FOOD DRYING
Proceedings of a Workshop
Held at Edmonton, Alberta, 6-9 July 1981
The International Development Research Centre is a public corporation created by the Parliament of Canada in 1970 to support research designed to adapt science and technology to the needs of developing countries. The Centre's activity is concentrated in five sectors: agriculture, food and nutrition sciences; health sciences; information sciences; social sciences, and communications. IDRC is financed solely by the Parliament of Canada; its policies, however, are set by an international Board of Governors. The Centre's headquarters are in Ottawa, Canada. Regional offices are located in Africa, Asia, Latin America, and the Middle East.
Food Drying

Proceedings of a workshop held at Edmonton
Alberta, 6–9 July 1981

Editor: Gordon Yaciuk

Sponsored by
International Development Research Centre,
Ottawa, Canada

in collaboration with
Alberta Department of Agriculture,
Edmonton, Canada
Abstract/Résumé/Resumen

The authors of this volume include researchers and scientists from many countries that encompass diverse climatic, geographic, and socioeconomic conditions. Their disciplines were also numerous: home economics, food science, nutrition, physics, and engineering.

The workshop covered the most important areas in the design and operation of a drying system. These are: drying requirements, consumer acceptance, heat and mass transfer, and heat sources. Within drying requirements, the need for drying the product is discussed as well as drying times and rates, sample preparation, quality changes during drying, rehydration problems, and problems with storage of the dried product. The section on consumer acceptance includes the effects of drying on the nutritive value of food, the introduction of a dried food to the consumer market, and how consumers provide valuable information to scientists to help in improving a process or product. The theory and design of a drying chamber and process control are explained under heat and mass transfer and an operational, full-scale drying system is examined. Finally, under heat sources, a number of examples are given in the use of the sun, petroleum products, agriculture wastes, and wood as heat sources for a drying process. A final concluding commentary is made on the overall recommendations derived from the workshop and proposals for future work are given.

Les auteurs de ce volume sont des chercheurs et des techniciens venus de pays très différents les uns des autres du point de vue climat, géographie et conditions socio-économiques. Les disciplines représentées étaient aussi très diverses: économie domestique, alimentation, nutrition, physique, génie mécanique.

Le colloque a examiné les questions les plus importantes en ce qui concerne la conception et l'utilisation d'une installation de séchage: besoins en matière de séchage, l'accueil du consommateur, transmission de la chaleur et évacuation de l'humidité, sources de chaleur. Le chapitre sur les besoins en matière de séchage traite de la nécessité et de la durée de cette opération, de la préparation des échantillons, de l'action du séchage sur la qualité du produit, des problèmes de réhydratation et des problèmes de stockage du produit sec. Le chapitre sur l'accueil du consommateur traite des effets du séchage sur la valeur nutritive du produit, de la commercialisation d'un produit sec et de l'aide que peuvent apporter les consommateurs à l'amélioration d'un procédé ou d'un produit. Le chapitre sur la transmission de la chaleur et l'évacuation de l'humidité traite de la théorie et de la conception d'un séchoir, des modes de réglage et décrit une installation en service. Enfin, le chapitre sur les sources de chaleur donne des exemples l'utilisation du soleil, des produits pétroliers, des déchets agricoles et du bois. Un exposé des conclusions dégagées par le colloque et de ses recommandations est présenté à la fin de l'ouvrage.

Los autores de este volumen comprenden investigadores y científicos de varios paises que, en conjunto, abarcan diversas condiciones climáticas, geográficas y socio-económicas. Sus disciplinas respectivas también son numerosas: economía del hogar, ciencias de alimentación, nutrición, física e ingeniería.

El cursillo abarcó los aspectos más importantes en el diseño y operación de un sistema de deshidratación. Estos son: requisitos de la deshidratación, aceptación por el consumidor, trasferencia de calor y masa y fuentes de calor. Entre los requisitos se examina la necesidad de deshidratar el producto así como los tiempos e índices del proceso, preparación de muestras, cambios en calidad durante la deshidratación, problemas que presenta la rehidratación y problemas resultantes del almacenamiento del producto deshidratado. La sección de aceptación por el consumidor comprende los efectos de la deshidratación sobre el valor nutritivo del alimento, la introducción de un alimento deshidratado en el mercado del consumidor, y cómo éstos a su vez proveen información valiosa a los científicos ayudándoles a mejorar un proceso o producto. Se explican la teoría y diseño de la cámara de deshidratación y el proceso de control bajo trasferencia de calor y masa, examinándose un sistema operativo de deshidratación a escala comercial. Finalmente, y bajo el concepto de fuentes de calor, se citan varios ejemplos relacionados con el uso del sol, de productos petrolíferos, y desechos agrícolas, así como el de la madera como fuentes de calor para procesos de deshidratación. Se efectúa un comentario final sobre recomendaciones generales derivadas del cursillo al tiempo que se efectúan propuestas para el trabajo futuro.
Contents

Foreword ......................................................... 5
Participants ....................................................... 6
Introduction
  Theme and objectives of the workshop G. Yaciuk ................. 9
Drying Requirements
  Drying of fish in India P.V. Prabhu and K.K. Balachandran .... 11
  Drying of vegetables in Egypt H.M. Ali and I.A. Sakr ........... 15
  Drying of potatoes (papa seca) in Peru C. Lescano ............... 20
  Drying of paddy in Indonesia Suahyadi .......................... 27
Consumer Acceptance
  Effect of drying on the nutritive value of foods in Kenya
    M.I. Gomez ................................................ 31
  Designing cowpea products for Northeastern Thailand
    T. Ngarmsak, M.D. Earle, and A.M. Anderson .................... 36
  Consumer acceptance of dehydrated banana weaning food in
    Costa Rica Celsa Lastreto G., Rodney Cooke, and
    Armando Campos S. ........................................ 40
  Marketing dried fish in East Java, Indonesia
    J.A. Sumardi, H. Purnomo, W.H. Susanto, Putiati, Darius, and
    I. Suryo .................................................. 47
Heat and Mass Transfer
  Drying of cereal grains in the Philippines S.C. Andales ......... 51
  Drying onions in Niger A. Ba, Ch. Banzet, and J.M. Degbe ....... 61
  Drying fish in the Philippines Ernesto V. Carpio ................ 63
  Drying grapes in northern Chile J.M. Olhagaray ................. 71
Heat Sources
  Solar energy as a heat source in crop drying in Sierra Leone
    Michael W. Bassey .......................................... 73
  Solar and natural air drying of rough rice in Korea
    Hak Kyun Koh and Chang Joo Chung ............................ 81
  Farm grain dryer — Thailand Sriwai Singhagajen ............... 89
  Economic evaluation of alternative energy sources for coffee bean
    drying R. Garcia, C. Porres, J.F. Calzada, J.F. Menchu, and
    C. Rolz .................................................. 94
  Dryers for cooperatives for food production in Indonesia
    Sjachputra ................................................ 99
Conclusions
  Commentary G. Yaciuk ........................................ 103
Foreword

For as long as we have historical record, the heat of the sun has been used to dry cereal grains, vegetables, fruit, fish, and meat. Solar radiation is widely used as a direct source of energy by which to dry and dehydrate foods of many kinds in many countries. As fossil fuel costs continue to rise, direct and indirect solar drying will gain increasing importance as a method of food preservation throughout the world.

The International Development Research Centre (IDRC) is supporting several research projects in which solar radiation alone or together with combusted agricultural wastes is used to dry crops and other food materials, in several of which the influence of variable drying conditions upon nutrient retention is being studied.

Because the food dehydration and crop drying projects financed by IDRC are located in countries with widely different environmental conditions and the spectrum of research activities calls for a variety of scientific disciplines, it appeared desirable to bring together research workers representative of the geographic and scientific diversity involved.

A workshop was, therefore, organized from 6 to 9 July 1981, at the University of Alberta and in collaboration with the Alberta Department of Agriculture (ADA), which included 2 days of formal sessions; a 1-day tour organized by the ADA of a grain dryer manufacturing plant, a local farm, and a primary elevator; and 1 day of informal visits to various university departments and commercial organizations by individual participants. Those attending the workshop came from Bangladesh, Chile, Egypt, Guatemala, India, Indonesia, Kenya, Korea, Malaysia, Mali, Niger, Costa Rica, Peru, the Philippines, Sierra Leone, Singapore, Thailand, and Zambia, encompassing immensely diverse climatic, geographic, and socioeconomic conditions and with experience that embraced home economics, food science, nutrition, physics, and engineering. The main topics covered included drying requirements, consumer acceptance, heat and mass transfer, and heat sources. This publication comprises the papers presented and discussed, together with a commentary by the technical coordinator of the meeting.

It is the belief of my colleagues in the Agriculture, Food and Nutrition Sciences (AFNS) Division that, thanks to the contributions by those who took part, this publication may prove of lasting value to others in developing countries who share similar interests and concerns.

J.H. Hulse
Director
Agriculture, Food and Nutrition Sciences Division
Participants

A. Alam, Post-Harvest Technical Scheme Project Co-ordinator, Central Institute of Agricultural Engineering, Shri Guru Tegh Bahadur Complex, T.T. Nagar, Bhopal 462 003, India.

Hatem Mohamed Ali, Head, Laboratory on Animal and Poultry Nutrition, National Research Centre, Dokki, Cairo, Egypt.

Silvestre C. Andales, Assistant Professor and Project Leader, UPLB/IDRC Postharvest Project, Department of Agricultural Process Engineering, University of the Philippines at Los Baños, College, Laguna 3720, Philippines.

M. Zohadie Bardaie, Department of Agricultural Engineering, Universiti Pertanian Malaysia, Serdang, Selangor, Malaysia.

Michael W. Bassey, Department of Mechanical Engineering, Fourah Bay College, University of Sierra Leone, Freetown, Sierra Leone.

Ernesto V. Carpio, Project Engineer, Department of Food Science and Technology, University of the Philippines at Los Baños, College, Laguna 3720, Philippines.


Chong Thean Chhong, Chemical and Food Process Section, Singapore Institute of Standards and Industrial Research, Maxwell P.O. Box 2611, Singapore 9046, Republic of Singapore.

J.M. Degbe, Office national de l'énergie solaire, B.P. 621, Niamey, Niger.

Dante B. de Padua, Technical Team Leader, Southeast Asia Cooperative Post-Harvest Research and Development Programme, c/o SEARCA, College, Laguna 3720, Philippines.

W. Edwardson, Senior Program Officer, Agriculture, Food and Nutrition Sciences Division, International Development Research Centre, 10454 Whyte Avenue, Suite 304, Edmonton, Alberta, Canada.

R.S. Forrest, Associate Director, Engineering and Home Design Sector, Alberta Department of Agriculture, Agriculture Building, 9718 107 Street, Edmonton, Alberta, Canada.

Ricardo García, Engineer, Applied Research Division, Instituto Centro-americano de Investigación y Tecnología Industrial, Avenida La Reforma 4-47 Zone 10, Apartado Postal 1552, Guatemala, C.A.

Celsa Lastreto Gomez, Centro de investigaciones on Tecnología de Alimentos, Universidad de Costa Rica, San Jose, Costa Rica.

M.I. Gomez, Lecturer, Department of Food Science and Technology, Faculty of Agriculture. University of Nairobi, P.O. Box 29053, Kabete, Nairobi, Kenya.

H.K. Koh, Associate Professor, Division of Agricultural Machinery and Process Engineering, Department of Agricultural Engineering, College of Agriculture, Seoul National University, Suweon, Korea 170.
Carlos Lescano, Jefe, Departamento de Tecnología de Alimentos y Productos Agropecuarios, Universidad Nacional Agraria La Molina, Apartado 456, Lima, Peru.

J. Lorenzana, Agricultural Engineering Department, Isabela State University, Echaque, Isabela, Philippines.

Joseph M. Mwale, Senior Scientific Officer, Food Technology Research Unit, National Council for Scientific Research, P.O. Box CH-158, Chelston, Lusaka, Zambia.

Candido Joven Miguel, Pasig Distributors Corporation, 114 Plaza Rizal, Pasig, Metro Manila, Philippines.

Tipvama Ngarmsak, Department of Agricultural Products, Faculty of Agriculture, Khon Kaen University, Khon Kaen, Thailand.

J.M. Olhagaray, Institute of Technological Research (INTEC/CHILE), Casilla 667, Santiago de Chile, Chile.

P.V. Prabhu, Scientist, Central Institute of Fisheries Technology, CIFT/IDRC Fish Processing Project, Willingdon Island, Matsuypuri P.O., Cochin 682 029, India.

Abdus Satter, Senior Scientific Officer, Agricultural Engineering, Bangladesh Agricultural Research Institute, Joydebpur, Dacca, Bangladesh.

O.G.A. Schmidt, Program Officer, Agriculture, Food and Nutrition Sciences Division, International Development Research Centre, 10454 Whyte Avenue, Suite 304, Edmonton, Alberta, Canada.

Sriwai Singhagajen, Chief, Storage and Processing Section, Agricultural Engineering Division, Department of Agriculture, Ministry of Agriculture and Cooperatives, Bangkhen, Bangkok 9, Thailand.

Wenceslao M. Sison, Agricultural Plans and Programs Supervisor/Project Leader, Technical Research and Services Directorate, National Food Authority, 101 E. Rodriguez Sr. Avenue, Matimyas Building, Quezon City, Philippines.

Sjachputra, c/o Haji Muslimin Nasution, Ministry of Co-operatives, Departemen Perdagangan Dan Koperasi, Sekretariat Menteri Muda Urusan Koperasi, P.O. Box 384, Jakarta, Indonesia.

Suahyadi, Project Leader, National Logistics Agency (BULOG), BULOG/IDRC Postharvest Rice Technology Project, P.O. Box 2345, Jakarta, Indonesia.


Salomon Chavez Tapia, Departamento de Tecnologia Pesquera, Universidad Nacional Agraria La Molina, Apartado 456, Lima, Peru.

Cheick Oumar Traoré, Laboratoire de l’énergie solaire, B.P. 134, Bamako, Mali.

S. Vogel, Program Officer, Agriculture, Food and Nutrition Sciences Division, International Development Research Centre, 10454 Whyte Avenue, Suite 304, Edmonton, Alberta, Canada.

G. Yaciuk, Program Officer, Agriculture, Food and Nutrition Sciences Division, International Development Research Centre, 10454 Whyte Avenue, Suite 304, Edmonton, Alberta, Canada.
IDRC Staff

M.C. Beaussart, Administrative Assistant, Agriculture, Food and Nutrition Sciences Division, IDRC, 10454 Whyte Avenue, Suite 304, Edmonton, Alberta, Canada.

A. Chouinard, Technical Editor, Communications Division, IDRC, Box 8500, Ottawa, Ontario, Canada K1G 3H9.

K. Kealey-Vallière, Assistant Technical Editor, Communications Division, IDRC, Box 8500, Ottawa, Ontario, Canada K1G 3H9.
Drying Requirements

Drying of Paddy in Indonesia

Suahyadi

Abstract. Several studies have been carried out in Indonesia on the use of artificial dryers as an alternative to the traditional sun drying of rough rice (paddy). Compared to sun drying, artificial drying produces a better quality milled rice mainly because it has a lower percentage of broken rice and yellow or damaged grains. Other advantages of artificial drying that appear promising, but require further study, are a high mill recovery rate, an increase in resistance to pests or fungi, and an increase in storage life. However, from the farmer's point of view, the economic profitability of artificial dryers is still doubtful, but because of government interest, the use of these dryers has been encouraged. Artificial drying may offer some solution to the problems encountered in long-term storage of milled rice; however, efforts must be made to reduce drying costs.

Since 1970, the Indonesian government has promoted the use of mechanical dryers in the private sector to encourage small-scale industry. The drying cost of the different dryers was between Rp 742/t (Rp 630 = U.S.$1.00) of rough rice to Rp 1648, and the cost of sun drying was Rp 300/t of rough rice. The use of artificial dryers at that time was very limited. In addition to being expensive, the dryers were relatively complicated and difficult to operate. However, artificial drying cannot always be replaced by sun drying. The possibilities of sun drying are limited under adverse weather conditions, and delays in drying generally lead to deterioration of the grain.

Advantages of a Proper Drying Process

When paddy is harvested, the moisture content (MC) is 20-22% when the weather is good, but after a rain fall the paddy could have 24-27% MC. Without aeration, grains with a high moisture content will deteriorate rapidly, sometimes within 24 hours. If the moisture content of the rough rice is reduced to 16% immediately after harvest, then the grain will be of good quality for 3-6 months (it is common practice for farmers to sun dry early to reach a 16% MC and then store the grain for several months).

If the farmers store paddy (rough rice) that has a high moisture content, the result will be discoloured grain — the high moisture grains will have a high degree of respiration that may result in heat-damaged grain and fungal damage. Discoloured grain is the most evident sign of damage and may reduce the price 25-30% as compared with sound grain. The amount of rice classified as discoloured is difficult to estimate because the National Logistics Agency (BULOG), the only institution responsible for price stabilization, sets certain standards that include a prohibition on yellow grains, and rice that does not meet the standard requirements is rejected and put on the free market at reduced prices. Although BULOG sets the standard requirements, sometimes the agency experiences losses because of damaged grains that are mostly from the purchase of rough rice. (In 1981, a minimum of 16,000 t decreased in price by at least 25% and, in the past, the decreased price has applied to close to 10%.) With appropriate drying processes the evidence of yellow or damaged grains may be avoided, and a large fraction of the postharvest problems may be eliminated.

With artificial drying, the dried rough rice may produce a higher quality of milled rice provided that excessive drying temperatures are not used. A comparison of milled rice dried by sun drying and by artificial drying is given in Table I. Another advantage of artificial drying over sun drying is increased resistance to insect attacks and fungi. An increase in storability may also be possible but further studies are required.

---

1National Logistics Agency (BULOG). P.O. Box 2345, Jakarta, Indonesia.
Table 1. Comparison of sun drying and artificial drying of milled rice.

<table>
<thead>
<tr>
<th></th>
<th>Sun drying (%)</th>
<th>Artificial drying (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture content</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td>Head rice</td>
<td>65</td>
<td>85</td>
</tr>
<tr>
<td>Broken grains</td>
<td>35</td>
<td>13</td>
</tr>
<tr>
<td>Chips</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Milling recovery</td>
<td>65</td>
<td>&gt;65b</td>
</tr>
</tbody>
</table>

*Represented by the standard of domestic procurement from BULOG.

*The milling recovery from artificial drying may be higher, but it is difficult to find an adequate sample.

Cost of Artificial Drying Compared to Sun Drying

In 1970–71, the Weitz-Hettelsater Company, Missouri, USA, studied the cost of several dryers, as well as sun drying, and found that the cost difference between sun drying and artificial drying is quite large (Rp 300/t of rough rice compared to Rp 742/t) and that there is a significant cost difference between dryers (Rp 742–1648/t).

The Department of Agriculture in 1976 did the same study and found that most of the flatbed dryers had relatively low drying costs, because they were the lowest in energy consumption, and the labour requirements were inexpensive. Therefore, any type of dryer to be introduced in Indonesia should be technologically simple and low in energy consumption to maintain low drying costs.

In 1978, a study was also conducted by BULOG and IDRC on sun drying and on the flat-bed dryer developed in the BULOG/IDRC project. The relative results were similar to the earlier study. The cost of sun drying was Rp 1500/t of rough rice and the artificial drying cost (flat-bed dryer) was Rp 3500/t of rough rice.

Although sun drying is much cheaper than artificial drying, artificial dryers must be used when the weather conditions are unsatisfactory for sun drying. Therefore, BULOG has installed 71 dryers throughout the village cooperatives and will soon install another 40 units as well as 60 small, flat-bed dryers.

Problems in the Use of Artificial Dryers

Artificial dryers have several technological advantages, but there are still some economic problems to be solved. It is not economical to use an artificial dryer at any other time than during the rainy season when sun drying is not possible. Otherwise, sun drying is a much cheaper method. Therefore, most of the dryers are only in operation for about 4 weeks. The use of an artificial dryer may only be economically feasible in areas where the incidence of harvesting in the rainy season is high such as in mountainous areas where rice cultivation is done continuously or in well-irrigated areas where, because of water rationing, harvesting has to be done in the rainy season.

A nontechnical condition that forced the use of artificial dryers is the fact that rice is still a political commodity in the country. Rice accounts for about 30% of the average family expenditures in Indonesia, so the government uses rice price stabilization for rice as the mean for stabilization of the economy of the country.

Economic Analysis on the Use of Artificial Dryers

A study on the economic feasibility of the use of a small flat-bed dryer (capacity 1500 kg/batch) by the BULOG/IDRC project economists determined that: investment in artificial dryers does not substitute for investment in additional floor for sun drying, quantitative losses in the absence of artificial drying in the rainy season harvest are 4%, and fuel is costed at commercial prices. Analysis shows that the cost-benefit ratio for artificial drying (discount rate 18%) is unlikely to exceed +1 in the absence of a further government subsidy for paddy dried by artificial means.

Another analysis by a Canadian University Service Overseas (CUSO) volunteer on the project concerned the possibilities of using a small flat-bed dryer, a vertical-bin dryer with a kerosine heater, and a vertical-bin dryer with a rice-hull burner. The model considered the following possibilities: three opportunity costs of labour (high, low, and zero wages), whether the use of artificial dryers can be considered as a substitute for additional investment in sun drying, and weather conditions observed for Jatisari (1970–80), a major paddy-producing region where the rainy season often presents serious problems for sun drying.

Among the conclusions of the analysis are: (1) mechanical dryers are unlikely to provide an efficient means of drying at the cooperative level if rice hulls are not used as fuel; (2) returns to artificial dryers are likely to fluctuate widely.
from year to year because of the weather, which is a serious problem to businesses or cooperatives that do not have easy long-term credit; (3) returns to artificial dryers depend critically upon alternative investments when artificial dryers are absent and upon whether losses on the floor during sun drying can be lowered to about 1%. If artificial dryers are not intended to be substitutes for investment in additional sun-drying capacity or if losses on the floor in sun drying can be lowered substantially (as has been argued by other researchers in Indonesia) then investment in artificial dryers is not appropriate; (4) the Indonesian government has for a long time provided extremely large indirect subsidies for private sector investment in artificial dryers (fuel subsidies increase the internal rate of return to flat-bed and vertical-bin dryers, using kerosine fuel and operating in the rainy season, by about 1.9 points), yet, artificial dryers have only been used in the private sector or in cooperatives when the government fully subsidizes investment costs as well. From this information, it appears that the use of artificial dryers is not yet economically viable, even though they do have some technological benefits.

Conclusions

(1) The use of artificial dryers improves the quality of milled rice.

(2) One benefit derived from the use of artificial dryers may be in improvements in long-term storability, etc., but this depends on changes in the demand for the quality of milled rice and requires further study.

(3) For now, the use of artificial dryers is still uneconomical or at least questionable, but in Indonesia, because of the government food policy, the use of artificial dryers has been encouraged.

(4) A further study should be carried out to find cheaper artificial drying processes or other drying processes, such as low-cost solar dryers that may overcome the drying problems encountered during periods of rain or supplement sun drying.