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***Full Length Article***

# Dehydration of Agricultural Products by Mixed Mode Solar Dehydrator

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## ABSTRACT

Agricultural products were dehydrated by solar energy using thermo-convectional dehydrators of direct and indirect type made from indigenously available material. By these dehydrators, agricultural products (fruits & vegetables) of common use were dried under hygienic environment. The cost of dehydration was nominal, whilst the quality of the dried products was of marketable standards. The findings suggested the large scale use of such dehydrators as an economic means of drying fruits and vegetables for off-season use.

**Key Words:** Agricultural products; Mixed mode; Solar; Dehydrator

## INTRODUCTION

Vegetables and fruits during on-seasons can be purchased at affordable prices in bulk and then can be preserved for their off-season use. In doing so, their dehydration has to be carried out. Dehydration is one of the preservation methods that involve removal of biologically active water in order to reduce the growth of microorganism (Esper & Mühlbauer, 1998). An effective approach to dehydrate and preserve the perishable goods such as fruits and vegetables is drying at low temperature so that the food should remain preserved in its natural texture (Esper & Mühlbauer, 1998). The slow drying can very easily be carried out by open sun drying but it needs longer period of time to reach required moisture level, but rain, dust, insects, pollution and contamination from the surrounding environment may adversely affect the quality of the products (Ivanova & Andonov, 2001). Furthermore, products died in open environments may not meet the USDA standards (Anonymous, 2007). Thus drying with solar dehydrator not only shortens the drying time but also meets hygienic standards and retains the colour, texture and food value of the product (Esper & Mühlbauer, 1998).

The solar driers are of two types; direct and indirect (Forson *et al.*, 2007). In a direct type solar dehydrator, air is heated in box type chamber covered from top with glass or transparent polythene sheet. In the indirect type dehydrator, air is at first heated convectionally by solar energy in a separate heat collecting unit (Forson *et al.*, 2007), then this hot and less humid air from this unit is circulated through the main drying chamber, where product is spread on perforated trays. The hot dry air stream while exhausting through this unit removes moisture of the product. A steady state of evaporation is achieved when the heat required for evaporation and the heat losses are equal to the total heat absorbed (Henry *et al.*, 1999).

When assessed the performance, in the direct solar dryers the color of the dried end product is different than that was at the beginning than indirect ones (Bolin *et al.*, 1978). This may be caused by the solar radiations, which produce heat within the bulk of the product upon penetration through its porous skin and change the colour (Sreekumar *et al.*, 2008). It is also observed that the surface of the dried product gets withered, which reduces its appealing look necessary for its marketing; whereas, in the indirect type solar dehydrator, colour and texture of the dried product remains un-changed (Bolin *et al.*, 1978).

Objective of this research was to fabricate and introduce the solar dehydrators using indigenous materials to assess their efficacy in drying fruits and vegetables at pilot scale. The fabricated driers utilized no chimney and both direct and indirect mode in the same unit.

## MATERIALS AND METHODS

Direct (A) and indirect (B) naturally thermo-convectional dehydrators in the combined mode were fabricated in the Department of Physics, University of Agriculture, Faisalabad, Pakistan. The dehydrator 'A' comprised two main parts, flat-plate solar heat collecting unit and a drying chamber. The inclination of the front portion was kept at $32^o$ azimuthally so that the solar radiations after passing through the front glass sheet may fall at the collector unit perpendicularly. The box type body

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of the unit was made of thick wooden planks with blackened iron sheet inner lining, which held the absorbed heat and maintained inner space temperature. A thick layer of carded cotton insulation was laid between the wooden body and the absorber plate. An adjustable shutter made from iron sheet was attached at the outer face of the collector with hinges. This shutter opening was adjustable in order for the controlled air convection as needed. Fresh air entered from the lower end in the collector unit through natural convectional current, where it got heated and then passed to the drying chamber (Fig. 1).

The drying chamber was oblong horizontal wooden box with blackened iron sheet absorber lining carrying carded cotton insulation in between the sheet lining and the wooden body. The open end of the unit was attached through adjustable iron hooks to the heat collecting unit whose opposite side was fitted with a shutter, which was adjustable in opening with the help of slotted brass arms. The top of both the units (A & B) was covered by a 5 mm thick glass sheet. To load agricultural product in the dehydrator, rectangular aluminum trays carrying fitted with stand and wire mesh at their bases at which the product was spread and loaded into the dehydrator (Fig. 1).

The indirect type dehydrator (B) was identical in design and fabrication with similar material, except its drying chamber was a separate unit, which was coupled to the heat collector (Fig. 2). In this unit the insulation used was 13 mm thick thermopore sheet to check the effect of insulation on the performance of dehydrator. The air circulation system was more refined than type A and controlled by two small adjustable shutters fitted at the lower end of the collector and also an adjustable shutter was fixed on its top (Fig. 2).

The performance of both the dryers (A & B) was studied by observing the inner space and of the hot plate temperatures during the months of February, March and April. Ambient temperature was also recorded. A variety of agricultural products were dried to test their practical usefulness. Preparations of the items to be dried were pretreated through blanching and sulfating as detailed in Table I (Cruess, 1958). Blanching of food was conducted in hot water for 5 to 8 min. This treatment protects the carotene and ascorbic acid contents and prolongs the storage life of the product (Somogyi *et al.*, 1988). Sulfiting is a necessary treatment for fruits and vegetables, which was done with a 5% solution of potassium metabisulfite. Sulfating was carried out immediately after blanching to protect the material against scorching damage by heat during dehydration.

**Fig. 1. Solar drier (A) direct type**

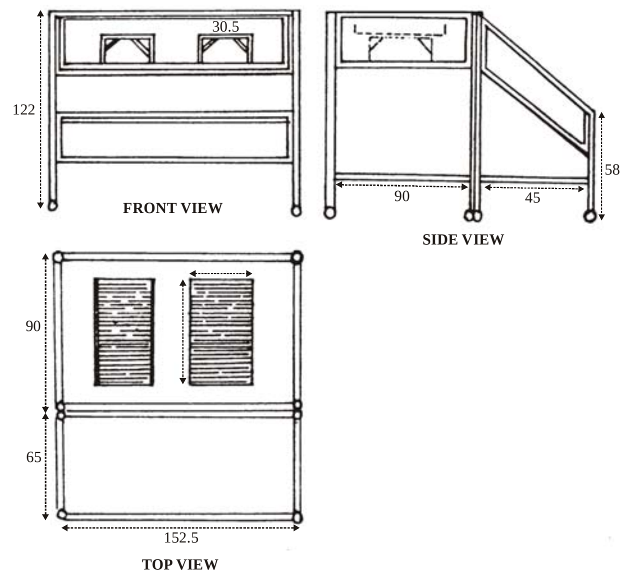
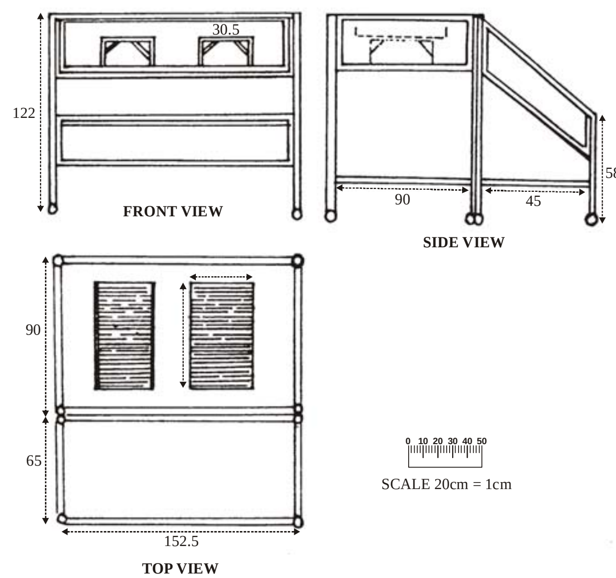



**Fig. 2. Solar drier (B) indirect type**




## RESULTS AND DISCUSSION

While testing the working of the dehydrators in this study, the parameters of interest were collector plate temperature; inner space temperature of the drying chamber; ambient temperature; time spent in dehydration for different food items; percentage of water removed from the solid flesh of the item and quality of the end dried product obtained. Results clearly indicated that all the food items to be dried in the dehydrator 'A' took about six hours whereas the dehydrator 'B' took almost less than four hours (Table II & III); hence the latter was found to be more efficient than the former throughout the experimental period. The reason of its high efficiency lied in collection of more heat in the drying chamber and the uniform and refined air circulation control, which immediately removed moisture collected in the drying chamber (Hawlader *et al.*, 2008). The drying time of both the dehydrators and drying process could be conveniently completed within a limited time during clear and sunny days.

**Table I. Preparation of food item prior to dehydration after Cruess (1958)**

| Item | Preparation | Treatment before drying | | Tests for dryness |
|---|---|---|---|---|
| | | Method | Time (Min.) | |
| **FRUITS** | | | | |
| Apples | Washed, peeled and cut into slices | Sulfiting | 15 | Leathery, no moist area in centre |
| Pears | " | " | " | Spring feel |
| Peaches | " | " | " | Pliable |
| Apricots | Washed, halved unpeeled | " | " | Leathery |
| Pomegranate | Shelled | " | " | Leathery but sticky |
| | | **Vegetables** | | |
| Potatoes | Washed, peeled and cut into slices | Blanching | 5 | Brittle |
| | | Sulfiting | 10 | |
| Bitter gourd | " | Blanching | 7 | Brittle |
| | | Sulfiting | 10 | |
| Garlic | Peeled | No treatment | | Brittle |
| Onion | Removed out skin layer and then cut into slices | No treatment | | Brittle, light coloured |
| Pumpkin | Washed, peeled, cut into slices | Blanching | 5 | Tough to brittle |
| | | Sulfiting | 9 | |
| Lady-finger | Washed, peeled, cut into slices | Blanching | 4 | Brittle |
| | | Sulfiting | 9 | |
| Peas | Shelled | Blanching | 6 | Hard, wrinkled |
| | | Sulfiting | 10 | |
| Beets | Washed, peeled, cut into slices | Blanching | 5 | Tough, leathery |
| Turnips | " | Blanching | 6 | Tough, leathery |
| Carrots | " | Blanching | 5 | Tough, leathery |

**Table II. Parametric Investigation for dehydration of fruit and vegetables**

| Data acquisition date | Item | Prepared wt. of the fresh item (g) | Average Tamp (ºC) Plate | Inner Space | Ambient | Time of data acquisition Initial (h) | Final (h) | Total (h) | Dried Wt.(g) | % of water removed |
|---|---|---|---|---|---|---|---|---|---|---|
| Feb. 15 | Potatoes (A) | 900 | 80.2 | 61.5 | 21.6 | 9.00 | 15.00 | 6.00 | 145 | 83.8 |
| | Potatoes (B) | 900 | 85.3 | 75.0 | " | " | 12.45 | 3.45 | 142 | 84.2 |
| Feb. 16 | Onions (A) | 1000 | 86.2 | 77.2 | 22.3 | 9.00 | 14.30 | 5.30 | 140 | 86 |
| | Onions (B) | 1000 | 82.7 | 64.3 | " | " | 12.30 | 3.30 | 138 | 86.2 |
| Feb. 18 | Peas (A) | 800 | 79.2 | 59.6 | 21.7 | 9.00 | 15.00 | 6.33 | 158 | 80.2 |
| | Peas (B) | 800 | 80.2 | 64.2 | " | " | 13.0 | 4.00 | 155 | 80.6 |
| Feb. 28 | Onions (A) | 1000 | 78.1 | 60.8 | 21.1 | 9.00 | 15.00 | 6.00 | 150 | 85 |
| | Onion (B) | 1000 | 80.2 | 65.2 | " | " | 13.00 | 4.00 | 148 | 85.2 |
| Mar. 1 | Carrots (B) | 900 | 89.3 | 69.3 | 24.6 | 9.00 | 14.30 | 5.30 | 59 | 93 |
| Mar. 2 | Apples (A) | 850 | 84.4 | 63.9 | 24.2 | 9.00 | 15.00 | 6.00 | 75 | 91 |
| Mar. 3 | Pomegranate (B) | 500 | 87.4 | 68.2 | 25.1 | 9.00 | 14.30 | 5.30 | 117 | 77 |
| Mar. 4 | Turnips (B) | 1000 | 83.3 | 66.9 | 24.8 | 9.00 | 15.00 | 6.00 | 98.5 | 90 |
| Mar. 8 | Radish (B) | 800 | 86.2 | 68.1 | 24.7 | 9.00 | 14.30 | 5.30 | 38 | 95 |
| Mar. 9 | Garlic (A) | 400 | 88.8 | 70.5 | 26.3 | 9.00 | 16.00 | 7.00 | 68 | 83 |
| Mar. 10 | Carrots (A) | 800 | 72.9 | 59.2 | 24.6 | 9.00 | 15.00 | 6.00 | 45 | 94 |
| Mar. 11 | Peas (B) | 2000 | 81.9 | 63.5 | 26.5 | 9.00 | 15.00 | 6.00 | 825 | 59 |
| Apr. 16 | Potatoes (A) | 1000 | 75.6 | 75.4 | 32.1 | 9.00 | 15.00 | 6.0 | 140 | 86 |
| Apr. 17 | Onions (A) | 800 | 78.0 | 77.2 | 35.7 | 9.00 | 13.15 | 4.15 | 73 | 91 |
| | Garlic (A) | 500 | | | | | | | 95 | 81 |
| Apr. 18 | Carrots (B) | 1100 | 80.4 | 76.0 | 35.0 | 9.00 | 11.20 | 2.20 | 48 | 95.6 |
| | Radish (B) | 1000 | | | | | | | 40 | 96.0 |
| Apr. 19 | Bitter gourd (A) | 1050 | 75.6 | 77.2 | 35.6 | 9.00 | 14.30 | 5.30 | 75 | 93 |
| Apr. 20 | Apples (B) | 800 | 80.6 | 80.8 | 36.0 | 9.00 | 11.30 | 2.30 | 50 | 94 |
| | Pumpkin (B) | 750 | | | | | 11.00 | 2.00 | 41 | 95 |
| Apr. 22 | Garlic (B) | 1000 | 82.8 | 82.4 | 36.5 | 9.00 | 13.00 | 4.00 | 175 | 83 |
| Apr. 27 | Peas (B) | 850 | 82.5 | 85.6 | 34.9 | 9.00 | 11.30 | 2.30 | 125 | 85 |

The drying time may vary with the prevailing climatic and seasonal conditions (Sayigh, 1978; Riaz, 1985). Therefore, the performance of dehydrator ‘A’ was also carried out in summer and winter seasons. The results revealed that seasonal performance of the dehydrator was quite satisfactory; although during winter it performed slowly and took about 15% longer time than summer season (Table III). Thus, it could be concluded that the dehydrator was equally effective in drying during both the seasons under Faisalabad conditions. The dried product in both the seasons was of superior quality, which was approved by sensory evaluation penal (Table IV).

**Table III. Seasonal performance of the dehydrator**

| Summer | | | | | | Winter | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Date** | **Item** | **Fresh wt. (g)** | **Dried wt. (g)** | **Drying time (h)** | **% of water removed** | **Date** | **Item** | **Fresh wt. (g)** | **Dried wt. (g)** | **Drying time (h)** | **% of water removed** |
| July 18 | Onion | 500 | 60 | 4 | 88 | Dec. 25 | Onion | 500 | 93 | 5-00 | 81.4 |
| July 19 | Potatoes | 700 | 114 | 2-30 | 83.7 | Jan.6 | Pomegranate | 239 | 100 | 5-30 | 58.1 |
| July 23 | Pomegranate | 700 | 159 | 4 | 77 | Jan. 7 | Potatoes | 500 | 106.5 | 3-30 | 78.7 |
| July 27 | Radish | 400 | 25 | 3 | 93.7 | Jan. 18 | Potatoes | 500 | 70 | 4-30 | 85.0 |
| Aug. 4 | Potatoes | 500 | 75 | 4 | 85 | Jan. 22 | Radish | 500 | 25 | 4-00 | 95.0 |

**Table IV. Remarks of sensory evaluation penal about the dried fruits and vegetables**

| **Item** | **Remarks of the sensory evaluation penal** |
|---|---|
| | **Vegetables** |
| Potatoes | Color: Fine; Dried: Well; Appreciated by the penal |
| Onions | Color: Brownish; Dried: Well; Taste: Natural, acceptable for reuse |
| Garlic | Color: Brownish; Dried: Well; Taste: Natural, accepted for reuse |
| Carrots | Color: Natural but fainted; Dried; Fully; Taste: acceptable |
| Radish | Color: Natural and dark; Dried: Fully; Taste: acceptable |
| Pumpkin | Color: Light brownish; Dried: Well; Taste: accepted for reuse |
| Peas | Color: Natural dark green; Dried: Well: Taste: Natural, accepted for reuse |
| | **Fruits** |
| Apples | Color: Light brown; Dried: Well; Taste: Good |
| Pomegranate | Color: Darkened; Dried: Well; Taste: Natural and accepted for reuse |

The quality of product depended upon the removal of moisture during drying process as reported in other studies as well (Van Leersum, 1987; Sharma *et al.*, 1987). The data revealed that the amount of moisture removed strongly depended upon the structure and nature of fruit or vegetable. Thus the rate of water content removal from the agricultural product might not be the same. To achieve good quality of dried product, drying condition varies from item to item and this was carried out by adjusting the shutter openings at inlet and out let portions of the dehydrator. With different ajar limits of the shutters, space and plate temperatures of the drying chamber were set at desired limit.

The results of these controlled air convectional dehydrators were better than the box type (Riaz, 1985). These dehydrators can dry fruits, vegetable, gains, peeled corn, legumes, paddy and any sort of commonly available agricultural products available at affordable costs in their peak season and needed to be used for certain processing like paddy to process into rice or off season use. These dehydrators can be conveniently used in remote and rural areas like Northern areas of Pakistan where abundant fruits like apricot, pomegranate, figs, raisins are available that can be marketed to big cities at later times or in off season. Their practical importance is even greater for the villages, where there is no regular supply of fruits and vegetables throughout the year. Based on the performance and quality of dried products, the domestic and commercial use of dehydrator 'B' is recommended. This hydrator is low cost, simple in design, simple in use, easily fabricate able from the indigenous material at nominal cost.

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