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PACKINGHOUSE NEWSLETTER

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DRYING FUNDAMENTALS - SURFACE DRYING

PART C. This article is the third in a 4-part series detailing considerations in packinghouse dryers. The principal point of discussion in this article is the surface drying phenomena.

Basic Process

The type of dryer utilized to surface dry fresh citrus is normally a tunnel-type arrangement. These dryers may consist of individual modules or one single unit. The heat sources are natural or LP-gas (direct or indirect), electric or steam (boiler, natural gas, or fuel oil). On occassion, infrared heat lamps have been used to supplement drying. These heat lamps accomplish only partial drying as the radiant heating is limited to line-of-sight contact between the fruit and heat source. In some installations, a combination of energy sources and drying techniques may be applicable.

The moisture load in drying originates from two sources: residual washer and rinse water after dewatering plus the water phase of the water wax emulsion. Other volatiles may be vaporized from the wax emulsion but their contribution to the moisture load calculations of the dryer is minor. Some of the wax ingredients may create drying difficulty in that they may form a chemical bond with water. Conversely, some materials may vaporize more readily than water or reduce surface tension facilitating drying. To measure the moisture load, a general approach would be to measure the surface water on fruit after dewatering and add to that (1.0 - % wax solids/100) x wax application rate.

Surface drying is a constant rate process. Hence, it is governed bv time, temperature, humidity ratio difference (HRD), and air velocity. The governing equation is:

$$\dot{m} = k_D A(HR_d - HR_i)$$

Where

$\dot{m}$ = m/t, mass transfer rate
k_D = mass transfer coefficient
A = surface area
HR_d = humidity ratio of dryer air
HR_i = humidity ratio at dryinginterface

The (HR_d - HR_i) value is known as the humidity ratio difference and is an indicator of the drying potential. These relationships can be analyzed by a nomograph (Fig. 1) or via a computer program (Miller, 1985, Applied Engineering in Agriculture). The mass transfer coefficient is a function of airflow, air properties, and the fruits' dimensions and geometry.

The major criterion in drying either by heated or dehumidified air is to create a sufficient HRD. This interrelation of HRD with a satisfactory drying time is developed in Fig. 1. The upper left graph (Fig. 1a) defines the air velocity relationship for the dryer air. Matching that condition, with a humidity ratio difference yields the moisture transfer rate/surface area (upper right graph, Fig. 1b). If the moisture load, m/A, is known, the drying time t can then be determined (lower right graph, Fig. 1c).

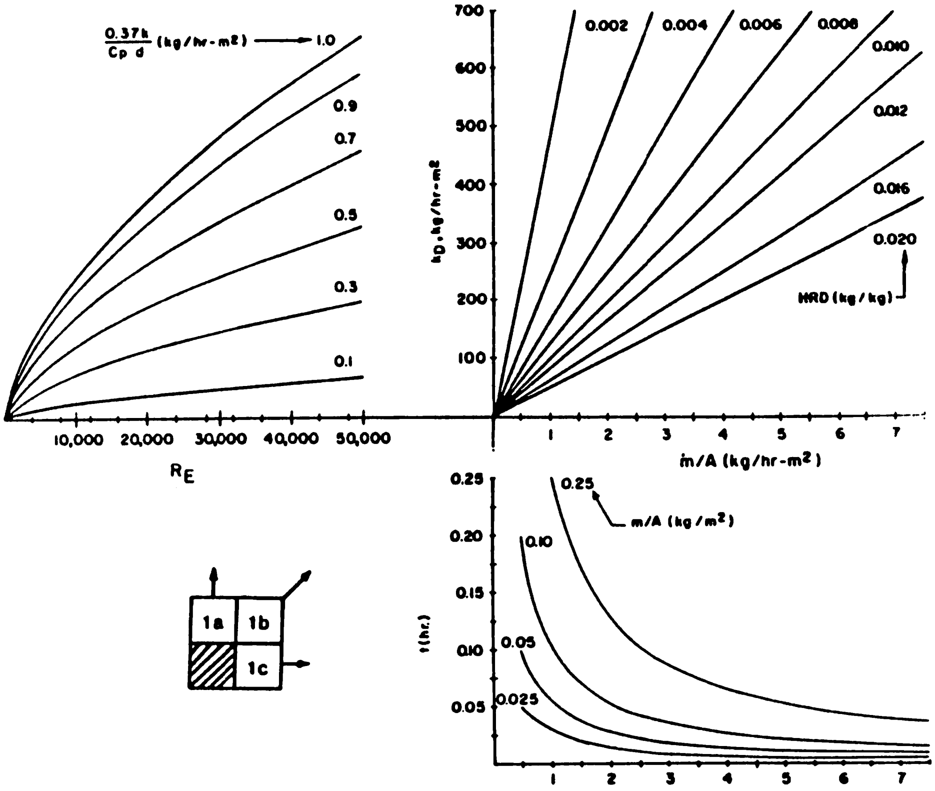

Fig. 1—Graphical representation of drying relationship to estimate surface moisture drying time.

An important aspect of the constant rate process is that HRD and m have a linear relationship. The drying time in conjunction with heated-air energy requirements are of interest to the packinghouse. Packinghouse design inputs (boxes/hr, fruit/box, H_2O/fruit, pre-dryer removal rate, and the surface water temperature) are required inputs to determine this interrelationship. Ambient conditions (dry/wet bulb, °C), heated air temp (dry bulb, °C) are also required. The general air recycle condition that would be established is shown in Fig. 2. For the input data provided, the HRD level and the total energy required are estimated for maintaining specified drying conditions (i.e. temperature and humidity). Makeup or exhaust airflow plus total airflow were also calculated. Those values determine the percent air recycled.

An example case of 200,000 fruit per hour, 10% pre-removal, heated air at 60°C, recycled air at 50°C is presented (Fig. 3). A linear relationship between total energy required and percent air recycled was found. The effect of ambient air conditions was more significant at lower recycle levels where the makeup air would constitute a higher percent of total airflow. Ambient conditions selected were considered to bracket the early summer to mid-winter conditions experienced in Florida citrus packinghouses. A knee-shaped curve was found in the HRD versus percent air recycled.

General Conditions: 200,000 fruit/hr, 10% pre-removal
1 g H_2O/fruit
Air heated to: 60°C
Air recycled at: 50°C

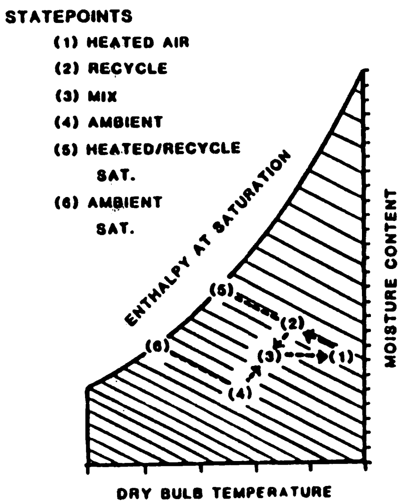

Fig. 2—General psychrometric conditions for air recycling in dryer units.

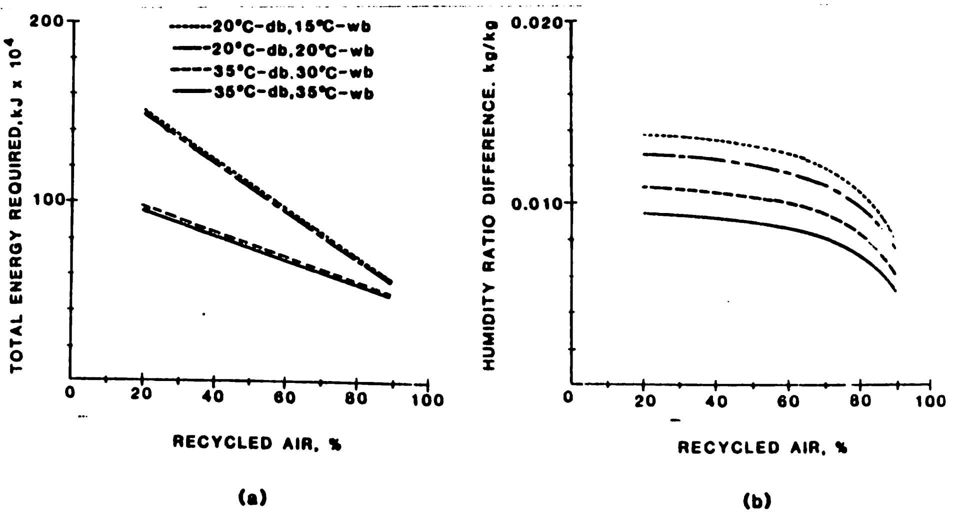

Fig. 3—Relationship of drying potential and energy requirements for various air recycle percentages.

A major design consideration from Figure 3b is the minor reduction in the HRD value with the air recycled increasing from 20 to 60%. For this same range, the total energy requirement decreased linearly (Fig. 3a). The reduction of the HRD level is indicative of the contribution of moisture load from the fruit. From this development, a fixed air recycling level, 50 to 60%, could be established which would achieve a significant energy reduction without incorporating elaborate controls. For example, at 20°C dry bulb and 15°C wet bulb ambient condition, the energy requirement is 36% lower at 60% recycle compared to 20% recycle. The resultant drying potential was only lowered 7%.

The dryer has been considered as a single unit in this analysis. For modular dryer units, an individual unit analysis might indicate differences in the percent air recycled as the fruit progresses through successive modules.

Practical Consideration

In conveyor dryers, fruit should be turned one or two partial revolutions to expose wet contact areas. The first rotation should not occur until the fruit has traversed at least 25% of the dryer length. A belt lagging contact strip may be used to rotate the rolls at two or three locations within the dryer. Other turning techniques include a drop transfer between conveyor sections which is commonplace in the case of separate dryer modules. Sprockets mounted to individual rollers can be included to engage a chain which will slowly rotate the rollers and fruit. Some commercial packinghouses have increased drying time by double or triple stacking fruit. This multiple layering of fruit would assure full conveyor coverage with more uniform airflow. However, when fruit is multilayered, some difficulty has been observed in rotating the upper layers of fruit due to slippage. For all installations, care should be taken to provide full conveyor coverage with fruit or the airflow will be predominately through the open areas.

In general, the main circulation blower should operate continuously. This practice will minimize fan maintenance and allow for cooling of heated metal surfaces (empty conveyor condition). Cleaning dryer conveyor rollers is essential. Sharp wax buildup points may cause mechanical damage. A scraper bar or steel brush arrangement can be utilized on the return roller section. Care should be exercised in using chemical cleaners. Any cleaning material should be fully vaporized so it does not interact with wax applied to fruit.

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AVAILABLE PUBLICATIONS

Available from Dr. W. M. Miller, CREC, 700 Experiment Station Road, Lake Alfred, Florida 33850

"Mechanical Dewatering Techniques for Fresh Citrus." Energy in Agriculture 5 225-238 1986.

"Prediction of Energy Requirements and Drying Times for Surface Drying Fresh Produce." American Society of Agricultural Engineers 1(2) 87-90 1985.

"Analysis of Automatic Weight-Fill Bagging Machinery for Fresh Citrus." American Society of Agricultural Engineers 2(2) 252-256 1986.

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