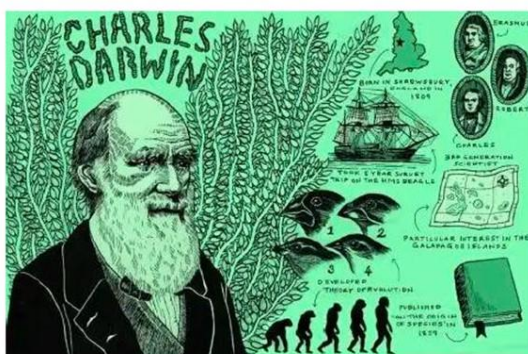


Drying and the origin of life



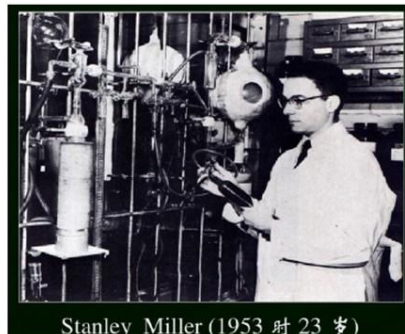
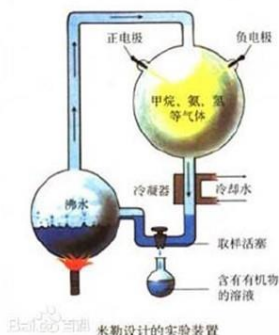
How and where did life originate? Continues to be one of the most fundamental questions for humanity to date. Before the birth of modern science, creationism occupied an important position.

Drying and the origin of life



Since the birth of modern science, various hypotheses about the origin of life have emerged one after another, among which the most influential hypothesis is that life originated from the sea.

Miller experiment



Stanley Miller (1953 时 23 岁)

TECHNICAL PAPER

A Production of Amino Acids Under Possible Primitive Earth Conditions

BY STANLEY L. MILLER • SCIENCE • VOL. 117, NO. 3046 • 15 MAY 1953: 528-529

REPORT

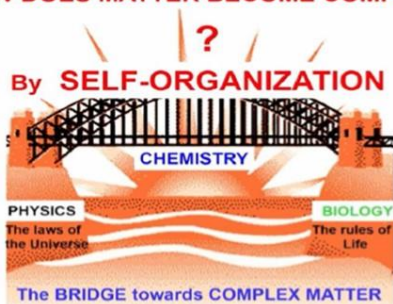
Phenylalanine and Tyrosine Synthesis under Primitive Earth Conditions

BY NADAV FRIEDMANN, STANLEY L. MILLER • SCIENCE • VOL. 166, NO. 3906 • 07 NOV 1969: 766-767

In 1953, a master student named Miller in the University of Chicago found that amino acids can be generated from inorganic substances under possible primitive earth conditions..

Drying is an essential step for the origin of life

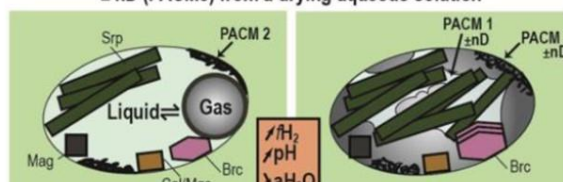
HOW DOES MATTER BECOME COMPLEX



Jean-Marie Lehn, 2022

Recent study indicate drying and concentration is the key step for the synthesizing living matter from inorganic substances in primitive Earth environment.

Fluid-olivine interaction:
carbonatation, serpentinization & development of PACM1&2
± nD (PACM3) from a drying aqueous solution



nature communications

Article

<https://doi.org/10.1038/s41467-022-36038-6>

The rocky road to organics needs drying

Received: 20 October 2021

Accepted: 13 January 2023

Published online: 21 January 2023

Muriel Andreani^{1,2}, Gilles Montagnac¹, Clémentine Fellah¹, Jihua Hao^{3,4,5},
Florence Vandier¹, Isabelle Daniel¹, Céline Pisapia⁶, Jules Galipaud^{7,8},
Marvin D. Lilley⁹, Gretchen L. Früh Green¹⁰, Stéphane Borenztein⁶ &
Bénédicte Ménez⁶

Cosmic embryo provenance hypothesis



Sir Svante August Arrhenius
(1859-1927)

$$D_{eff} = D_0 \exp \left[-\frac{E_a}{R(T + 273.15)} \right]$$

REPORT

Aromatic Hydrocarbons in the Murchison Meteorite

BY KATHERINE L. PERING, CYRIL PONNAMPERUMA • SCIENCE • VOL. 173, NO. 3993 • 16 JUL 1971 • 237-239

REPORT

Phenolic Ethers in the Organic Polymer of the Murchison Meteorite

BY RYUICHI HAYATANI, RANDALL E. WYMAN, ROBERT G. SCOTT, ROBERT L. MCBETH, LEON P. MOORE, MARTIN H. STUDER • SCIENCE • VOL. 207, NO. 4426



Murchison meteorite

More than 100 amino acids, along with purines and pyrimidines, have been found in the meteorites, and analysis of indicated they were formed before they reached Earth.

Drying is not only the key to the origin of life, but also an important protective mechanism for living things



The life of dried lotus seeds can last for thousands of years



Water bear worms develop a unique ability to withstand harsh environments by dehydration themselves of 95% of their body water.

-272 °C - +151°C

Even the most delicate sperm can be preserved by drying for a long time

References

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- 2 Smith, A.U. and Polge, C. 1950. Survival of spermatozoa at low temperatures. *Nature* **166**: 668–669.
- 3 Polge, C. and Rowson, L.E.A. 1952. Fertilizing capacity of bull spermatozoa after freezing at -79°C . *Nature* **169**: 626–627.

Result shows that DNA integrity was not affected by the freeze-drying procedure. –Nature Reviews Urology 2012



Mouse pups born from sperm stored on the International Space Station for 9 months. Wakayama et al., *Proceedings of the National Academy of Sciences* 114, 21 (23 May 2017)

Research
09 Dec 1961
Nature
Volume: 192, P: 995–996

Freeze-drying of Bovine Spermatozoa

R. G. SAAKKE & J. O. ALMQUIST

Research
01 Jul 1998
Nature Biotechnology
Volume: 16, P: 639–641

Development of normal mice from oocytes injected with freeze-dried spermatozoa

Teruhiko Wakayama & Ryuzo Yanagimachi

Sperm drying was a hot topic in Nature.

United States Patent

Liu et al.

[19]

[11]

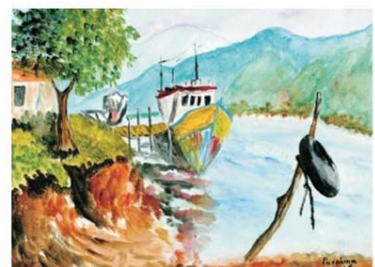
[6]

Patent Number: 6,071,745

Date of Patent: Jun. 6, 2000

- US000071745A
- [54] METHOD AND FORMULATION FOR LYOPHILIZING CULTURED HUMAN CELLS TO PRESERVE RNA AND DNA CONTAINED IN CELLS FOR USE IN MOLECULAR BIOLOGY EXPERIMENTS
- [75] Inventors: Ching-I Peter Lin, Hercules, Robert Bruce Wallace, Germantown, both of Calif., Jeffrey Comman, Potomac, Md., Cynthia French, Irvine, Calif.
- [73] Assignee: Bio-Rad Laboratories, Hercules, Calif.
- [21] Appl. No.: 08/84,829
- [22] Filed: Jun. 27, 1997
- [51] Int. Cl.⁷: C12N 002/10; C12N 5/06
- [52] U.S. Cl.: 435/374; 435/375; 435/376
- [56] Field of Search: 435/374, 375, 376
- OTHER PUBLICATIONS
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- Chomczynski, P. (1993) "A Reagent for the Single-Step Simultaneous Isolation of RNA, DNA and Proteins from Cell Tissue Samples", *BioTechniques* 15(3): 535–537.
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- Jennings, Thomas, A. (1997) "Effect of Isolation on Topicalization, part 2", *IVF Technology* 9(2): 43–45.
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Section II: Drying and food security





飯食反

**Food security is the cornerstone of national stability and security.
Without food, there must be rebellion!**

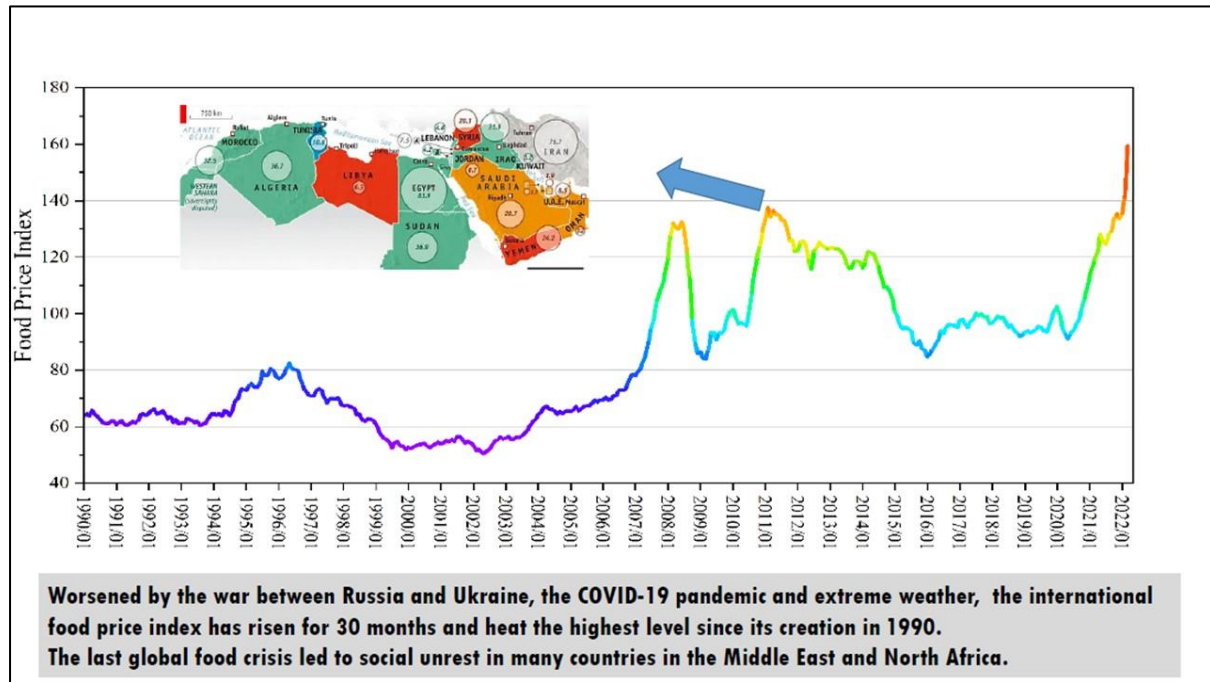
17

Food Prices and Political Instability

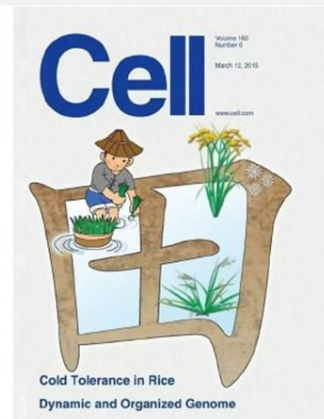
It was found that in low income countries increases in the international food prices lead to a significant deterioration of democratic institutions and a significant increase in the incidence of anti-government demonstrations, riots, and civil conflict.

-International Monetary Fund Report based on over 120 countries during the period 1970-2007





Feeding the world is a ground challenge



- (1) The global population will rise from 8 billion currently to 10 billion before 2100 (Science 2014, 346: 234-237)
- (2) With the increase of urbanization and income, the food diet structure will be transformed from plant based food to animal based food, which needs more resource (Nature 2014, 515: 501-502).
- (3) Food production is also affected by extreme weather, water shortages, pests and diseases, soil degradation etc.

Drying is an important way to reduce postharvest loss



(1) Due to their high moisture content, strong respiratory metabolism, perishable texture, postharvest fruits and vegetables spoil easily. The average postharvest loss rate is 28-36% (Environmental Science and Technology 2016, 50: 8432-8443).

(2) Drying is an important way to reduce postharvest loss

- prevent the growth and reproduction of microbial proliferation;
- mitigate moisture-mediated deteriorative biochemical reactions;
- reduce the costs of packaging, transportation, storage and processing

Therefore, suitable drying technology and equipment is of great significance for ensuring world food security!

21

Section III: Drying and human health



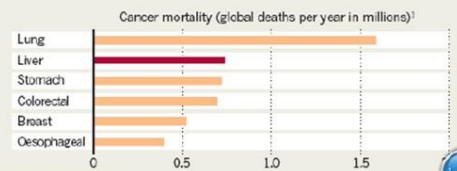
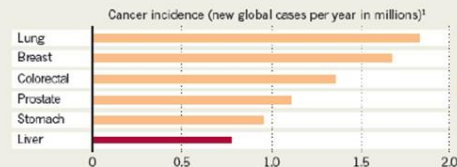
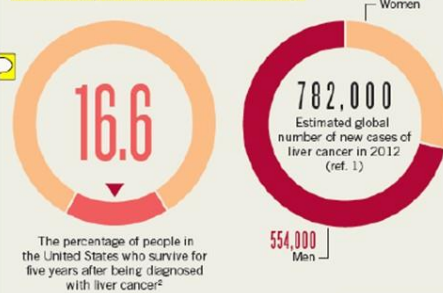
Drying and human health

A PREVENTABLE CANCER

Liver cancer is difficult to treat, and lethal if not caught early. But its most common causes, such as hepatitis viruses and obesity, can be prevented. By Lucas Laursen.

OUT OF PROPORTION

Not only does liver cancer strike more men than women, it also causes a disproportionate number of cancer-related deaths. Although it is the sixth most common malignancy worldwide, it is second only to lung cancer in terms of mortality¹.

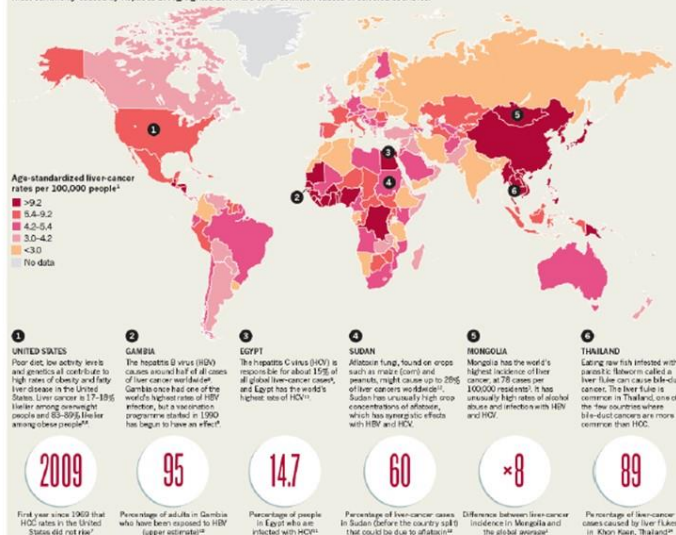


Nature 2014, 516: S2-S3.

Globally, 28 percent of liver cancer is caused by insufficiently dried and moldy food, and the figure is as high as 60 percent in Sudan !

RISK ASSESSMENT

Liver-cancer rates vary widely between countries, with the highest rates occurring in Africa and east Asia. The disease is nearly always preceded by chronic liver damage, most commonly caused by hepatitis B. Highlighted below are other common causes in selected countries.



Nature 2014, 516: S2-S3.

Excessive levels of mycotoxins in agricultural products are a common problem in many developing countries, where mechanical drying is inadequate.



Dried foods that have been reported to be contaminated with aflatoxins

Category	Food sample
Cereals, grains, and related products	Rice ^[76]
	Maize ^[77-79]
	Soybean meals ^[76]
	Breakfast cereals ^[80,81]
Dried fruits and vegetables	Apricot ^[82]
	Date ^[83]
	Fig ^[84-86]
	Quince ^[87]
	Raisin ^[88]
Nuts	Almond ^[89]
	Brazil nut ^[90]
	Peanut ^[91-94]
	Pistachio ^[95-98]
	Hazelnut ^[93,89]
	Walnut ^[88,89,99]
	Cashew nut ^[82]
	Chili powder ^[30,100-102]
Herbs and spices	Dried chili (pod) ^[101]
	Black pepper ^[77,100]
	Cumin powder ^[103]
	Paprika ^[100,104,105]
	Ginseng roots ^[106]
	Ginger powder ^[103]

Drying Technology 2015, 33: 1700-1707

The International Association for Research on Cancer classifies aflatoxin as a Class 1 carcinogen

The famous journal Nature reported the discovery of aflatoxin and its carcinogenicity were reported for three continued years from 1961 to 1963!

on heat-sterilized, non-toxic groundnuts. After 7 days at room temperature extracts prepared from the visibly mouldy nuts were shown to contain the blue-fluorescent material and to be lethal to day-old ducklings, producing the typical liver lesions.

The toxin-producing fungus has now been identified as *Aspergillus flavus* Link ex Fries.

NO. 4846 September 15, 1962 NATURE

Biological tests on day-old ducklings indicate an LD_{50} of about 60 μ g for this material. Note a cation w
Work is in progress on the further characterization of the compounds described and on the elucidation of their structures. a mixtu

Toxicity and Fluorescence Properties of the Aflatoxins

The isolation, characterization and some of the properties of four closely related components of aflatoxin, the mixture of toxic metabolites produced by certain strains of *Aspergillus flavus*, have been described previously¹. These

Assessment scores and grades of common carcinogens

常見致癌物質的評估分數及其致癌等級

致癌物名稱	分數	級數
黃麴毒素(aflatoxin)	100	I
二甲基亞硝胺(dimethyl nitrosamine)	95	I
氯乙烯(vinyl choline)	90	I
2,3-二溴丙基磷酸酯[tris(2,3-dibromopropyl-phosphate)]	90	I
2-萘胺(2-naphthylamine)	81	II
溴化鉀(KBrO ₃)		II
氯仿(chloroform)	65	III
2-硝基苯胺(2-nitroaniline)	51	IV
丁基羥基苯(BHA)		IV
氯丹(chlordane)	40	V
糖精(saccharin)	36	V
滴滴涕(DDT)	31	V

IARC: International Agency for Research on Cancer

20

In 1991, two Nature papers revealed the mechanism of aflatoxins causing liver cancer

Mutational hot spot in the p53 gene in human hepatocellular carcinomas

I. C. Hsu, R. A. Metcalf, T. Sun, J. A. Welsh, N. J. Wang & C. C. Harris

Nature 350, 427–428 (1991) | [Cite this article](#)

1142 Accesses | 1436 Citations | 12 Altmetric | [Metrics](#)

Abstract

HUMAN hepatocellular carcinomas (HCC) from patients in Qidong, an area of high incidence in China, in which both hepatitis B virus and aflatoxin B₁ are risk factors¹, were analysed for mutations in p53, a putative tumour-suppressor gene. Eight of the 16 HCC had a point mutation at the third base position of codon 249. The G → T transversion in seven HCC DNA samples and the G → C transversion in the other HCC are consistent with mutations caused by aflatoxin B₁ in mutagenesis experiments^{2,3}. No mutations were found in exons 5, 6, 8 or the remainder of exon 7. These results contrast with p53 mutations previously reported in carcinomas and sarcomas of human lung, colon, oesophagus and breast; these are primarily scattered over four of the five evolutionarily conserved domains, which include codon 249 (refs 4–9). We suggest that the mutant p53 protein may be responsible for a selective clonal expansion of hepatocytes during carcinogenesis.

Selective G to T mutations of p53 gene in hepatocellular carcinoma from southern Africa

Brigitte Bressan, Michael Kew, Jack Wands & Mehmet Ozturk

Nature 350, 429–431 (1991) | [Cite this article](#)

1004 Accesses | 1250 Citations | 12 Altmetric | [Metrics](#)

Abstract

HEPATOCELLULAR carcinoma (HCC) is a prevalent cancer in sub-Saharan Africa and eastern Asia¹. Hepatitis B virus and aflatoxins are risk factors for HCC², but the molecular mechanism of human hepatocellular carcinogenesis is largely unknown³. Abnormalities in the structure and expression of the tumour-suppressor gene p53 are frequent in HCC cell lines⁴, and allelic losses from chromosome 17p have been found in HCCs from China⁵ and Japan⁶. Here we report on allelic deletions from chromosome 17p and mutations of the p53 gene found in 50% of primary HCCs from southern Africa. Four of five mutations detected were G → T substitutions, with clustering at codon 249. This mutation specificity could reflect exposure to a specific carcinogen, one candidate being aflatoxin B₁ (ref. 7), a food contaminant in Africa⁸, which is both a mutagen that induces G to T substitution⁹ and a liver-specific carcinogen¹⁰.

27

The development of drying techniques to reduce mycotoxin contamination is closely related to everyone's health



The impact of drying on human health is not only that it inhibits the growth of mycotoxins but also that most medicines and vaccines are produced by drying



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New Results

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Lyophilized mRNA-lipid nanoparticle vaccines with long-term stability and high antigenicity against SARS-CoV-2

Liangxia Ai, Yafei Li, Li Zhou, Hao Zhang, Wenrong Yao, Jinyu Han, Junmiao Wu, Ruiyue Wang, Weijie Wang, Pan Xu, Zhouwang Li, Chengliang Wei, Haobo Chen, Jianqun Liang, Ming Guo, Zhixiang Huang, Xin Wang, Zhen Zhang, Wenjie Xiang, Bin Lv, Peiqi Peng, Shanglei Zhang, Xuhao Ji, Zhangyi Li, Huiyi Luo, Jianping Chen, Ke Lan, Yong Hu
doi: <https://doi.org/10.1101/2022.02.10.479867>

Harris, R.J.C. Preservation of biological materials by freeze-drying. *Nature* 1951, 168 (4181), 851-853

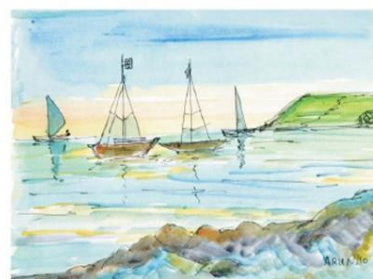
Bourne, G.H. Freezing and drying. *Nature* 1952, 170, 723-724

Bell, L.G.E. Edmond about and the technique of freezing and drying tissues. *Nature* 1952, 170 (4326), 547

Drying of Vaccines and Biomolecules >

Bhaskar N. Thorat, Ayantika Sett & A. S. Mujumdar
Drying Technology, Volume 40, 2022 - Issue 3

Section IV: Drying and Climate change



Section IV: Drying and Climate change



- ❑ Climate change is one of the most ground challenges threatening sustainable development of the world and human well-being.
- ❑ Reducing GHG emissions is the inevitable choice to control climate change.
- ❑ Drying is the most energy-consuming industrial sector, accounting for about 10-15% of a country's total industrial energy consumption

Drying is playing a key role in curbing climate change



- ❑ Coal drying can enhance power generation performance and reduce carbon emissions. Removing 6% of moisture in fuel, the boiler performance can be enhanced by 2.6-2.8%.
- ❑ Natural gas can be transported long distances only when it is dehydrated.

Taking natural gas for another example

MOLECULAR SORPTION

Hydrolytically stable fluorinated metal-organic frameworks for energy-efficient dehydration

Amandine Cadiou,^{1*} Youssef Belmabkhout,^{1,2*} Karim Adil,¹ Prashant M. Bhatt,¹ Renjith S. Pillai,¹ Aleksander Shkurenko,¹ Charlotte Martineau-Corcoss,^{2,3} Guillaume Maurin,⁴ Mohamed Eddaoudi^{1,†}

Natural gas must be dehydrated before it can be transported and used, but conventional drying agents such as activated alumina or inorganic molecular sieves require an energy-intensive desiccant-regeneration step. We report a hydrolytically stable fluorinated metal-organic framework, AIFVIVE-1-Ni (KAUST-8), with a periodic array of open metal coordination sites and fluorine moieties within the contracted square-shaped one-dimensional channel. This material selectively removed water vapor from gas streams containing CO₂, N₂, CH₄, and higher hydrocarbons typical of natural gas, as well as selectively removed both H₂O and CO₂ in N₂-containing streams. The complete desorption of the adsorbed water molecules contained by the AIFVIVE-1-Ni sorbent requires relatively moderate temperature (~105°C) and about half the energy input for commonly used desiccants.

In this paper, a metal-organic compound was developed to replace molecular sieve to adsorb the moisture in natural gas, which reduced the resurrection temperature from 300–320 °C to 105°C, and reduced the energy consumption of drying.

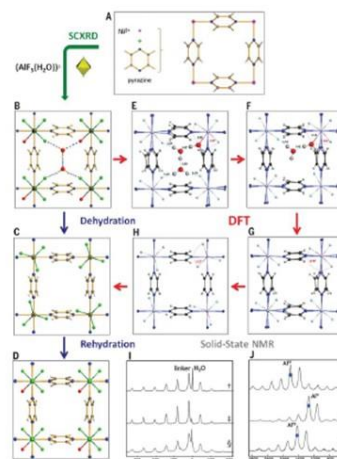
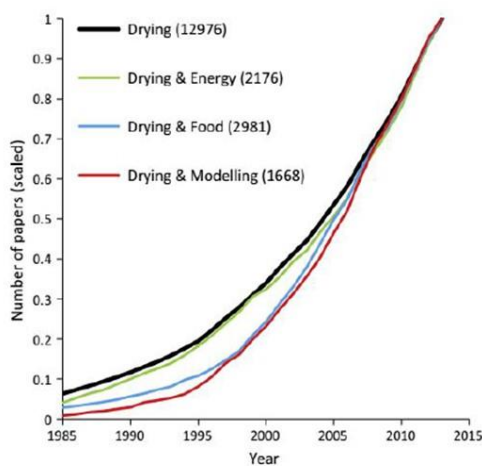


Fig. 1. Structure description and characterization of as-synthesized, dehydrated, and rehydrated forms of AIFVIVE-1-Ni (KAUST-8). (A) Repetitive square motif in the Ni-pyrazine.

Science2017, 356:731–735

Reducing energy consumption of drying is an eternal topic. This is true even for expensive vaccines that are not energy-sensitive



Applied Energy 2014, 131:323–344

Drying a tuberculosis vaccine without freezing

Yun-Ling Wong*, Samantha Sampson¹, Willem Andreas Germishuizen², Sunal Goonesekera³, Giovanni Caponetti⁴, Jerry Sadoff⁵, Barry R. Bloom⁶, and David Edwards⁶

¹Division of Engineering and Applied Sciences, Harvard University, Cambridge, MA 02138; ²Department of Immunology and Infectious Diseases, Harvard School of Public Health, Boston, MA 02115; ³Univest S.r.l., 20100 Piacenza, Italy; and ⁴Novartis Global TB Vaccine Foundation, 1405 Research Boulevard, Suite 200, Rockville, MD 20850

Contributed by Barry R. Bloom, December 11, 2006 (sent for review October 5, 2006)

With the increasing incidence of tuberculosis and drug resistant disease in developing countries due to HIV/AIDS, there is a need for vaccines that are more effective than the present bacillus Calmette-Guérin (BCG) vaccine. We demonstrate that BCG vaccine can be dried without traditional freezing and maintained with remarkable refrigerated and room-temperature stability for months through spray drying. Studies with a model *Mycobacterium* (*Mycobacterium smegmatis*) revealed that by removing salts and cryoprotectant (e.g., glycerol) from bacterial suspensions, the significant osmotic pressures that are normally produced on bacterial membranes through droplet drying can be reduced sufficiently to minimize loss of viability on drying by up to 2 orders of magnitude.

By placing the bacteria in a matrix of leucine, high-yield, free-flowing, “vial-filling” powders of bacteria (including *M. smegmatis* and *M. bovis* BCG) can be produced. These powders show relatively minor losses of activity after maintenance at 4°C and 25°C up to and beyond 4 months. Comparisons with lyophilized material prepared both with the same formulation and with a commercial formulation reveal that the spray-dried BCG has better overall viability on drying.

Results and Discussion

“The current energy efficiency of dryer is very low. So Even small improvements in energy efficiency can lead to huge energy savings and reduced GHG emissions. Employing multistage drying, intermittent drying, and hybrid drying technologies, as well as developing innovative drying and energy savings technologies, such as optimization of each stage of the drying process through more precise detection and better control, and utilizing renewable energy such as solar, wind, and biomass.”

Drying Technology 2015, 33: 1679–1680.

For more reading you can refer to the papers

nature

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Seafood

Mining shell waste will not be easy

Hong-Wei Xiao , Zhen-Jiang Gao & A. S. Mujumdar

Nature **525**, 321 (2015) | Cite this article

1941 Accesses | 1 Citations | 5 Altmetric | Metrics

If the chemical industry is to profit from refining waste crustacean shells and other by-products of seafood processing, collection problems and food-safety issues need to be overcome (see N. Yan and X. Chen *Nature* **524**, 155–157; 2015).

Gathering sufficient animal feedstock for commercial purposes will be a formidable challenge (R. L. Naylor *et al. Proc. Natl Acad. Sci. USA* **106**, 15103–15110; 2009). The transport and storage of seafood by-products from different processing plants is also likely to be extremely costly.

Moreover, expensive energy-intensive drying of crustacean shells would be necessary to prevent microbial growth and production of carcinogenic bacterial aflatoxins. Other health risks could arise from bioaccumulation of contaminants (such as heavy metals in shells) or from cross-species transmission of pathogens and perhaps even of prions through the food chain (L. Cao *et al. Science* **347**, 133–135; 2015).

Drying Technology

An International Journal

ISSN: 0737-3937 (Print) 1532-2300 (Online) Journal homepage: <https://www.tandfonline.com/loi/lprt20>

Importance of drying in support of human welfare

Hong-Wei Xiao & Arun S. Mujumdar

To cite this article: Hong-Wei Xiao & Arun S. Mujumdar (2020) Importance of drying in support of human welfare, *Drying Technology*, 38:12, 1542–1543, DOI: 10.1080/07373937.2019.1686476

To link to this article: <https://doi.org/10.1080/07373937.2019.1686476>

Drying Technology, Volume 38, 2020 - Issue 12

Editorial | Published Online: 06 Nov 2019 | Views: 6056 | Citations: 26

Drying Technology: An International Journal

Publication details, including instructions for authors and subscription information: <http://www.tandfonline.com/loi/lprt20>

Guest Editorial: Some Mitigation Strategies for Climate Change

Hong-Wei Xiao

Published online: 01 Sep 2015.

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Much basic phenomenon in the drying process is still poorly understood.

When a particle-laden droplet evaporates on a solid surface, the particles form a ring-like deposit. The explanation for this phenomenon, provided in 1997, has led to advances in many areas of science and engineering.

Capillary flow as the cause of ring stains from dried liquid drops

Deegan, R.D.; Bakajin, O.; (---); Witten, T.A

Oct 23 1997 | *NATURE* 389 (6653), pp.827-829

“Why coffee stains have pronounced boundaries, where most of the materials is deposited. This material is uniformly distributed in the initial drop, so why does it get concentrated around the edges?”

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Closing remarks

"Just like the situation by the end of the 19th century, most people believed that almost all of the mysteries of the physical world, from electricity and magnetism to optics and radioactivity have been discovered. The history of science and technology is replete with examples of declarations by famous men of science and technology that there was nothing more truly worthwhile remaining to be done in their areas. History has also shown this to be consistently wrong."

-Prof. Mujumdar, Drying Technology 2013, 31:1191.

When we are confused about the future of drying research we can go back to the origin of the question "What is the importance of drying to human being" ?

Thanks for the encouragement and help of my mentors and collaborators and PhD students both at home and abroad.



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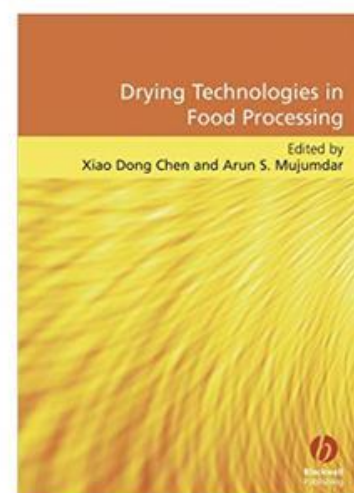
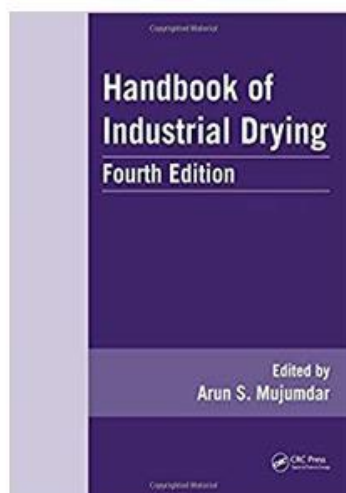
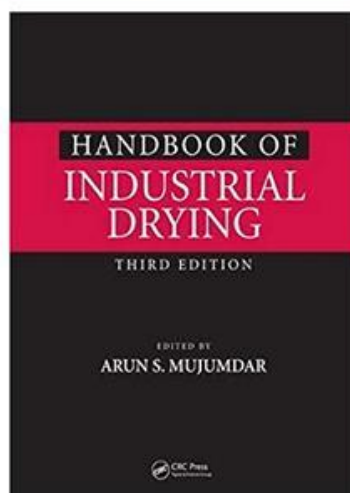
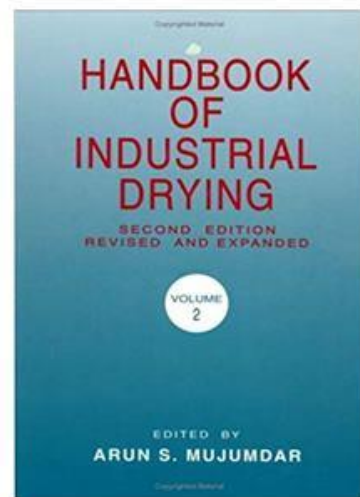
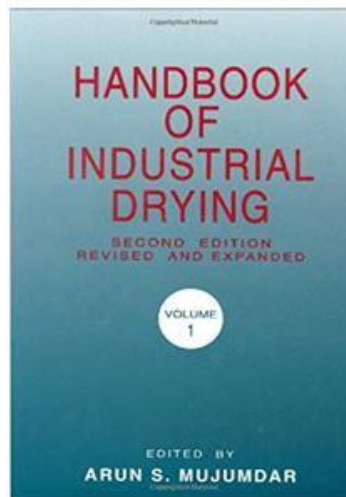
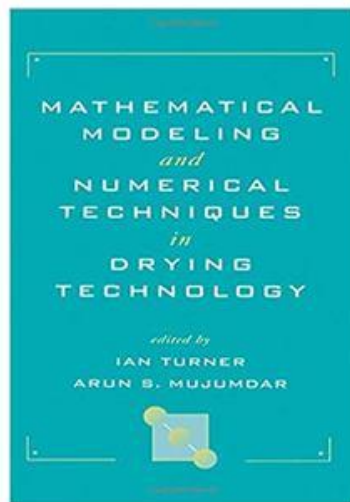


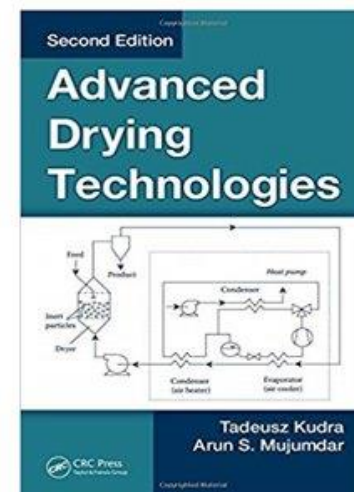
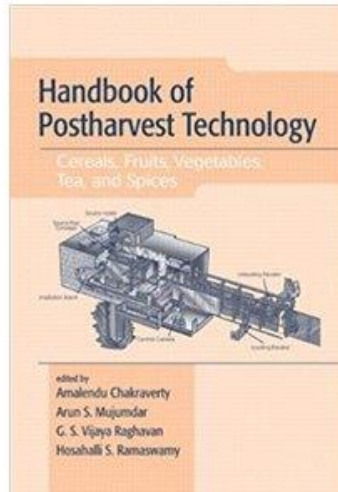
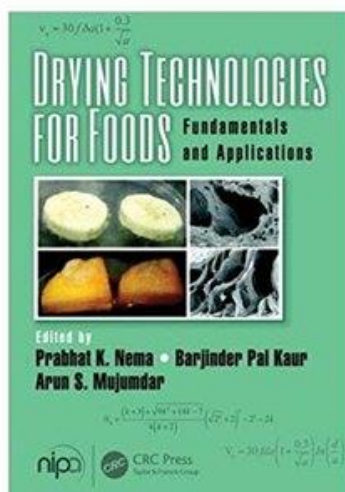
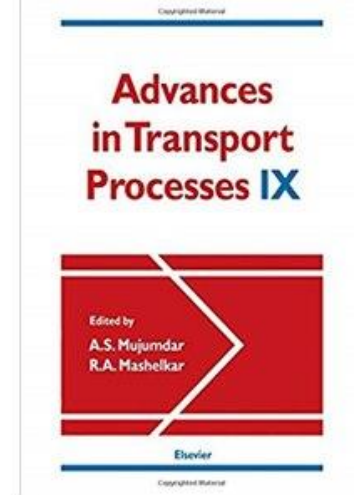
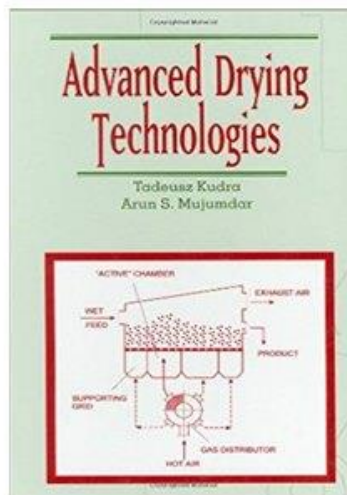
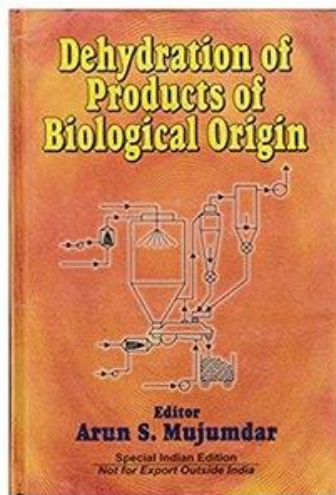
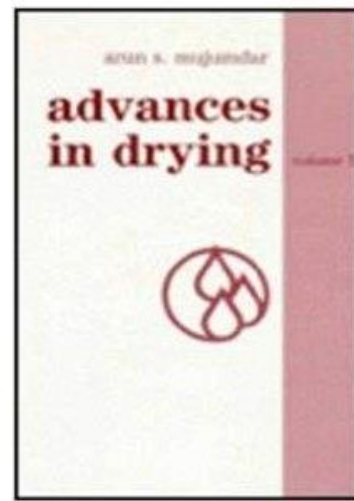
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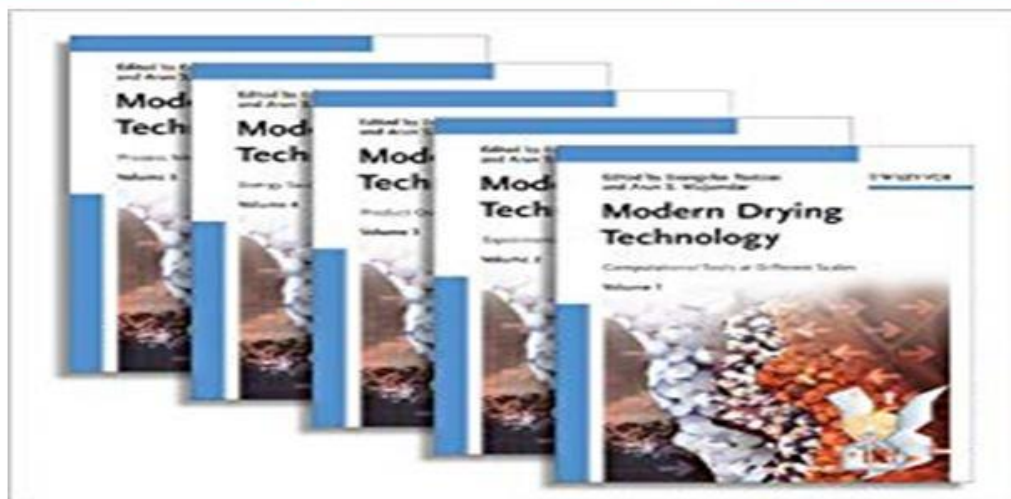
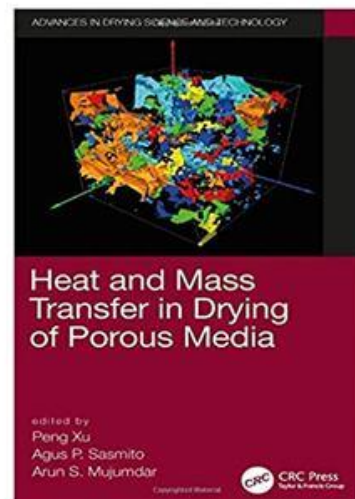
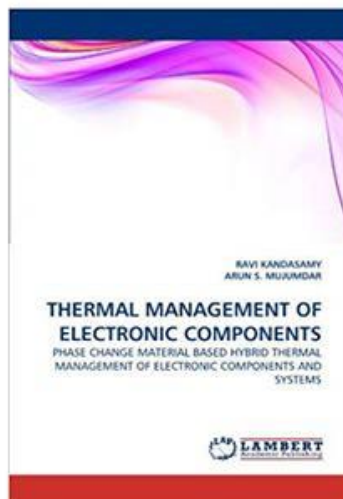
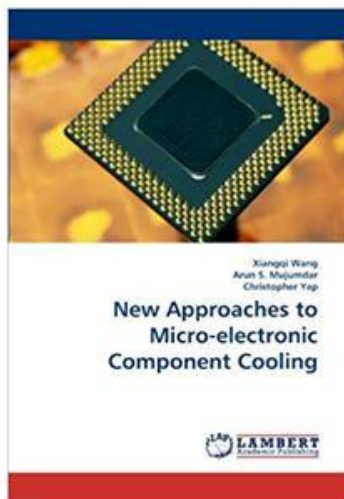
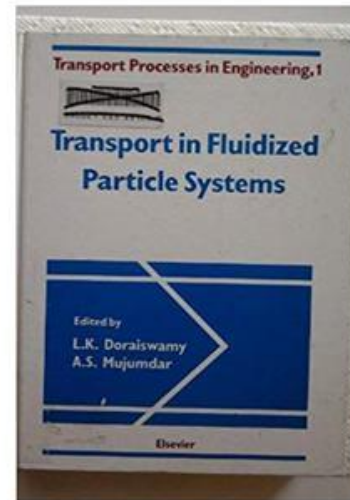
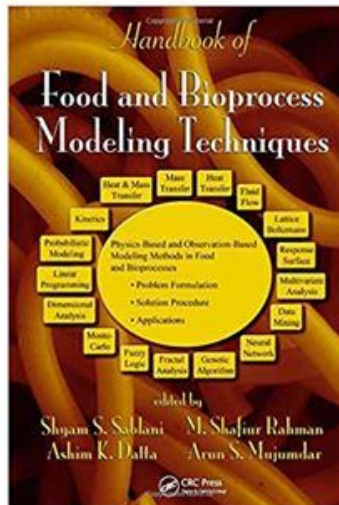
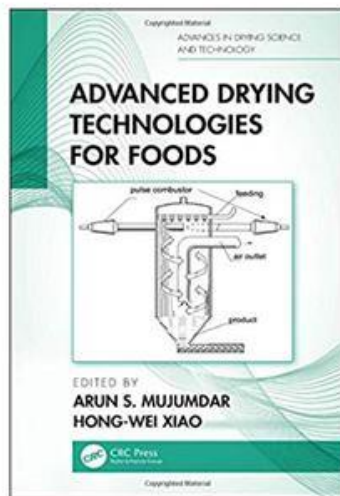
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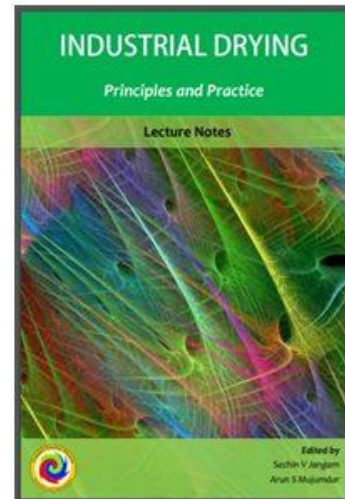
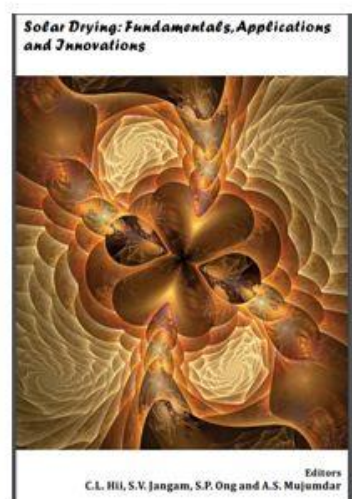
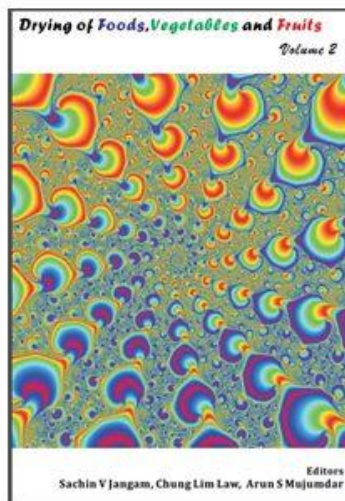
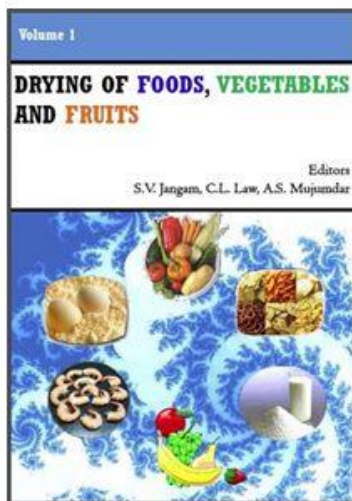
Prof. Arun S. Mujumdar





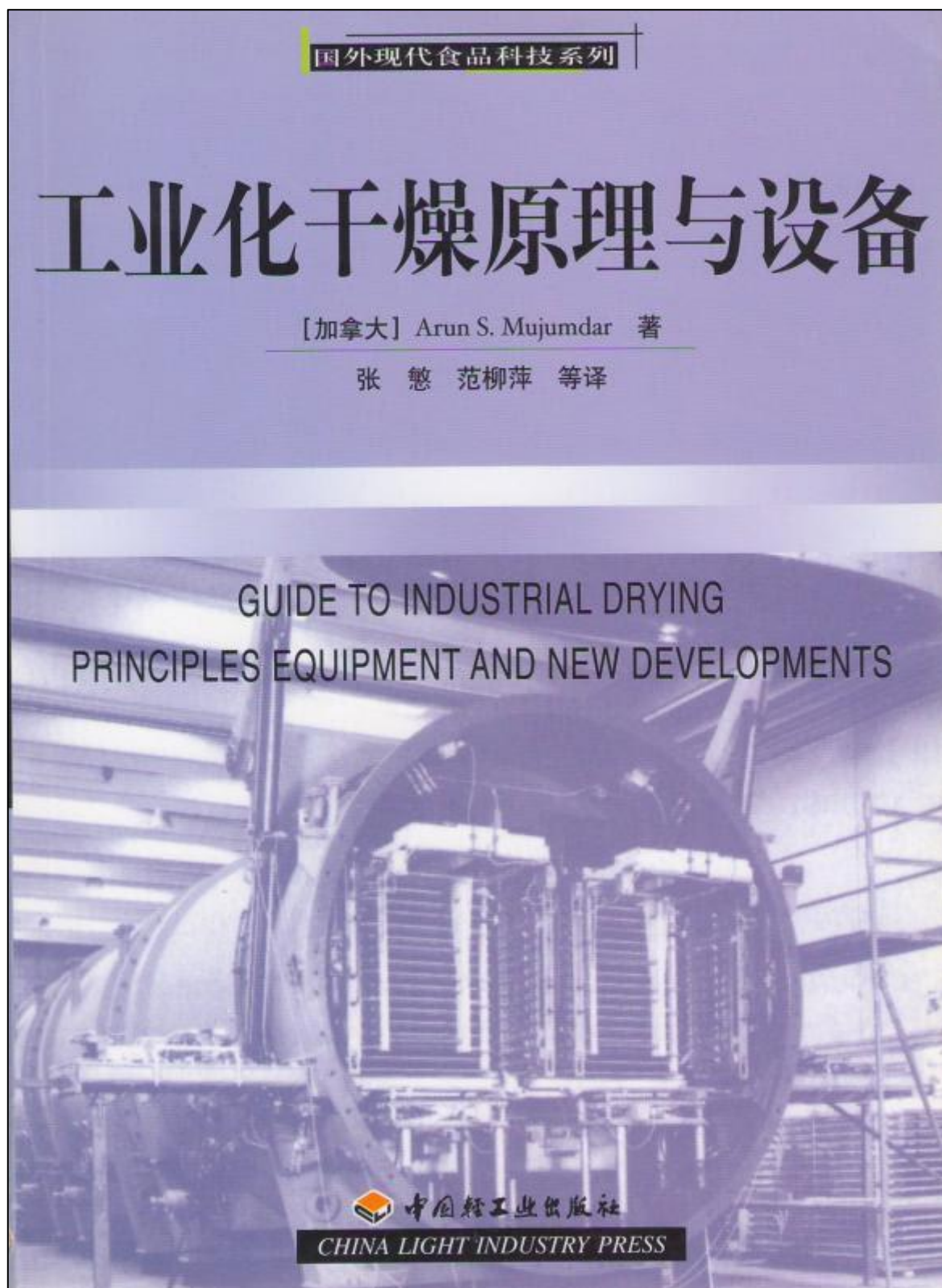


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