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Review

Low-cost drying methods for developing countries

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Low-cost drying technologies suitable for rural farming areas are presented. Some of the important considerations with regard to their suitability include: 1. Low initial capital; 2. easy-to-operate with no complicated electronic/mechanical protocol, and 3. effective in promoting better drying kinetics. The drying technologies that were selected include fluidized bed, spouted bed, infrared, solar, simple convective and desiccant drying. A brief introduction on each drying technology has been presented followed by some technical details on their working operations. Examples of farming crops suitable for the employment of individual drying technology are provided to illustrate their potential application in agricultural product drying.

Introduction

Many of the third world countries produce large quantities of fruits and vegetables for local consumption and export. According to the Food and Agricultural Organization (FAO, 1991), the estimates for 1990 were approximately 341.9 million metric tons. In Asia, India produces 27.8 million metric tons or 8.1%, while China has a production capacity of 21.5 million metric tons or 6.3% of the total world production. Many of these fruits and vegetables contain a large quantity of initial moisture content and are therefore highly susceptible to rapid quality degradation, even to the extent of spoilage, if not kept in thermally controlled storage facilities. Therefore, it is imperative that, besides employing reliable storage systems, post harvest methods such as drying can be implemented hand-in-hand to convert these perishable products into more stabilized products that can be kept under a minimal controlled environment for an extended period of time.

Many food industries dealing with commercial products employ state-of-the-art drying equipment such as freeze dryers, spray dryers, drum dryers and steam dryers. The prices of such dryers are significantly high and only commercial companies generating substantial revenues can afford them. Therefore, because of the high initial capital costs, most of the small-scale companies dealing directly with farmers are not able to afford the price of employing such high-end drying technologies that are known to produce high quality products. Instead cheaper, easy-to-use and practical drying systems become appealing to such companies or even to the rural farmers themselves. It is also useful to note that in many remote-farming areas in Asia, a large quantity of natural building material and bio-fuel such as wood are abundant but literacy in science and technology is limited.

In this paper, the authors reviewed literature on different types of dryers for agricultural foodstuffs, and proposed several low cost dryers for application in farming areas where raw materials and labor are readily available. The proposed dryers should possess the following characteristics:

1. low initial capital costs;
2. easy to construct and fabricate with available natural materials;
3. easy-to-operate with no complicated electronic/mechanical protocol;
4. effective in promoting better drying kinetics and product quality than the sun-drying method;
5. easy to maintain all parts and components; and
6. simple replacement of parts during breakdowns.

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The paper identifies and provides an overview of several suitable dryers that satisfy the above criteria. For each dryer, its working mechanism, ease of operation and product suitability will also be elucidated.

Fluidized bed dryer

The first proposed low-cost drying system is the fluidized bed dryer. Fluidized bed drying (FBD) has found many practical applications in the drying of granular solids in the food, ceramic, pharmaceutical and agriculture industries. FBD is easy to implement and has the following advantages (Mujumdar & Devahastin, 2000): 1. High drying rates due to good gas-particle contact, leading to optimal heat and mass transfer rates; 2. smaller flow area; 3. high thermal efficiency; 4. lower capital and maintenance costs; and 5. ease of control. Some of the food products suitable for FBD include peas, beans, diced vegetables, fruits granules, onion flakes and fruit juice powders (Jayaraman & Das Gupta, 1995).

In a typical FBD system, hot air is forced through a bed at a sufficiently high velocity to overcome gravitational effects on the particles while ensuring that the particles are suspended in a fluidized manner. FBD has been known to be an effective way of optimizing the limited drying volume.

A typical layout of a simple FBD system is shown in Fig. 1. Such a simplified FBD system can be easily constructed with simple steel-frames, steel-sheets and wooden planks. The wet feed enters from one side of the fluidized bed into the main drying zone. Hot air passes from the bottom through the perforated plate and interacts with the wet feed in a cross-flow manner. This interaction causes the particles to fluidize, enabling efficient gas–particle contact to take place and resulting in the particles being dried effectively. The dried particles are then discharge through the exit port of the fluidized bed. Such a system is cheap and easy to design requiring low capital cost. The favorable results using such a bed include: 1. lower temperature drying resulting in minimizing of thermal-related quality degradation; 2. uniform drying resulting in particles having even dryness; and 3. improved drying kinetics resulting in shorter drying times. The effectiveness of the heat and mass between fluidized particles and the drying air can usually be improved by increasing the drying gas velocity. However, if the gas flow is too high there is a possibility that the gas passes around the particles' surfaces without allowing sufficient time for heat and mass exchange to take place between the particles' surface moisture and gas flow. One possible way to minimize this contact problem is via the employment of intermittent fluidization.

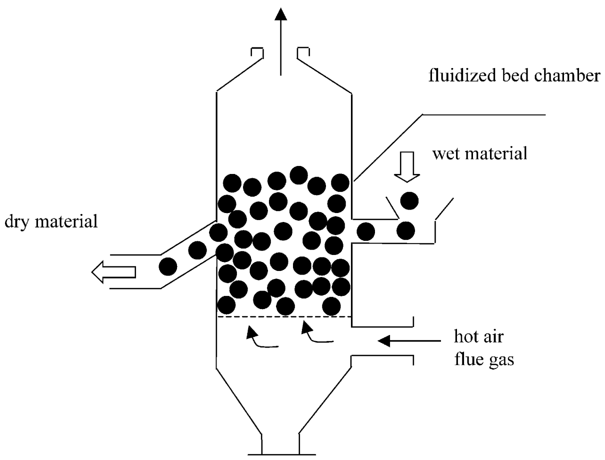

Fig. 1. Longitudinal schematic of the fluidized bed system (Hovmand, 1995).

Recent works have found significant advantages in operating fluidized beds in an intermittent manner by regulating the airflow to the bed in an intermittent manner. Pan, Zhao, Dong, Mujumdar, & Kudra (1999) in their study of intermittent drying of carrot cubes in a vibro-fluidized bed investigated the nutritional value of dry carrot, which was quantified in terms of β-carotene retention in the dried product. They found that the concentration of β-carotene in carrot undergoing continuous drying decreased with drying time due to thermal degradation. With intermittent regulation of the airflow, there was significant improvement in β-carotene retention. In a separate work, Pan, Zhao, and Hu (1999) conducted drying experiments for squash slices in a vibrated fluidized bed. From their experimental observations, a reduction in drying time of up to 40% was observed based on a drying time of 96 min for the squash slice to reach 14.75% moisture content. Comparing the preservation of β-carotene for continuous and intermittent air drying, Pan, Zhao, and Hu (1999) have shown that 87.2% of β-carotene in squash can be preserved in tempering-intermittent drying, while only 61.5% was found for conventional continuous drying. Intermittent fluidization is easy to implement and operating cost can be reduced since the fan speed needs to be regulated in an intermittent fashion. Also there is no additional cost incurred and the positive impact in terms of improved product quality is appreciable.

Spouted bed dryer

Spouted bed drying is often considered as a good option for the drying of granular products that are too coarse to be readily fluidized. Figure 2 shows a typical draft-tube Spouted Bed Dryer (SBD). Basically it comprises a cylindrical vessel with a conical bottom fitted with an inlet nozzle for introduction of the spouting air (drying medium). A draft tube is held in the center to enhance the height for which the granular particles can be spouted. The wet material enters from the side entrance port and undergoes spouting with the assistance of the draft tube. The incoming drying air, introduced through a centrally located opening at the conical base, interacts well with the particles. The particles, upon interaction with the air, rise rapidly through a hollowed central core, namely spout zone, within the vessel. These particles, after raising a certain height above the bed surface, get separated from the air stream and drop into the annulus region where they move slowly downward due to the angular shape of the bed. As the particles undergo spouting motion, moisture is removed from the particle surface. Due to the good air–particle contact, high drying rates can be achieved leading to optimal heat and mass transfer rates.

SBD is suitable for drying of granular agricultural products like wheat, corn, oats, cereal seeds and also cattle feeds. SBD incorporates several advantages (Pallai, Szentmarjay, & Mujumdar, 1995), they include:

1. Higher drying rates due to excellent particle–gas contact resulting in shorter drying times in the spout.
2. Lower drying temperatures which is advantageous with heat-sensitive foodstuffs.
3. Can be used for drying processes that require coating, granulation and agglomeration operations.
4. Employing inert particles, viscous paste and slurries can be effectively dried to yield end products in powdery form.

According to Pallai *et al.* (1995), the design and operating parameters necessary for granular product drying is not only dependent on their chemical composition and physical properties but also their potential use. For example, products such as corn and oats may require higher air temperatures to save valuable nutrients such as proteins and vitamins. However, for seeds

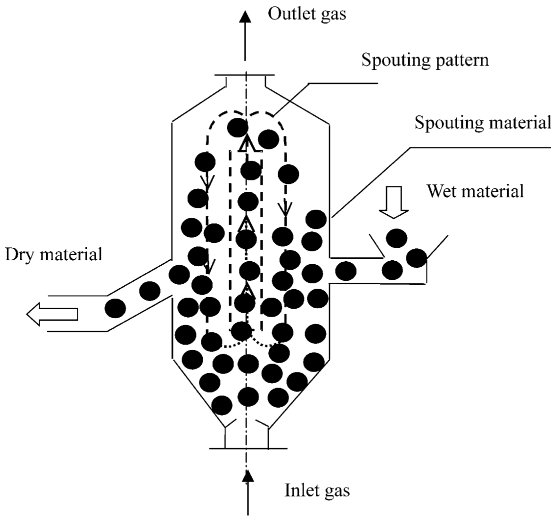

Fig. 2. Schematic diagram of a spouted bed showing spouting pattern (Pallai *et al.*, 1995).

used for sowing purposes, lower air temperatures might be necessary to conserve the seeds' ability to germinate. For such low temperature application, an intermittent spouting process is a viable option for consideration. Recently, Jumah, Mujumdar, and Raghavan (1996) implemented the principle of intermittent drying in a novel spouted bed system for corn. Experiments were carried out to test the hypothesis that corn, as a slow drying material, can be dried at a lower temperature to produce high quality grain with lower energy consumption via an intermittent air schedule. The intermittent scheduling was achieved using various drying periods alternated by long tempering periods. The resulting effect is a period of high intense heat and mass transfer. During the no-flow periods, the temperature and moisture gradients are effectively relaxed with favorable moisture re-distribution inside the particle. They also observed minimal mechanical damage to the kernels due to reduced attrition caused by inter-particle collisions during spouting.

Some conventional SBDs are not practical for industrial applications due to the problems of scale-up and control of the cyclic pattern. One design that has potential application in grain industries, and is practical for small to large scale farms, is the draft plate SBD as portrayed in Fig. 3. In the draft plate spouted bed, drying occurs mostly in the spout region. The grains are exposed to a drying medium with high velocity and temperature whilst drying in the annulus, where the grains and air move in the opposite direction (Hung-Nguyen, Driscoll, & Srzednicki, 1998). Researchers such as Madhiyanon, Soponronnarti, and Tia (2001) have conducted paddy drying experiments in a spouted bed dryer with draft plates. During their experiments, they observed that thermal energy consumption was in the range of 3.1–3.8 MJ/kg water evaporated at an approximate drying capacity of 3000 kg/h. The head rice yield after drying in such a draft-plate spouted bed design was observed to reduce by approximately 1% compared to the reduction in head rice yield obtained from a fluidized bed dryer. In addition to the higher head rice yield, the rice whiteness was also found to be better.

Infrared drying

Another low cost drying method suitable for employment in rural farming areas is Infrared (IR) Drying. IR drying can be considered to be an artificial sun-drying method which can be sustained throughout the entire day. Sandu (1986) described the advantages of applying IR to foodstuffs including: 1. Versatility; 2. simplicity of the required equipment; 3. fast response of heating and drying; 4. easy installation to any drying chamber and 5. low capital cost. Ginzurg (1969) has shown the suitability of applying IR drying to foodstuffs such as grains, flour, vegetables, pasta, meat and fish. During IR drying, raditative energy is transferred from the

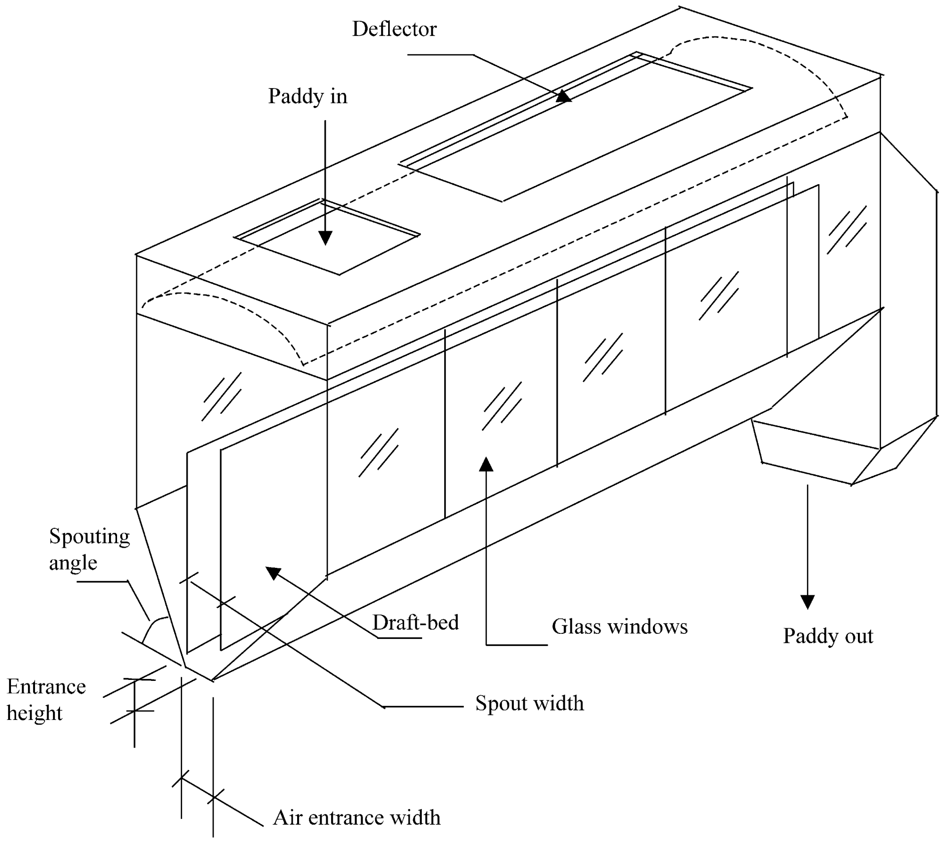

Fig. 3. Schematic diagram of a draft plate spouted bed (Madhiyanon *et al.*, 2001).

heating element to the product surface without heating the surrounding air. Fig. 4 shows a simple IR dryer design that can be easily constructed for use in rural farming areas. The design includes a manual-conveyor system whereby the food product enters from the inlet hoop and is dried as it moves parallel to the IR lamps. The level of irradiation can be adjusted via the voltage regulator while intermittent IR drying can be implemented by turning the timer relay knob.

IR drying has been the subject of investigations by several recent researchers. Experimental tests have shown that IR technology is well-suited to the extraction of high-potency vitamins from herbal sources which are widely available in high altitude farming areas. Extracted vitamin concentrate is used in dietary supplements, infant formula, personal care products, pet foods and livestock feed. Work by Paakkonen, Havento, Galambosi, and Pyykkonen (1999) has shown that IR drying improves the quality of herbs. A good example of herb drying employing simple IR technology is the dehydration of rosemary to extract Vitamin E. Dehydration by convection to reduce the moisture content from 60–70 to 8% would require a 24-h drying cycle. It has been reported that it is possible to achieve this 8% target in 3 h via the IR drying system. Furthermore, IR drying has the additional benefit of enhancing the potency of the Vitamin E yield by as much as 2 times.

To dry heat-sensitive materials, two options are available. They are: 1. To constantly monitor the product surface temperature and regulate the intensity of the IR; or 2. to operate the IR in an intermittent mode. Recent works have shown that the latter option is easy to implement and yields favorable results in terms of better product color and drying kinetics. Researchers such as Dostie, Seguin, Maure, Ton-That, and Chatingy (1989), and Carroll and Churchill (1986) have reported shortened drying time with improved product quality with intermittent heat input. According to Ginzburg (1969), the effectiveness of drying is increased by the application of intermittent irradiation. For heat sensitive heat materials, intermittent radiation treatment is beneficial both in respect of decreasing the duration of the drying process and hence the amount of energy required, and in respect of improving the product quality. Tan, Chua, Mujumdar, and Chou (2001) have shown reductions in drying time by as much as 50% for agricultural products, while Chua, Mujumdar, Chou, and Ho (2003) have shown favorable quality results in terms of reduced product color degradation; as high as 60% with appropriate IR intermittencies. The process of IR intermittent can be simply implemented by a tim-

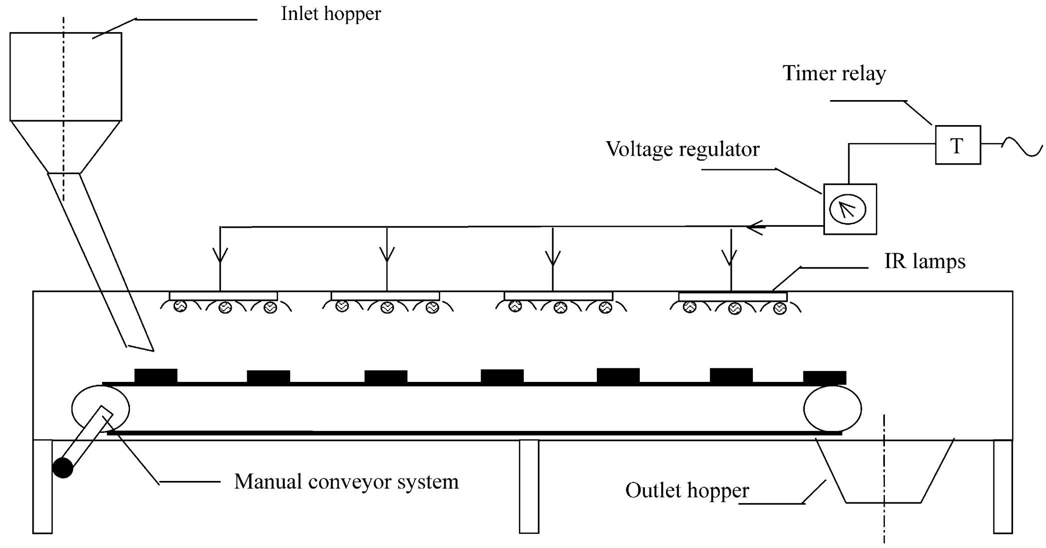

Fig. 4. Schematic diagram of a conveyor IR drying system (Ratti & Mujumdar, 1995)

ing-relay and a voltage regulating knob which can be easily regulated by a lay person.

Solar drying

Solar drying is often differentiated from "sun drying" by the use of equipment to collect the sun's radiation in order to harness the radiative energy for drying applications. Sun drying is a common farming and agricultural process in many countries, particularly where the outdoor temperature reaches 30°C or higher. In many parts of South East Asia, spice crops and herbs are routinely dried. However, weather conditions often preclude the use of sun drying because of spoilage due to rehydration during unexpected rainy days. Furthermore, any direct exposure to the sun during high temperature days might cause case hardening, where a hard shell develops on the outside of the agricultural products, trapping moisture inside. Therefore, the employment of solar dryer taps on the freely available sun energy while ensuring good product quality via judicious control of the radiative heat. Solar energy has been used throughout the world to dry food products. Such is the diversity of solar dryers that commonly solar-dried products include grains, fruits, meat, vegetables and fish. A typical solar food dryer improves upon the traditional open-air sun system in five important ways:

1. It is faster. Foods can be dried in a shorter period of time. Solar food dryers enhance drying times in two ways. Firstly, the translucent, or transparent, glazing over the collection area traps heat inside the dryer, raising the temperature of the air. Secondly, the flexibility of enlarging the solar collection area allows for greater collection of the sun's energy.
2. It is more efficient. Since foodstuffs can be dried more quickly, less will be lost to spoilage immediately after harvest. This is especially true of products that require immediate drying such as freshly harvested grain with a high moisture content. In this way, a larger percentage of food will be available for human consumption. Also, less of the harvest will be lost to marauding animals and insects since the food products are in safely enclosed compartments.
3. It is hygienic. Since foodstuffs are dried in a controlled environment, they are less likely to be contaminated by pests, and can be stored with less likelihood of the growth of toxic fungi.
4. It is healthier. Drying foods at optimum temperatures and in a shorter amount of time enables them to retain more of their nutritional value such as vitamin C. An added bonus is that foods will look and taste better, which enhances their marketability and hence provides better financial returns for the farmers.
5. It is cheap. Using freely available solar energy instead of conventional fuels to dry products, or using a cheap supplementary supply of solar heat, so reducing conventional fuel demand can result in significant cost savings.

Types of solar dryer

Solar dryers can generally be classified into two broad categories: active and passive. Passive dryers use only the natural movement of heated air. They can be constructed easily with inexpensive, locally available materials which make them appropriate for small farms where raw construction material such as wood is readily available.

A direct passive dryer is one in which the food is directly exposed to the sun's rays. Direct passive dryers are best for drying small batches of fruits and vegetables such as banana, pineapple, mango, potato, carrots and French beans (Jayaraman, Das Gupta & Babu Rao, 2000). This type of dryer comprises of a drying chamber that is covered by a transparent cover made of glass or plastic. The drying chamber is usually a shallow, insulated box with air-holes in it to allow air to enter and exit the box. The food samples are placed on a perforated tray that allows the air to flow through it and the food. Figure 5 shows a schematic of a simple direct dryer. Solar radiation passes through the transparent cover and is converted to low-grade heat when it strikes an opaque wall. This low-grade heat is then trapped inside the box by what is known as the "greenhouse effect." Simply stated, the short wavelength solar radiation can penetrate the transparent cover. Once converted to low-grade heat, the energy radiates as a long wavelength that cannot pass back through the cover.

Active solar dryers are designed incorporating external means, like fans or pumps, for moving the solar energy in the form of heated air from the collector area to the drying beds. Figure 6 shows a schematic of the major components of an active solar food dryer. The collectors should be positioned at an appropriate angle to optimize solar energy collection. A gear system can be designed to manually adjust the angle of the collectors. Tilting the collectors is more effective than placing them horizontally, for two reasons. Firstly, more solar energy can be collected when the collector surface is nearly perpendicular to the sun's rays. Secondly, by tilting the collectors, the warmer, less dense air rises naturally into the drying chamber. In an active dryer, the solar-heated air flows through the solar drying chamber in such a manner as to contact as much surface area of the food as possible. Thinly sliced foods are placed on drying racks, or trays, made of a screen or other material that allows drying air to flow to all sides of the food. Once inside the drying chamber, the warmed air will flow up through the stacked food trays. The drying trays must fit snugly into the chamber so that the drying air is forced through the mesh and food (Imre, 1995). Trays that do not fit properly will create

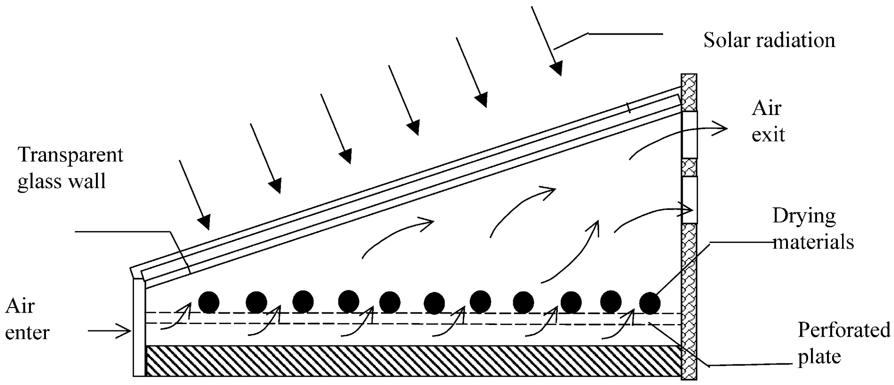

Fig. 5. Structure of a passive cabinet food solar dryer (Grabowski & Mujumdar, 2000.)

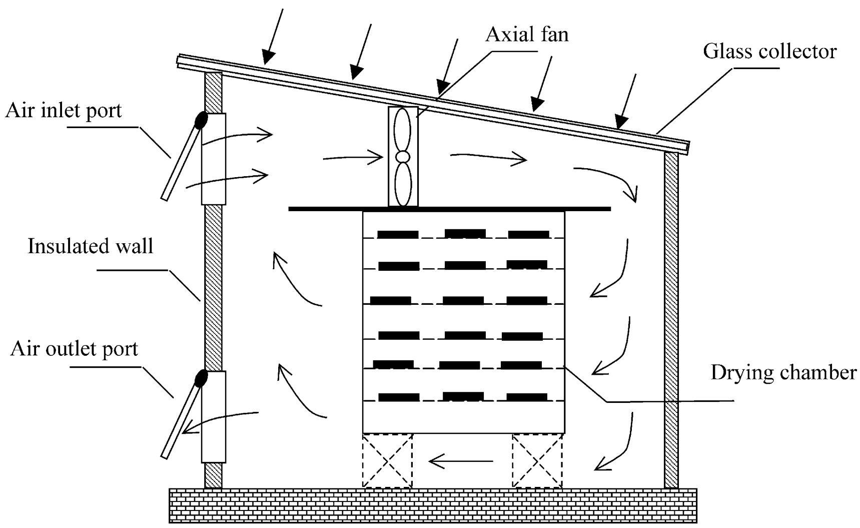

Fig. 6. Structure of an active solar convective dryer (Imre, 1995).

gaps around the edges, causing large volumes of warm air to bypass the food, and prevent the dryer from maximizing the potential of the drying air to remove moisture from the food. As the warm air flows through several layers of food on trays, it becomes moisture-laden. This moist air is vented out through the outlet port. Fresh air is then taken in to replace the exhaust air. Active solar dryers are known to be suitable for drying higher moisture content foodstuffs such as papaya, kiwi fruits, brinjal, cabbage and cauliflower slices.

Low-cost convective dryers

Low-cost convective dryers have great potential in small farming areas of less than 1 ha, where electricity can be made available. Even in remote places where electricity is not available, diesel generator is a viable alternative. Hot convective air dryers are generally used for drying piece-form fruits and vegetables such as banana, mango and pineapple slices, various tea leaves and some sturdy herbs such as basil, lemon balm and bay leaves. One good example of a low cost convective dryer is the SRR-1 dryer shown in Fig. 7 (Phan, 2002). It comprises three basic components: an axial fan, an electric heater, and a bamboo-mat drying bin. The drying bin is made up of two concentric bamboo-mat fabricated cylinders. Such a simple bin structure can easily hold one ton of paddy.

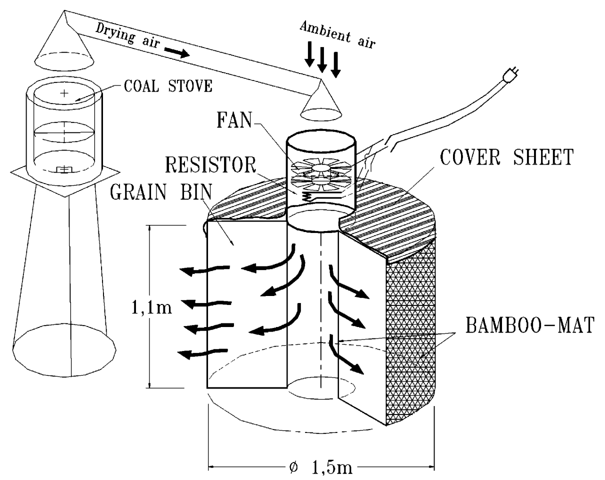

Fig. 7. Construction of SRR-1 dryer with coal stove (Phan, 2002).

To further improve the efficiency of drying with little added cost, a coal stove can be incorporated as an auxiliary heating system to the dryer, as shown in Fig. 7. The coal stove can be one sold on market for use in restaurants or large families. It burns pulverized-and-compressed coal (locally called ''honey-comb coal'') with a calorific value of about 25 MJ/kg. It is noteworthy that one unit-heat of this coal is approximately 7–12 times cheaper than one unit-heat of electricity. With the installation of the stove, the heated flue gas from the stove is sucked through a pipe to the fan inlet, and mixed with the ambient air. The stove consumes 0.9–1.0 kg of coal per hour. The time period for refilling of the coal is 3 h. According to Phan (2002), employing the stove allows the air temperature to be raised in the range of 5–9°C, with a correspondingly lower air humidity, from 95–100% down to 75–60%, resulting in a significant improvement in the drying potential of the air and hence, shortening the drying time to obtain the desired moisture content of the grain.

Figure 8 shows a simple cabinet dryer made from materials such as wood, galvanized iron sheeting, AC sheet, asbestos rope, and mild steel sheet. The dryer comprises a centrifugal fan, a drying chamber, a food tray system and a heating unit. The drying chamber has an air distribution unit in the center with copra trays on both sides. The hot air is distributed over the trays by the air distribution unit and exit of the air is provided such that the hot air then passes through the material to be dried. This ensures uniform mixing of the air and material being dried. The capacity of the dryer is 1000

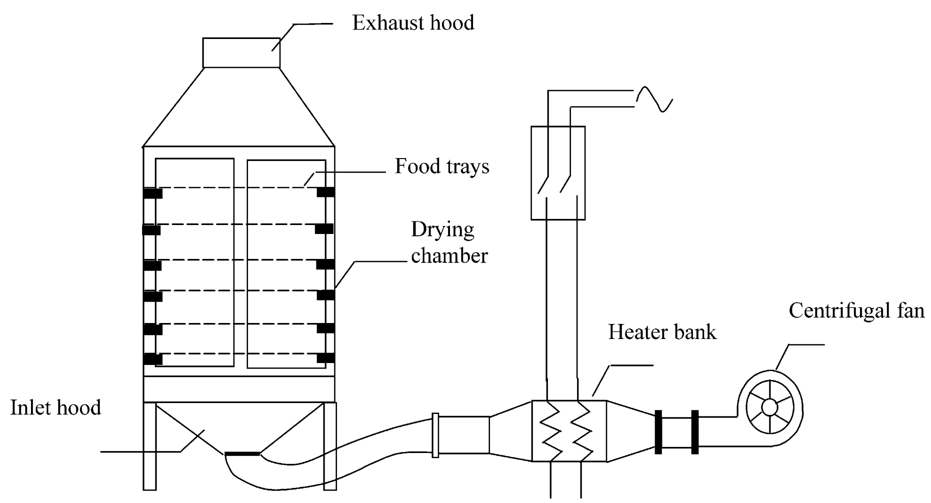

Fig. 8. Mechanical copra dryer developed by CPCRI (Patil & Singh, 1983).

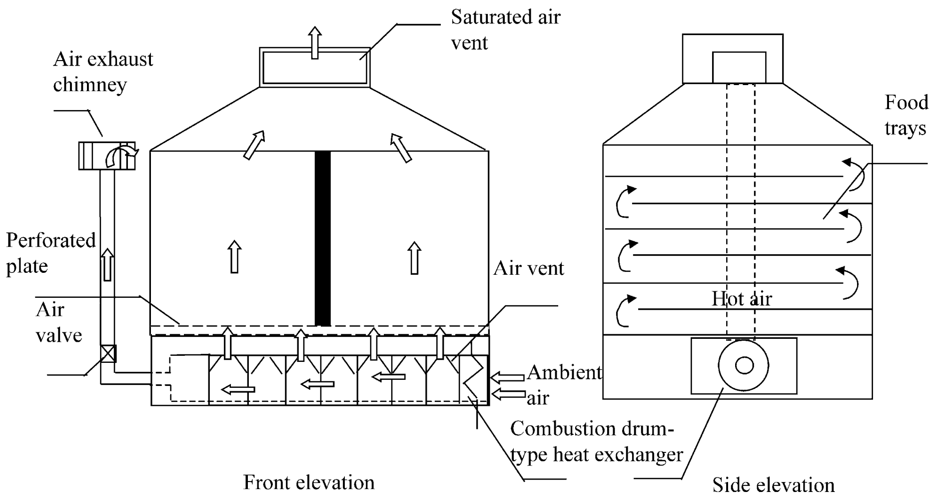

Fig. 9. Natural convection food dryer for soyabean (Patil & Shukla, 1988).

nuts/batch and drying time is 30 h. The cost of the dryer is approximately AUS$ 1200 and the operating cost AUS$ 65.3/ton (Patil & Singh, 1983).

Another low operating cost convective dryer, using agricultural waste as fuel and working on the principle of natural convection of hot air currents, has been developed (Patil & Sukla, 1988). The dryer is made in two parts (Fig. 9). The bottom portion is a mild steel angle frame and is covered with asbestos sheet on the sides and wire mesh on the top. A drum-type, combustion heat-exchange unit with fins for effective heat transfer is located at the center of this chamber. A chimney with a regulator valve has been provided at the other end to allow the smoke to escape. A drying chamber made of softwood and plywood can easily hold 20 food trays. The bottom of the drying chamber is open and the top portion is provided with an air vent with an adjustable opening. Fuel is burned in the burning chamber at the rate of 3 kg/h. The dryer can house 100 kg of wet material. The average temperature in the dryer, at this rate of combustion, is 49°C at no load, and 46°C while drying. The trays are interchanged and the material is mixed/stirred at 1-h intervals. The drying time for soy split to reduce moisture content from 60 to 10% was 15 h. To dry flakes from 30 to 10% required 6 h. The approximate cost of the dryer is AUS$ 570 and the cost of drying is expected to be low at AUS$ 25/ton.

Desiccant drying

Desiccant drying started off mainly in the air-conditioning industries to improve air quality for thermal comfort. However, in recent years, desiccant drying has become a popular method for the drying of herbs and flowers. Flowers dried via desiccant drying possess excellent product quality in terms of color, texture and lasting. Typical desiccants suitable for herbs and flower drying include silica gel, borax, cornmeal or alum.

The advantages of a desiccant drying system include:

1. the moisture-laden desiccant can be re-generated by passing it through a stream of hot air which absorbs the moisture;
2. the system is easy to design and ensures years of maintenance-free operation;
3. incorporating the desiccant with other drying systems such as solar and fluidized bed results in a significant reduction in energy consumption per kg of moisture removed;
4. easy access of replacement of the desiccant media after cycles of operations.

Examples of typical flowers suitable for desiccant drying are roses, lavender, chamomile and clover. These flowers are often dried as a whole or with their petals removed for efficient drying. Parsley, rosemary and thymes are known to be suitable herbs for desiccant drying.

For very heat-sensitive products like mushroom, study has found desiccant drying to be the best drying technique (Gürtas Seyhan & Evranuz, 2000). Previously mushroom drying was carried out using freeze dryers, which is often expensive and time consuming. Desiccant drying not only ensures that the structure of the mushroom is well maintained but also its chemical constitutes, often known for possessing medicinal effects, are well preserved. Several researchers have recently found improved quality of dried agricultural products by integrating the desiccant system into the traditional solar drying system. Hodali and Bougrad (2001) found improved quality and reduced drying time, from 52 to 4 h, for the drying of apricots in Morocco. Dai, Wang and Xu (2002), in combining a rotary desiccant wheel system with a solar-powered adsorption refrigeration system for the cooling of grain, found better performance in terms of energy savings and lower operating

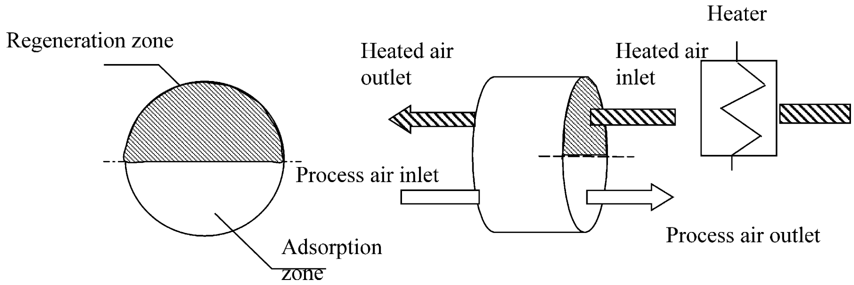

Fig. 10. A desiccant wheel system for drying application (Zhang & Niu, 2002).

costs for this hybrid system compared to a purely adsorption refrigeration system.

One of the most promising desiccant drying systems of recent years is the desiccant wheel (Zhang & Niu, 2002), as shown in Fig. 10. In the adsorption region, the desiccant adsorbs water vapor and the dehumidified air is then delivered through the process outlet directly into the drying chamber. Then, as the desiccant media rotates it switches the adsorption and regeneration zone, and the hot air entering into the regeneration zone inlet drives off the moisture and exhausts it into the atmosphere. After regeneration the hot, dry desiccant rotates back into the process air stream where a small portion of the process air cools the desiccant so that it can begin the adsorption process all over again. To increase dehumidification capacity, farmers can either increase the diameter of the rotating bed to hold more desiccants, or increase the number of beds stacked on top of one another. Such a rotating horizontal bed design offers low first cost and reduced operating overheads. Also, the design is simple, compact and easy to produce as well as install and maintain, which makes it suitable for application in rural farm areas.

A dual role of the desiccant system can be considered when storage is required for both dried and freshly-harvested products. Products like cereal grains and plant seeds often require special attention after drying as they need to be stored in vast quantities and for long periods. The two factors that most influence the seed viability are temperature and moisture content. The moisture content of the seed is a function of the surrounding ambient relative humidity (RH). Therefore, to minimize fungal activity which can cause a decrease in seed viability, discoloration and possible production of harmful substances such as mycotoxins, proper storage conditions requires a RH of below 70%. The desiccant wheel system can then be utilized in storage facilities to produce the required RH to ensure optimal germinability of seeds, and longer shelf life of grains. This additional application of the desiccant systems makes it even more attractive to rural farming areas whereby drying and storage functions are often known to be inadmissible.

Conclusions

Given a proper sized, low-cost dryer, food processing can proceed uninterrupted in rural areas. At the village level, localized farmers, or factories, wanting to process their surplus crops into acceptable and marketable food items need low-cost but efficient dryers for their operations. Presented in this paper are some practical low-cost, easy-to-fabricate and easy-to-operate dryers that can be suitably employed at small-scale factories or at rural farming villages. Such low-cost food drying technologies can be readily introduced in rural areas to reduce spoilage, improve product quality and overall processing hygiene. The eventual objective of employing these appropriate drying technologies is to significantly improve the agricultural returns for farmers in appreciation of the hard effort they have devoted in crop cultivation.

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