FOOD DRYING

Proceedings of a Workshop
Held at Edmonton, Alberta, 6-9 July 1981
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IDRC-195e


Microfiche edition available
Abstract/Resumé/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 países 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, transferencia 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 el 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 como 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 transferencia 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.
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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.

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Heat Sources

Farm Grain Dryer — Thailand

Sriwai Singhagajen

Abstract. This paper discusses the work of the Agricultural Engineering Division, Department of Agriculture of the Government of Thailand, in postharvest technology, specifically in the development of a farm grain dryer to assist local farmers in the processing of a second harvest. The dryer helps to reduce losses and drying time and improve the quality of the final product. The work on this type of paddy dryer has already been completed, and design specifications and performance results are given. Further research is needed to determine appropriate design modifications and changes in methods of operation to meet the requirements of the farmers.

In 1976, the Agricultural Engineering Division, Department of Agriculture of the Government of Thailand, began work on postharvest technology with support from the International Development Research Centre (IDRC). The survey on postharvest practices of farms conducted in that year indicated that the introduction of a farm grain dryer was essential because of the government support for second cropping in various parts of the country. The second harvesting begins in May and ends in early August, which is during the wet season. The farmers have problems in drying because there are no sunny days in succession to dry paddy at one time. This causes quality loss because of mould infection and because paddy grain changes in colour and quality, which results in low milling yield. The dryer helps to reduce losses and drying time and to improve and stabilize the quality of the produce to increase the farmer's income.

Batch drying dries paddy down to 14% moisture content (MC) giving the paddy a longer storage life and a higher milling yield than sun drying. The Agricultural Engineering Division has designed, developed, and tested the performance of the dryer based on its simplicity of operation, and construction, and its ability to be constructed using local materials and labour. The work on this type of paddy dryer has already been completed and made available to both farmers and local manufacturers (Fig. 1).

Components of the Dryer

The engine of the dryer is 6 kW minimum, and the engine from the power tiller can be converted for this purpose (Fig. 2). The rice-hull furnace (total size: 0.6 × 0.6 × 0.6 m) is made of ordinary bricks with an angle-iron bar frame. Rice husks can be burned, because ash does not come in contact with product. The ash is then used to make bricks. The furnace has a 45° inclined fire grate made of a series of 6 mm diameter iron rods with 1.5 mm spacing arranged vertically. The proper operation of this furnace would hold the desired temperature at ±3°C fluctuation. The diesel burner is used when the rice-hull furnace is not available. Kerosine is more expensive and not normally available in large quantities. The kerosine vaporizing-pot burner designed by the University of the Philippines at Los Baños (UPLB) was further modified by adding another perforated sheet to increase the vaporizing rate. The consumption rate of the diesel burner is 1.5–2.0 L/hour.

The cyclo fan has a 0.6-m diameter rotor with eight 0.15 × 0.3 m blades at a 70° pitch angle enclosed with a 0.6-m diameter metal sheet housing. The delivery rate is 0.5 m³/sec/m² at 1600 rpm. The holding capacity of the grain-holding bin is 3.6 m³. It is composed of six pieces of plywood, 1.22 × 2.44 × 0.006 m, and wooden bars, 0.038 × 0.076 m. It takes four people about 40 min to assemble the bin.

Construction and Operation Costs

The 6 kW diesel engine at 1981 prices costs U.S.$700. The materials for the rice-hull furnace

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Fig. 1. Diagram of the farm grain dryer.

Fig. 2. Components of the paddy dryer: (1) grain bin (244 × 244 × 122 cm), (2) thermometer, (3) screen (no. 8½), (4) canvas air duct, (5) engine (6 kW), (6) rice-hull furnace, (7) air duct, and (8) cyclo fan.
The total construction cost amounts to U.S.$534, and the total cost of the dryer is U.S.$1234.

The operation costs depend on the drying time, which is determined by the initial moisture content (MC), and the materials (fuel) used are: rice hulls, at a consumption rate of 8–10 kg/hour with a duration of 4–6 hours/operation — rice hulls are widely available at no cost; dieselene, at a consumption rate of 1.5–2.0 L/hour and a cost of U.S.$0.50–$0.75 — used if rice hulls are not available; and gasoline (power engine), at a consumption rate of 2.0–2.5 L/hour and a cost of U.S.$1.15–$1.40 — can be either gasoline or diesel engine.

Drying of Various Agricultural Products

Paddy

The capacity of the dryer is 2 t/lot of paddy. Generally, rice harvested from the field contains 20–26% MC and will take 3–6 hours to reduce to 14% MC. The rate of drying is about 2% of moisture reduction per hour. The temperature range is between 38 and 49°C, and static pressure is 50 mm of water. If the capacity is 1 t, the static pressure should be 10 mm of water obtained by adjusting the speed device on the engine.

The characteristics of the drying curves in drying paddy by using the diesel burner are shown in Fig. 3. The grain depth is 0.3 m, 22% MC, and final moisture content (MCₐ), the average after 4 hours of drying, is 13.4%. The characteristics of the drying curves in drying paddy by using the rice-hull furnace are shown in Fig. 4. The grain depth is 0.46 m, 22% MC, and 12% MCₐ, on an average of 4 hours drying. The curves indicate that the drying rate of the dryer using rice hulls as the heat source is greater than the diesel heat source.

Corn

The capacity of the dryer is 1.5 t. Figures 5–7 show the characteristics of the drying curves obtained from the three comparative tests on ear-corn drying. In drying by unheated air (Fig. 5) the drying time is 14 hours, the average initial moisture content is 15.9%, average final moisture content 14.4%, and the drying rate is 0.1%/hour. In drying by heated air from rice hulls (Fig. 6) the drying time is 9 hours, initial moisture content is 17.6%, average moisture content is 14.35%, and the drying rate is 0.4%/hour. Drying by heated air from diesel fuel (Fig. 7) involves a drying time of 13 hours, average initial moisture content is 16.4%, average final moisture content is 13.5%, and the drying rate 0.2%/hour. The general practices in ear-corn drying on the farm before marketing are: sun drying of newly harvested ear-corn containing 40% MC (the final moisture content is 20–22%), corn shelling, and sun redrying of
Fig. 6. Corn drying curves (heat source: rice-hull furnace).

Fig. 7. Corn drying curves (heat source: diesel).

It takes many days to reduce the moisture content from 20–22% to 8%. Procedures that may help to reduce the time used to complete the above steps are the artificial batch drying of ear corn and shelling after the drying has been completed. The time can be reduced to 1 day maximum.

Coffee

The capacity of the dryer for coffee berries is 140 kg. The general practice at present is sun drying, which usually takes 7–10 days. If there is rain during the drying period the farmers will pile up the produce indoors and take it out again when the sun shines. This can cause fermentation and, therefore, reduce the quality and price. The tests on drying coffee berries by using the batch dryer have been reported as follows:

1. The maximum temperature suitable for drying is about 93.3°C, because the berries are high-temperature tolerant.
2. The higher the temperature is, the greater increase in heated air quantity. The quantity of air varied from 0.028 to 0.047 m³/sec, and the temperature also varied from 65.5 to 93.3°C. A flow of 0.028 m³/sec, however, was found not to be sufficient to go through the layer of berries.
3. The batch dryer reduced the drying time from 7 to 10 days to 20 hours.

Figures 8 and 9 show the characteristics of the drying curves of coffee berries with an initial moisture content of 64%. The drying period was reduced to 15 hours to attain 8–10% MC.

Fig. 8. Coffee berry drying curves with an initial moisture content of 64% and airflow rate of 0.038 m³/sec.

Fig. 9. Coffee berry drying curves with an initial moisture content of 64% and an airflow rate of 0.047 m³/sec.
Chilli

The capacity of the dryer is 200–720 kg. Sun drying is the general drying practice for chilli, which takes 2–3 days. Chillies become mouldy if exposed to rain, which affects the quality and lowers the cash income of the farmers. The dryer reduces the drying time of chillies (14% MC) by about one-third, and it reduces the risk in quality loss to nearly zero. The farmer’s income will be higher if the dried chilli is at the market before the large supplies of lower-priced fresh chilli.

Conclusion

The batch-type dryer for farm grain (paddy) has been successfully designed, tested, and introduced to the farmers to help in drying the second harvest. Some extensions have been made through the workshop service section, the Department of Agricultural Extension, and the Office of Accelerated Rural Development. The source of heat used depends on the availability of the fuel supply in each area, but rice hulls are available in most areas. Farmers also tried this type of dryer in drying other cash crops: corn, coffee berries, and chilli, as previously noted, but further research is needed to provide the appropriate design modifications and changes in methods of operation to suit the requirements of the farmers.