Al-Azhar Journal of Agricultural Engineering 3 (2022) 26-36

Contents lists available at Egyptian knowledge Bank (EKB)

Al-Azhar Journal of Agricultural Engineering

journal homepage: https://azeng.journals.ekb.eg/

Full length article

The date fruit drying systems: acritical over review

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ARTICLE INFO

Handling Editor - Dr. Mostafa H. Fayed

Keywords:
Date Fruit
Drying Systems
Solar drying
Oven, Microwave.

Agricultural Products Process Engineering

ABSTRACT

Aswan Governorate is considered the largest governorate of Egypt producing dried dates, and the most famous varieties are Sakkoti, Bartamuda, Gondaila, Malkabi, and Shamia. Immediately after harvest, dates contain a high percentage of moisture, which must be properly disposed of in order to maintain chemical composition and natural properties, and also for long-term storage. There are many drying systems that can be used to dry dates and reduce the moisture content to the safe storage limit. In Aswan, we practice sun drying in the open air for a period of 1 to 2 months, the date fruit is dehydrated, but the quality is very poor compared to industrial drying. This research aims to study the different drying systems that can be used to dry dates and maintain their physical and chemical properties.

1. Introduction

The drying process is one of the oldest forms of processing and preserving food; the drying process aimed to extend the shelf life of certain foods, minimize packaging requirements and reduce shipping weights (Okos et al., 1992). Drying of data decreases the water activity and increases the sugars concentration, which inhibits enzymatic degradation and limits microbial growth. Therefore, the shelf life of dry dates is high and is available for extended periods. Due to the absence of liquid water and the low temperature required for the process, most deterioration and microbiological reactions are stopped which gives a final product of excellent quality (Al-Shahib and Marshall, 2002). Barreveld (1993) found that heat treatment of dates provided it is applied at a maximum of 60-65°C may have the combined beneficial effect of destroying insect life, reducing the microbial count, and decreasing enzyme activity, all factors that work in favor of creating a product with a prolonged storage life. The dehydration in air driers at controlled temperatures and airflow will ensure an appropriate level of moisture in date sand better preservation of the product quality. Reduction of moisture to a very low level would result in fruits being too hard to eat and inappropriate for some consumers and may necessitate rehydration (Falade and Abbo, 2007). Also, Kader and Hussein (2009) reported that dates need to be dehydrated to the optimal moisture content for preserving their quality during subsequent handling and storage. Dehydration may be done concurrently with ripening. Heated air must be used to dry the dates to their desired moisture content. Dry the dates to 20% moisture or lower to greatly reduce the incidence of molds and yeasts.

2. Literature review

2.1. Drying methods for dates

There are different methods available for drying dates like sun drying, hot air oven drying, solar drying, drum drying tray drying, etc. (Borchani *et al.*, 2011).

Drying methods for dates may be concluded as follow:

1. Open sun drying.

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Peer review under responsibility of Faculty of Agricultural Engineering, Al-Azhar University, Cairo, Egypt.
Received 24 April 2022; Received in revised form 9 May 2022; Accepted 10 May 2022
Available online 3 August 2022

2. Solar dryers.
3. Vacuum drying of dates.
4. Hot Air oven drying.
5. Spraying drying of date pulp.
6. Drum drying of dates.
7. Microwave drying of dates.
8. Freeze drying.
9. Microwave-vacuum dryer.

2.2. Open Sun Drying

The most common method throughout history for drying dates has been sun drying. This process of sun-drying has its challenges in that daytime temperature and humidity cannot be controlled, the fruit is in contact with the open environment (a possible source of contamination due to dust, soil, sand particles, and insects), and the fact that the process takes too much time. Due to the downsides of this processing method, sun drying does not provide an effective process for quality production (Doymaz, 2005).

To reduce these problems, other forms of processing should be taken into consideration, which may improve quality in terms of color or nutrients. In today's world, it seems that the most effective and common form of processing is the convective drying method, because of its ability to reduce the moisture content in food and preserve it well (Mundada et al., 2010). However, there are many downsides to the convective method that must be observed. For example, the detriments of using this method include the high temperatures and the long drying times that are used. These detriments can have negative effects on the actual flavor and nutrients of the final product produced (Maskan, 2001).

Manaa et al. (2013) investigated that many varieties are well suited, and a very productive part of the surplus production is processed into dried dates. Practically, after sun drying in the open air for a period of 10 to 15 days, the date fruit is dehydrated, but the quality is very poor compared to industrial drying.

Fig. 1. Shows the working principle of open sun drying by using only solar energy. (Saikiran et al., 2018)

The crops are generally spread on the ground, mat, cement floor where they receive short-wavelength solar energy during a major part of the day and natural air circulation. A part of the energy is reflected, and the remaining is absorbed by the surface depending upon the color of the crops. The absorbed radiation is converted into thermal energy and the temperature of the material starts to increase. However, there are losses like the long wavelength radiation loss from the surface of the crop to ambient air through moist air and also convective heat loss due to the blowing wind through moist air over the crop surface. In general, the open sun drying method does not fulfill the required quality standards and sometimes the products cannot be sold in the international market. With the awareness of inadequacies involved in open sun drying, a more scientific method of solar-energy utilization for crop drying has emerged termed solar drying (Sharma et al., 2009).

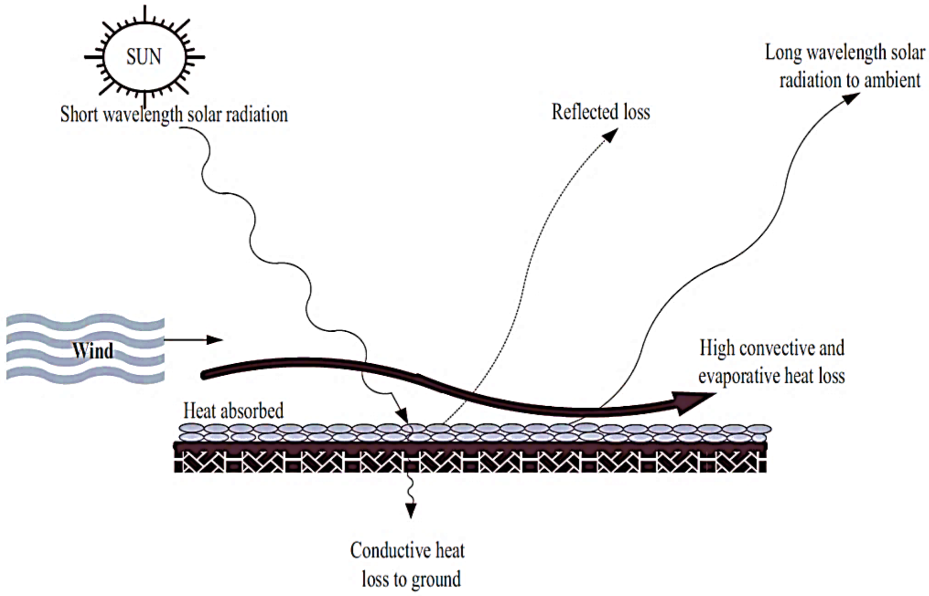

Fig. 2. Working principle of open sun drying. (Tomar et al., 2017)

2.3. Solar Dryers

In many parts of the world, there is a growing awareness that renewable energy has an important role to play in extending technology to the farmer in developing countries to increase their productivity (Waewsak et al., 2006). Solar thermal technology is a technology that is rapidly gaining acceptance as an energy-saving measure in agriculture applications. It is preferred to other alternative sources of energy such as wind and shale because it is abundant, inexhaustible, and non-polluting (Akinola, 1999; Akinola and Fapetu, 2006).

2.3.1. Classification of Solar Dryers

1. Drying equipment may be classified based on two methods:
2. the method of transferring heat to the product or
3. the handling characteristics and physical properties of the product.

The first method of classification reveals differences in dryer design and operation, while the second method is most useful in the selection of dryer type. A classification chart of solar dryers based on heat transfer is shown in Fig. 3 (Sharma et al., 2009; Ekechukwu, 1999).

This chart classifies dryers as direct or indirect solar dryers, with subclasses of continuous or batch-wise operation. Solar energy drying systems are classified primarily according to their heating modes and how the solar heat is utilized (Belessiotis and Delyannis, 2011).

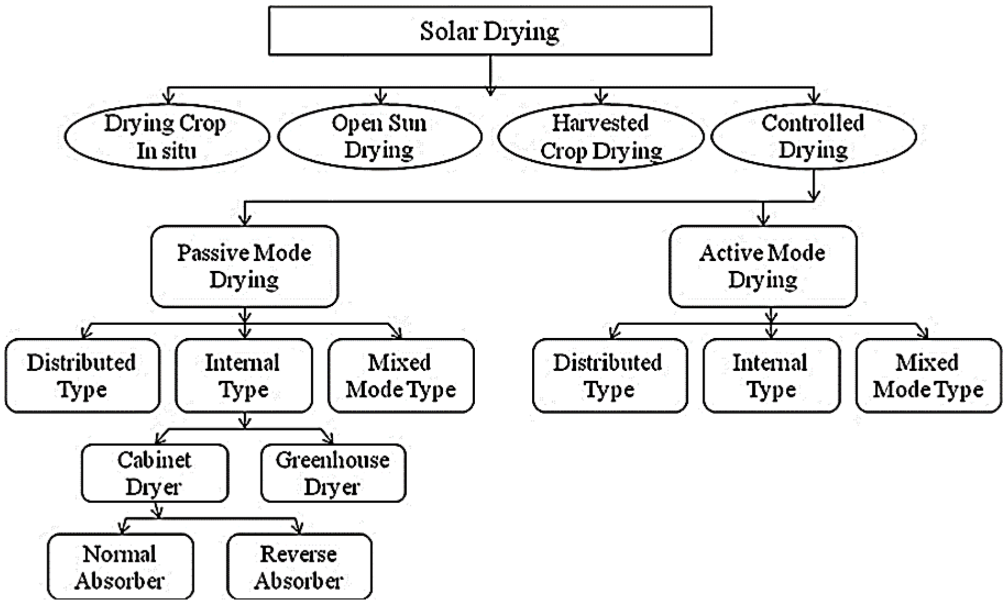

Fig. 3. Classifications of dryers and drying modes. (Tomar et al., 2017)

In broad terms, they can be classified into two major groups, namely: the first group is the Passive solar-energy drying systems (conventionally termed natural-circulation solar drying systems) and, the second group is the active solar-energy drying systems (most types of which are often termed hybrid solar dryers). Three distinct sub-classes of either the active or passive solar drying systems can be identified namely, (1) direct-type solar dryers; (2) indirect-type solar dryers; and hybrid solar dryers. The main features of typical designs of the various classes of solar-energy dryers are illustrated in Fig. 3 showing three main groups for solar dryers based on the energy sources used (Leon et al., 2002). The design of solar dryers is adjusted to the quantity, character, and designation of the material to be dried as well as to the energy sources used, and accordingly, various types of solar dryers have been developed and are in use to date.

2.3.2. Passive Solar Drying Systems

In a passive solar dryer, the air is heated and circulated naturally by buoyancy force or because of wind pressure or in a combination of both. Normal and reverse absorber cabinet dryer and greenhouse dryer operates in passive mode. Passive drying of crops is still in common practice in many places around the world, tropical and subtropical regions especially in Africa and Asia, or in small agricultural communities. These are primitive, inexpensive in construction with locally available materials, easy to install and to operate especially at sites far off from the electrical grid. The passive dryers are best suited for drying small batches of fruits and vegetables such as banana, pineapple, mango, potato, carrots, etc. (Hughes and Oates, 2011).

2.3.2.1. Direct-Type Passive Solar-Energy Dryers

The features of a typical direct-type passive solar dryer are illustrated in Fig. 4. In this type of solar dryer, the direct exposure of the crop to the sunlight enhances the color ripening desired in certain varieties of grapes, dates, coffee, and the development of full flavor in roasted beans. Two basic types of dryers in this category can be identified the cabinet and greenhouse dryers (Visavale, 2012).

The working principle of direct solar crop drying is shown in Fig. 4. Here the moisture is taken away by the air entering the cabinet from below and escaping through at the top exit as shown in Fig. 4. In the cabinet dryer, of the total solar radiation impinging on the glass cover, a part is reflected the atmosphere, and the remaining is transmitted inside the cabinet. A part of the transmitted radiation is then reflected from the crop surface and the rest is absorbed by the surface of the crop which causes its temperature to increase and thereby emits long-wavelength radiations that are not allowed to escape to the atmosphere due to the glass cover. The overall phenomena cause the temperature above the crop inside the cabinet to be higher. The glass cover in the cabinet dryer thus serves in reducing direct convective losses to the ambient which plays an important role in increasing the crop and cabinet temperature (Sharma et al., 2009).

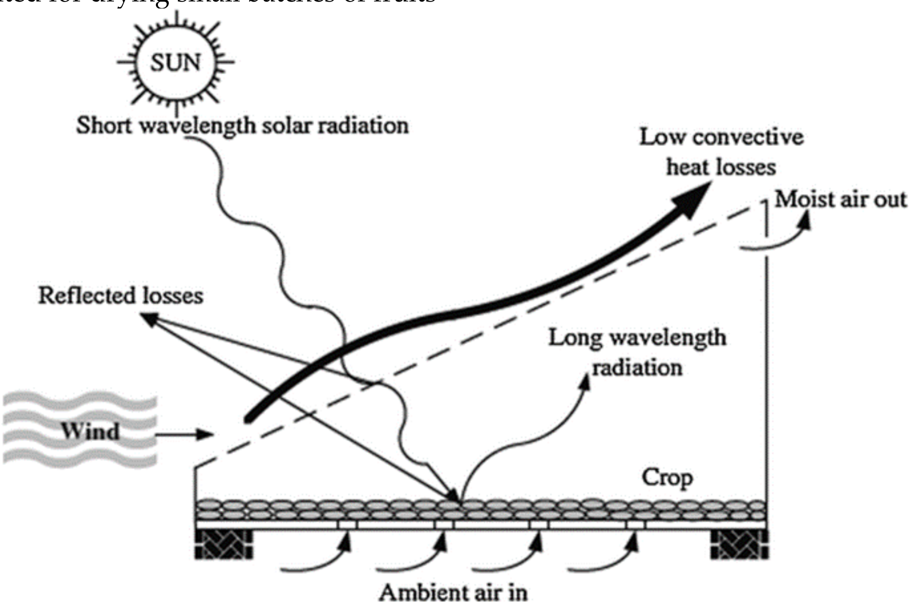

Fig. 3. Working principle of direct solar drying. (Tomar et al., 2017)

2.3.2.2. Indirect-Type Passive Solar-Energy Dryers

These are indirect-type dryers with natural convection of air for drying. To increase the capacity of a dryer i.e., operate with more than one layer of trays with crops within the available area, the trays are generally placed in vertical racks with some space in between consecutive trays. The additional resistance generated for the air movement due to this arrangement of the trays is achieved by the "chimney effect". The chimney effect increases the vertical flow of air because of the density difference of the air in the cabinet and atmosphere (Visavale, 2012).

These differ from direct dryers with respect to heat transfer and vapor removal. Fig. 5 describes the working principle of indirect solar drying. The crops in these indirect solar dryers are in trays or shelves inside an opaque drying cabinet and a separate unit termed as a solar collector is used for heating the entering air into the cabinet. The heated air is allowed to flow through/over the wet crop that provides the heat for moisture evaporation by convective heat transfer between the hot air and the wet crop. Drying takes place due to the difference in moisture concentration between the drying air and the air in the vicinity of the crop surface (Sharma et al., 2009).

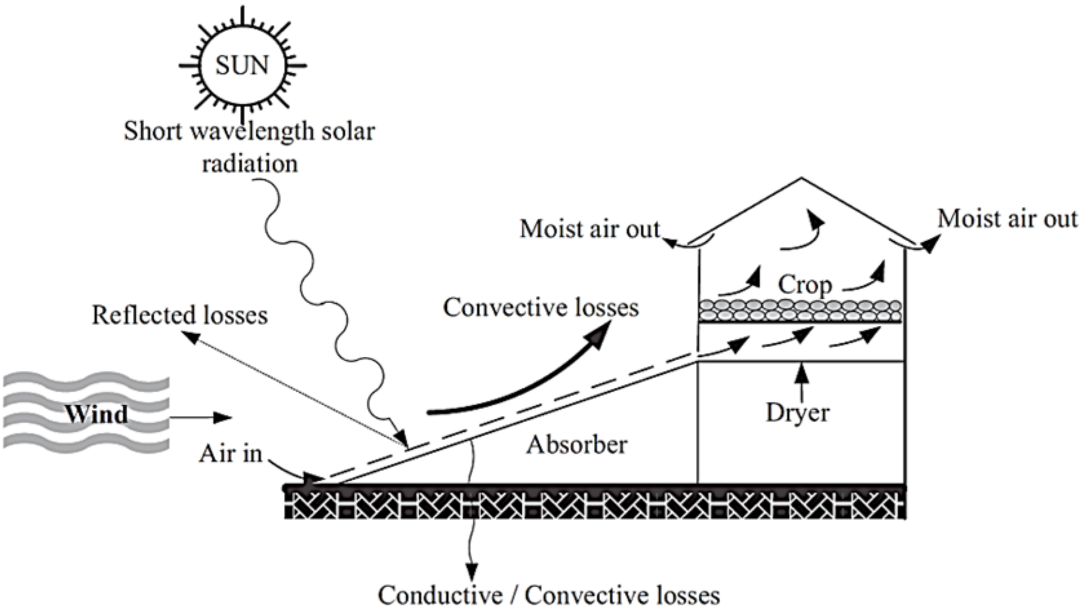

Fig. 5. Working principle of the indirect solar drying system. (Tomar et al., 2017)

2.3.2.3. *Hybrid-Type Passive Solar-Energy Dryers*

A hybrid type passive solar-energy dryer would have the same typical structural features as the indirect-type and direct-type (i.e., a solar air heater, a separate drying chamber, and a chimney), and in addition, has glazed walls inside the drying chamber so that the solar radiation impinges directly on the product as in the direct-type dryers as shown in Fig. 6. Several other designs of the hybrid-type passive solar energy have also been reported in (Hughes and Oates, 2011; Amer et al., 2010).

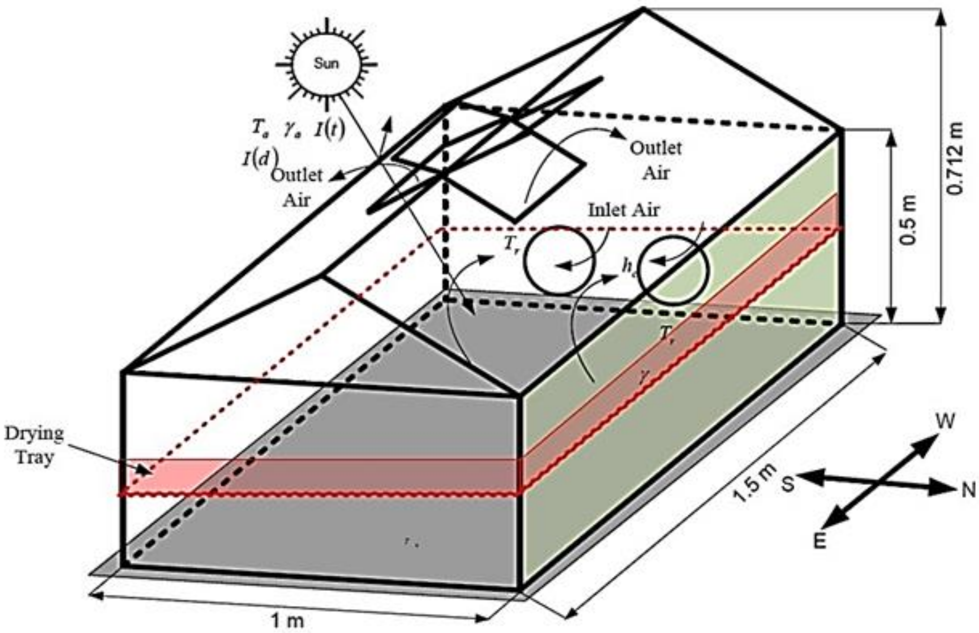

Fig. 6. Greenhouse dryer under passive mode. (Prakash and Kumar, 2014)

2.4. Active solar drying systems

Active solar drying systems 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. Thus, all active solar dryer is, by their application, forced convection dryer. A typical active solar dryer depends on solar energy only for the heat source, while air circulation uses motorized fans or ventilators. These dryers find major applications in large-scale commercial drying operations in combination with conventional fossil fuel to have a better control over-drying by consolidating the effect of fluctuations of the solar insolation on the drying air temperature. Active solar dryers are known to be suitable for drying higher moisture content foodstuffs. A variety of active solar-energy dryers exist which could be classified into either the direct-type, indirect-type, or hybrid dryers (Visavale, 2012).

2.4.1. Indirect-Type Active Solar Drying Systems

These active dryers have a separate collector and drying unit. They are generally comprised of four basic components viz., a solar air heater, drying chamber, a fan for air circulation and ducting. Due to the separate air heating unit, higher temperatures can easily be obtained with control on airflow rate. However, as the efficiency of the collector decreases at higher temperature operation, an optimum temperature and airflow rate have to be determined to have a cost-effective design. While most solar collectors are made up of metal or wood absorbers with appropriate coatings, materials like black polythene are also used as they form an economic substitute. Fig. 6 shows a typical indirect-type active solar dryer (Visavale, 2012).

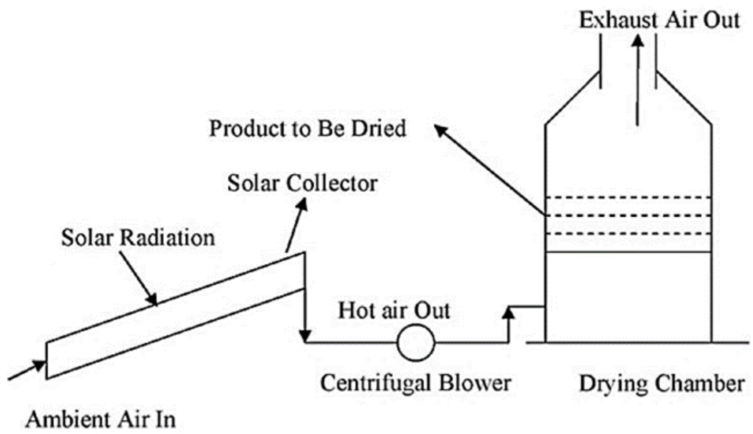

Fig. 6. Indirect solar drier (Forced convection solar drier). (Amer et al., 2010)

2.2.2. Direct-Type Active Solar-Energy Drying Systems

The direct-type active solar dryers are designed with an integrated solar energy collection unit. Generally, three distinct designs of direct-type active solar dryers can be identified viz., the absorption type, and storage type, and greenhouse dryers (Visavale, 2012).

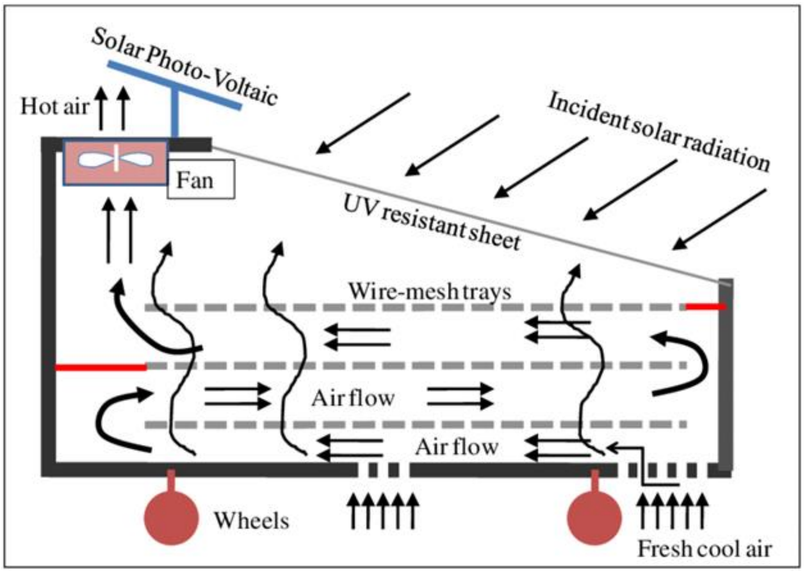

Fig. 7. Direct-Type Active Solar-Energy Drying Systems. (Gupta, 2016)

2.2.3. *Hybrid-Type Active Solar-Energy Dryers*

The hybrid solar dryers combine the features of solar energy with a conventional or some auxiliary source of energy and can be operated either in combination or in a single mode with either source of energy. These dryers generally are medium to large installations operating in the range of 50-60% and compensate for the temperature fluctuations induced by the climatic uncertainties. Fig. 8 shows the features of a typical active-type hybrid solar dryer. Typical practical designs for large-scale commercial forced-convection greenhouse dryers are of the type of solar kilns for timber drying (Fig. 8), transparent roof solar brans, and small-scale force-convection dryers equipped with auxiliary heating. Typical designs include the roof or wall of the dryer functioning as a collector of the drying chamber (Bena and Fuller, 2002).

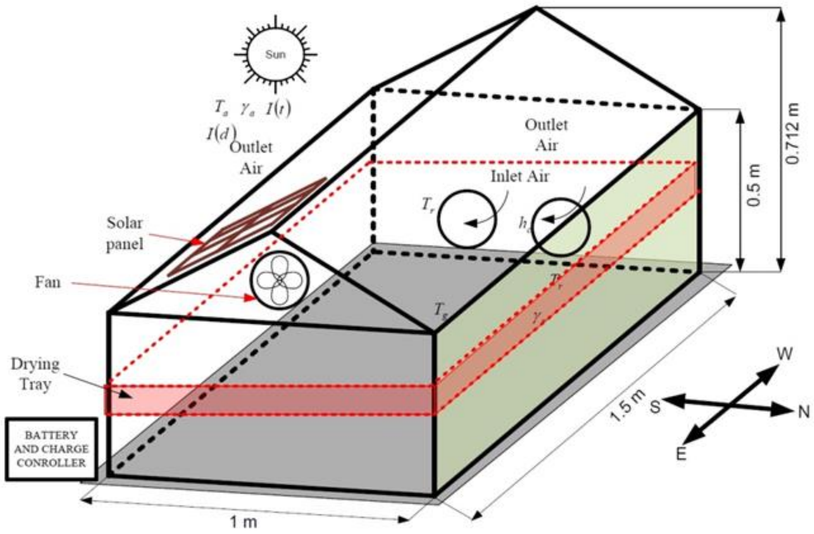

Fig. 8. Greenhouse dryer under active mode. (Prakash and Kumar, 2014)

2.5. *Vacuum* Drying of Dates

Drying under vacuum is more expensive than atmospheric drying because vacuum dryers need to be strong enough to withstand the pressure difference between the inside and the outside of the drying chamber. Thus, there must be advantages to justify the use of vacuum drying instead of atmospheric drying. Among these advantages, the greatest is the superior quality of the product which results from processing at a lower temperature. The absence of oxygen under vacuum constitutes an additional advantage when drying oxygen-sensitive materials. Increased drying rates also contribute. It is well-known that at atmospheric pressure, 101.325 kPa, water boils at 100 °C. During a vacuum drying process, sub-atmospheric pressures are achieved inside the drying chamber. Therefore, it is possible to boil the water contained in the food at lower temperatures when compared to atmospheric drying. The simplest equipment for vacuum drying foods is a vacuum oven. In this equipment, a drying chamber containing a metallic plate at the bottom that is heated by an electrical resistance receives the food sample. The food is usually placed inside a glass or metal container to form one single layer. A pump provides the chamber with a vacuum. A gauge called a vacuometer shows the value of the pressure inside the chamber. A digital display and buttons allow temperature control. Fig. 9 shows the schematic of a vacuum oven (Reis, 2014).

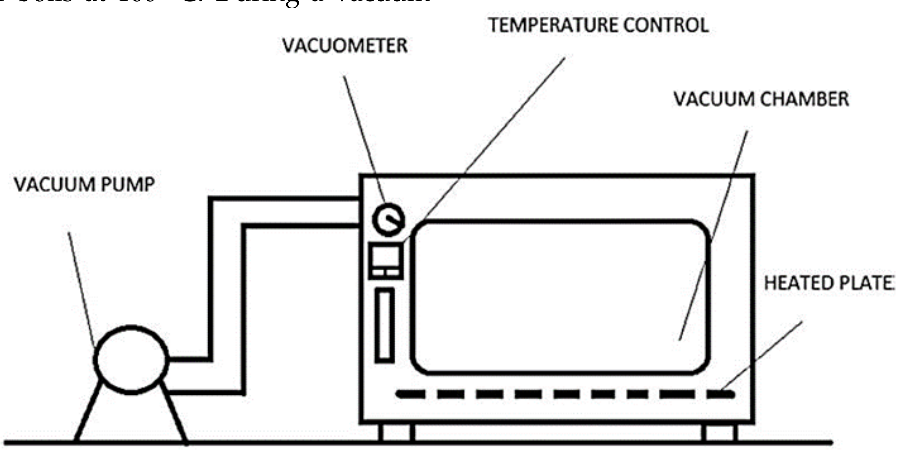

Fig. 9. Schematic of a vacuum oven. (Reis, 2014)

2.6. Hot Air Oven Drying

The dates of Aseel variety, a quantity of 33 kg was kept in a hot air oven dryer at a temperature of 60°c for 22-24 hrs such that the hot air inside the oven is circulated by the blower, later the dates were cooled 4-5°c and are packed in card boxes. And the observations in processed dates are pH 6.1, acidity 0.26%, moisture 16.2% total sugar 60.3% (Haider et al., 2012).

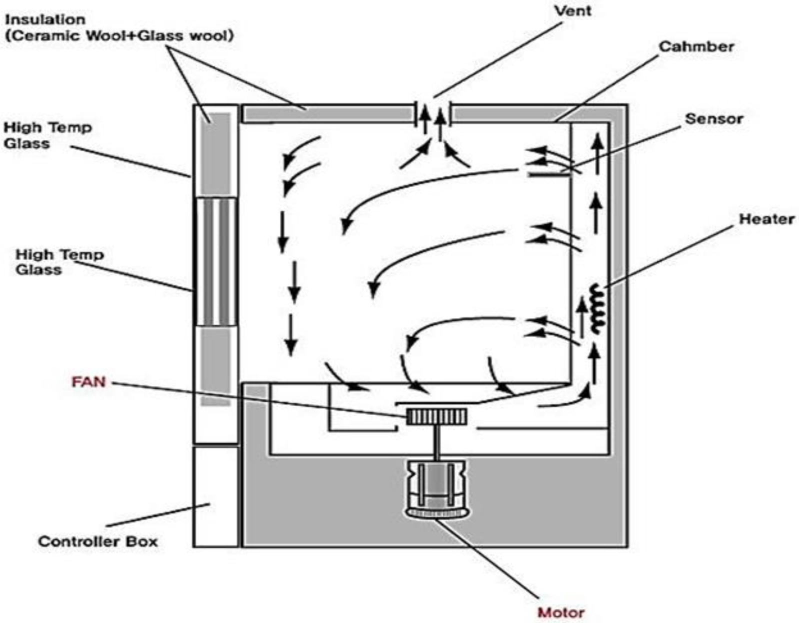

Fig. 10. Hot Air Oven Drying (Zhang et al., 2006)

2.7. Spraying Drying of Date Pulp

A study was carried by Manickavasagan et al. (2015) to produce free-flowing powder by using a pilot-scale spray drier. The feedstock required for the drying was prepared by removing the seed and the cap of dates and soaking them in water at a temperature of 60°C for 10 minutes. The variety of dates used in this study was Fardh cultivar dates, the most common commercial variety of dates in Oman. They dried the feedstock by using a pilot scale spray drier. They determined the physicochemical properties of the obtained spray dried product and also the powder was to scanning electron microscope to know the texture and structure of the developed powder. The different processing conditions of the study were, 2 carrier agents were maltodextrin and gum Arabic, 2 inlet air temperatures 150°C and 170°C, 2 feedstock flow rates 25 ml/min and 40 ml/min. The carrier agents were added at 0.4 kg per 1 kg of the date's pulp. The feedstock prepared for spray drying operation was at a 20% concentration. The date powder obtained in all 8 treatments was subjected to various analyses like moisture content, color, bulk density, wettability, solubility index, hygroscopicity, SEM analysis, and also the determination of total phenolic compounds of the dates powder. The carrier agent affects the gum physiochemical properties of the date's powder, but there was no difference in the phenolic compounds produced by maltodextrin and gum Arabic. The results of the SEM revealed that the dates powder produced from maltodextrin was smooth and spherical but with severe agglomeration, whereas the dates powder produced from gum Arabic was having irregular spheres with small particles with a dented surface (Hassan and Hobani, 2000; Navarro, 2006).

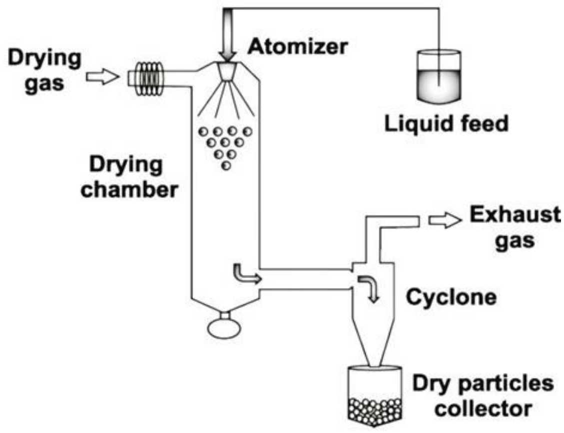

Fig. 11. Spraying Drying of Date Pulp. (Alejandro and Seremeta, 2015)

2.8. Drum Drying of Dates

The drum dryer is a type of drying equipment that works on the principle of direct application of heat to the product to remove moisture from the product. The drum dryer is used for drying liquid foods and pulps. The dates of variety koalas which were taken at the unripe stage and the seed is removed, the date flesh is made into pulp by using the mixer. The pulp obtained is divided into 6 parts, each of 340 g. The drum is operated at 20 rpm, 30 rpm, and 40 rpm. Out of total of 6 samples, it was observed that the moisture removed from the pulp during the low speeds (20 rpm, 30 rpm) is very high compared to that of moisture removed during the drum at 40 rpm. So, the drum drying of dates (as the pulp) at low drum speeds is an efficient process for moisture removal from dates. The powder obtained from the dryer was analyzed for moisture, ph, water activity, color, and TSS. The samples obtained from drum drying were dried in a tray drier for 72 hours at a temperature of 65°C to bring the samples to the safe moisture level. The obtained tray dried samples were analyzed for moisture, ph, water activity, color, and TSS. (Manickavasagan et al., 2015).

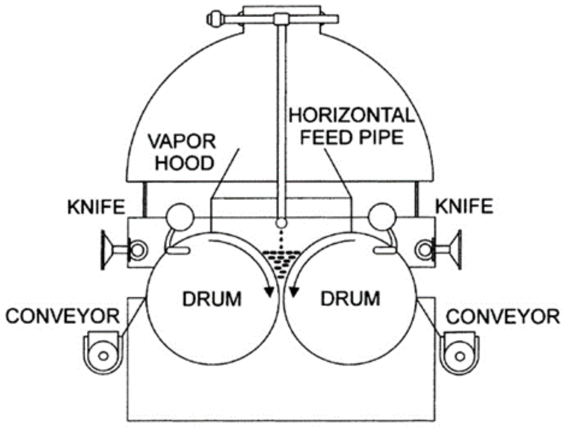

Fig. 12. A twin-drum dryer for thin slurries. (Sloan, 1967)

2.9. Microwave Drying of Dates

In a study conducted by İZLİ et al., (2017) the microwave drying reduced the drying time (16 min) when compared to other methods. The reduction in drying time is due to the drying temperatures in the range of 60°C to 80°C. The phenolic compounds of the dried dates increased to the fresh dates, and this might be due to the increased temperatures which lead to greater cell disruption. The freeze-drying of dates took more time compared to that of microwave drying. For any quality assessment, color is the most important factor, the color of dates obtained by freeze-drying is very impressive than the fresh dates. The total phenolic compounds also decreased when compared to microwave drying.

2.10. Freeze-Drying

The process of freeze-drying could be described as follows: initially, the Product is frozen solid; then it is exposed to a controlled temperature-pressure environment in a suitable chamber; the pressure in the chamber is regulated as to promote the direct transition from the solid-state to the vapor state (sublimation), avoiding ice melting. When pressure is reduced below 0.006 atm, solid ice sublimates. For example, at 0.003947 atm, the ice sublimates at −6 °C; at 0.000658 atm ice sublimates at −25 °C. Although, the water in food is seldom pure, presenting soluble compounds that low its freezing point. Therefore, it is necessary to be aware of the eutectic point, which can be defined as the lowest freezing point of food, being directly related to this food composition (Caro-Corrales et al., 2005).

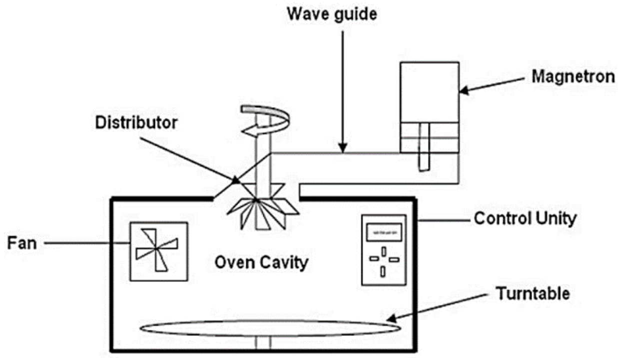

Fig. 13. Schematic diagram of the microwave dryer. (Karaaslan and Tunçer, 2011)

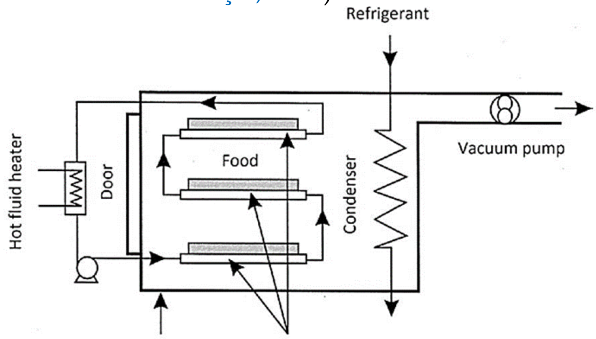

Fig. 14. Schematic of a freeze-dryer. (Deng and Zhao, 2008)

2.11. Microwave-vacuum dryer

In a microwave-vacuum dryer, the heat is obtained by electromagnetic radiation. Such energy is absorbed by the water molecules contained in the food and converted into kinetic energy. This promotes an intense vibration in water molecules, generating heat, which is used for their evaporation. The results are high drying rates at low temperatures. Nevertheless, to obtain homogeneous sample heating, it is necessary to use samples with a small thickness (Cui et al., 2004).

A typical microwave-vacuum dryer of foods is composed by a microwave oven, a glass vacuum desiccator, a vacuum pump, a pressure regulator, and a condenser. Fig. 15 shows the schematic of a microwave-vacuum dryer (Antal *et al.*, 2011).

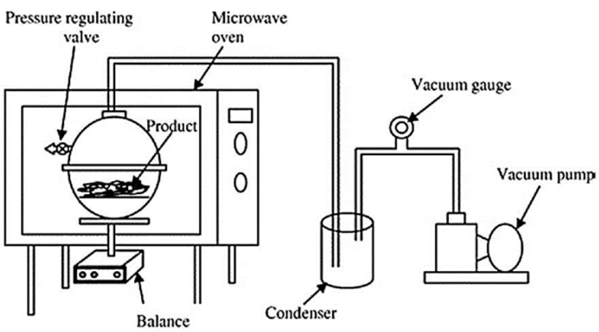

Fig. 12. Schematic of a microwave-vacuum dryer. (Cui et al., 2004).

3. Conclusions

Because of the drying process of Aswan's dry dates, is extremely important to reduce the moisture percentage to the safe level for storage. The existing drying method in Aswan Governorate is direct solar drying in the open air; this method led to contamination of the dates with dust, insects, rodents, animals, and other materials that can lead to poisoning sometimes, and this research aimed to do surveying of the different methods that can be used in drying Aswan's dry dates which can lower the moisture level and security on public health. I recommend that depending on Aswan's weather conditions, the appropriate drying methods can be used in the greenhouses by installing air suction fans and using them to dry the dates, with no additional cost for farmers.

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دراسة مرجعية عن أنظمة تجفيف ثمار البلح

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الملخص العربي

تعتبر محافظة أسوان أكبر محافظات مصر التي تنتج التمور المجففة، وأشهر أصنافها: الملكابي، الجنديلة، السكوتي، البرتمودة، والشامية. بعد الحصاد مباشرة، تحتوي التمور على نسبة عالية من الرطوبة، والتي يجب التخلص منها بشكل صحيح من أجل الحفاظ على التركيب الكيميائي والخصائص الطبيعية، وكذلك للتخزين طويل الأجل. وهناك العديد من أنظمة التجفيف التي يمكن استخدامها لتجفيف التمور وتقليل محتوى الرطوبة إلى حد التخزين الآمن. في أسوان، يتبع المزارعين نظام التجفيف بالشمس في الهواء الطلق لمدة تتراوح من شهر إلى شهرين، يتم تجفيف ثمار التمر، ولكن الجودة رديئة جدًا مقارنة بالتجفيف الصناعي. يهدف هذا البحث إلى دراسة أنظمة التجفيف المختلفة التي يمكن استخدامها لتجفيف التمور والحفاظ على الخواص الفيزيائية والكيميائية.