International Journal of Engineering Sciences Paradigms and Researches (IJESPR)
(Vol. 36, Issue 01) and (Publishing Month: November 2016)
(An Indexed, Referred and Impact Factor Journal)
ISSN: 2319-6564
www.ijesonline.com

Analysis of food preservations and study of thermo physics of crops,systems and components

Himansu Sekhar Moharana[1], Prakhar Kharwar[2] and Bibhuti Sabat[3]

[1]Aryan Institute of Engineering & Technology, Bhubaneswar, Odisha

[2]NM Institute of Engineering and Technology, Bhubaneswar, Odisha

[3]Capital Engineering College, Bhubaneswar, Odisha

Keywords:
Drying
Solar dryer
Moisture content
Drying rates
Thin-layer drying
Crop properties
Psychrometrics
Air heating solar collector

ABSTRACT

The paper deals with, drying reduces the moisture content of harvested crops thus slowing decay processes to enable longer-term storage. The importance of key environmental, operational and design parameters for solar dryers are discussed including: (i) air-heating solar collector selection, (ii) feasibility of using powered components such as fans and, (iii) how initial crop properties are converted to final desired product attributes, (iv) psychrometry of drying processes and ambient conditions

1. Introduction

Solar crop drying ensues naturally when seeds dry in-situ to render them sufficiently light for air-borne dispersal. Human intervention to dry crops in the open sun to enable their storage for off-season food consumption was probably intrinsic to the inception of farming-based civilizations. The key strategic goal in preserving crops is to reduce the number of undernourished people worldwide (Anon., 2004). Fiber and energy is provided by carbohydrates and protein usually retained after a drying process.

Open sun drying simply exposes harvested crops to solar radiation by placing them on the ground or a mat. It is prone to high crop losses due to (i) uneven moisture removal, (ii) insects and rodents consuming the crop and (iii) failure to achieve safe storage moisture content before the crop has to be collected. As an example, the estimated annual postharvest losses of various commodities together with the associated costs for India is shown in Table 1.

The first modern use of fossil fuels in drying was recorded in France in 1795 for drying of thinly sliced fruits and vegetables (Delong, 1992). Fossil-fuelled dryers are now commonplace as they can operate in any ambient conditions, are readily controlled and their operation and maintenance infrastructures are well established. However, in many remote rural locations supplies of fossil fuels can be (i) insecure (ii) expensive and require combustion equipment and (iii) their use incurs emissions of both local pollution and global greenhouse gases I(mre, 1993). In contrast, solar drying often constitutes a cost-effective and environmentally sustainable use of local solar energy resources and fabrication labour resources.

Solar dryers can be distinguished from open-sun drying by (i) enclosure of the drying crop and (ii) direct or indirect production of a solar heated airflow. When compared with open-air sun drying, solar drying generally is (i) faster, (ii) more efficient (iii) hygienic and (iv) incurs lower crop losses (Arata et al., 1993; Budin and Mihelic-Bogdanic, 1994; Chua and Chou, 2003; Karim and Hawlader, 2004; Mahapatra and Imre, 1990; Muhlbauer, 1986; Zaman and Bala, 1989). There are generally more viable than open sun drying as they provide more control and protection of product quality over a wider range of weather conditions (Alam and Singh, 2004; Sodha and Chandra, 1994; Lorriman and Hollick, 2003; Nair and Bongirwar, 1994; Tiwari, 2003; Esper and Muhlbauer, 1998; Farkas, 2003). In a solar dryer, solar radiation passes through a transparent aperture and retained as heat in a drying chamber, a solar collector, or both. In a passive solar dryer, thermal energy transferred from solar energy collection to the drying chamber is by natural convection whereas in an active system a fan drives heated air through the dryer (Norton, 2013). The interrelationship

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between the key factors that determine solar dryer viability (Ekechukwu and Norton, 1999b) are summarised in Fig. 1.

Table 1
Estimates of post-harvest losses for various commodities in India (Alam et al., 1980; Anon, 2004).

		Post-harvest losses	
		% of produce	Value (Rupees in Crore)
Commodity	Grains	10	16,500
	Pulses	15	2000
	Fruits	30	13,600
	Vegetables	30	14,100
	Floriculture	40	400
	Fish	15	2700
	Dairy (milk)	1	900
Total Rs. 50,200 Crore			

2. Psychometry of air in a solar dryer

The more dry the surrounding air, the greater the rate of evaporation from a crop that lowers the wet bulb temperature. The specific humidity of unsaturated air increases due to water evaporation from a crop as energy transferred from air to water. A thermal equilibrium prevails when the energy transferred from warm air to the crop becomes equal to energy needed for water vaporization. At temperatures below this equilibrium thermodynamic wet bulb temperature or adiabatic saturation temperature, air will rapidly become saturated and if cooled further, will lose water in the form of dew above 0°C. Water vapour moves from air with a higher humidity ratio (i.e. ratio of water vapour weight to dry air weight) to air with a lower humidity ratio.

As indicated in Fig. 2 for appropriate combination of humidities and temperatures, air taken directly into a drying chamber will be heated sufficiently to enable drying. When the temperature and humidity of directly-introduced ambient air would provide an insufficient drying rate, an air heating solar energy collector produces higher temperature air for introduction to the drying chamber. The indicative conditions for which use of air heating collector is advised are illustratively in Fig. 2; The specific for a particular installation are contingent conditions would depend on crop parameters, collector characteristics and drying chamber specifications (Ekechukwu and Norton, 1999a).

Wet-basis moisture content (defined as the relative weights of moisture present per unit of undried material) is used generally for commercial purposes. For system engineering purposes, the (closely related; see Fig. 3) dry basis moisture content (defined as the weight of moisture present per unit weight of totally dry material) is preferred as on a dry basis the same weight changes are associated with each percentage moisture reduction (Ekechukwu and Norton, 1999a, 1999b; Ekechukwu, 199)9. The final moisture contents required for long-term storage of crops, are referred as safe storage moisture content are listed for common crops in Table 2.

National and international standards specify labelling for correct ingredient and nutritional information to ensure that products are safe and fit for consumption. Nutrition colour, flavour and texture of the dried product must also be of acceptable quality to consumers. The term ‘‘quality” has three overlapping connotations; (i) degree of excellence, (ii) fitness for purpose, and/or (iii) conformance to specified requirements. The consequences of improper drying can include (i) loss of nutrients, (ii) microbial spoilage, (iii) possibility of food poisoning, (iv) lower market value and (v) excessive shrinkage.

Shrinkage during drying alters shape, reduces volume and increase surface hardness. This is a desired outcome for some crops such as some dried fruits. Non-uniform shrinkage leads to imbalanced stresses that crack surfaces. Shrinkage can limits the ability to rehydrate a dried product as moisture-absorbing capillaries are closed; for example when cauliflower is dried. J(ain and Tiwari, 2004b). The stresses causing shrinkage depend on removed water volume, internal crop structure, drying rate, temperature, relative humidity, and velocity of drying air. Being a major factor when controlling the drying rate (Rahman et al., 1996; Zogzas et al., 1994), shrinkage has been the subject of extensively modelling; (Lozano et al., 1983, 1980; Mayor and Sereno, 2004; Mclaughlin and Magee, 1998; Mulet et al., 2000; Ochoa et al., 2002; Park, 1998; Rahman et al., 1996; Ratti, 1994; Simal et al., 1998; Wang and Brennan, 1995). To avoid high drying temperatures can adversely affect the colour and phenolic composition of aromatic, herbal and medicinal plants. pre-treatments have been devised for specific herbs such as thyme (Lahnine et al., 2016). For colour retention in dried cherry tomatoes, osmotic dehydration in a hypertonic solution has been employed for partial water removal before subsequent drying in a solar dryer (Nabneun et al., 2016) to produce high quality dried tomatoes with desired colour in a

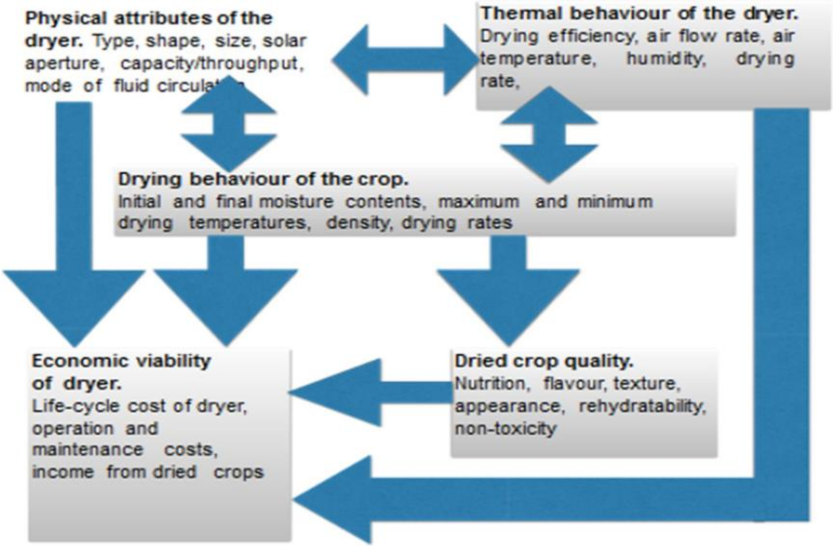

Fig. 1. Interplay between key grouped aspects of solar dryer viability.

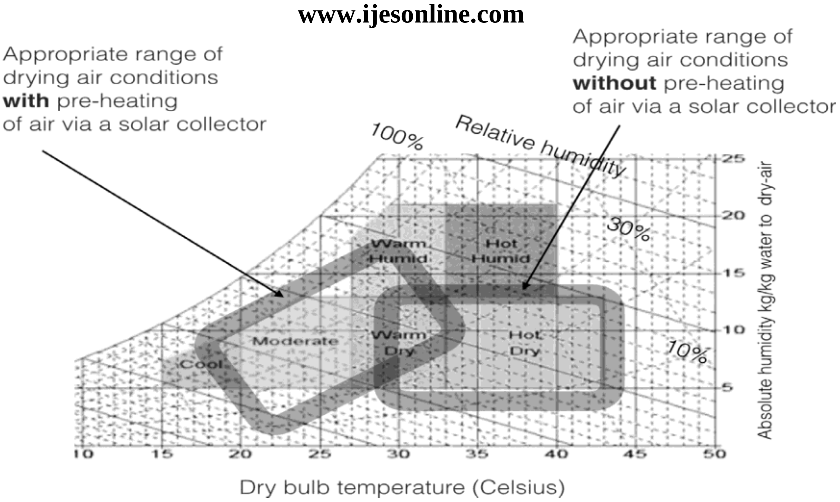

Fig. 2. Indicative psychometry of conditions for the inclusion in a solar dryer of an air heating solar collector.

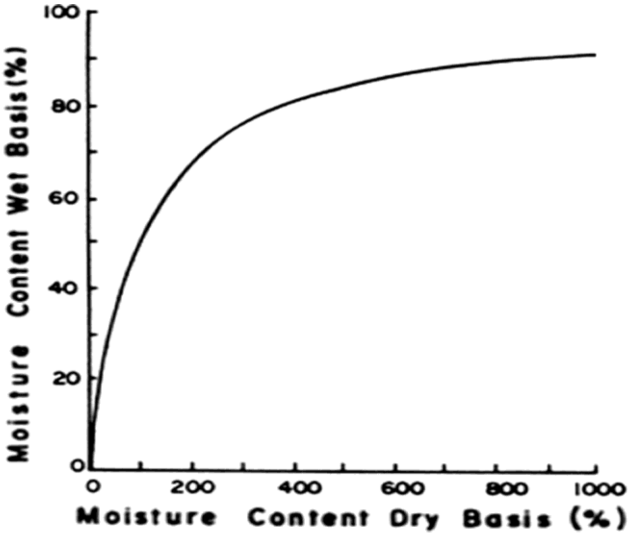

Fig. 3. Difference between moisture contents measured on wet and dry basis.

considerably reduced drying time. The latent heat of vapourisation depends on the crop, its preparation, moisture content, and temperature (Ekechukwu and Norton, 1999a; Ekechukwu, 199)9.

Each crop has a characteristic water vapour pressure below or above which moisture will be absorbed or desorbed moisture respectively for particular combinations of temperature and moisture content, At equilibrium moisture content, the corresponding relative humidity of the immediate surrounding air is also in equilibrium with its environment. For particular temperature and relative humidity, a particular crop's equilibrium moisture content depends on the specific crop variety, maturity at harvest, and growth history (Soysal and Öztekin, 2001) Two methods are used to determine equilibrium moisture content (i) in the static method, a crop is exposed to still surrounding air without agitation; however, to reach equilibrium long exposure of the crop, can allow mould to grow before equilibrium is reached and (ii) in the dynamic method, the air temperature in an the crop enclosure is controlled thermostatically and the relative humidity of the surrounding air is regulated with either an acid or a saturated salt solution. Static equilibrium moisture contents determination is preferred for examining stored crops whereas dynamic methods used for crop samples taken from dryers in operation B(ala, 2003). Several theoretical, semi-theoretical and empirical models for the moisture equilibrium isotherms of agricultural crops produces have proposed to determine the relationship between equilibrium moisture content and equilibrium relative humidity (Brunauer et al., 1938; Day and Nelson, 1965; Henderson, 1952; Thomson et al., 1968; Chen and Clayton, 1971; Pfost et al., 1976; Iglesias et al., 1976; Chen and Morey, 1989; Soysal and Öztekin, 2001; Blanco-Cano et al., 2016a). There is no universal equation that represents accurately the moisture equilibrium isotherms of all agricultural crop products. Illustrative representative examples of the relationships between equilibrium moisture content for selected crops are given inFig. 4.

3. Conclusion

For many crops, particular combinations of crop pre-preparation, solar drying equipment and process management are now in use successfully to dry crops in applicable seasonal weather conditions. In other instances, promising research has not been applied to-date to significantly reduce crop-processing losses. More research is required to determine how solar drying could be readily incorporated into existing part-harvest processing chains thereby reducing barriers to appropriate adoption. As has been shown, solar crop drying brings together the complexities of internal crop structures, human nutrition, food aesthetics and process of crop decay with those of solar dryer design and process control under varying solar radiation intensities. It is probably unnecessary to have a theoretical framework that deals in all details of such a complex system in all circumstances. However research that draws together generic crop, dryer and climate com- binations would enable more systematic future development of solar drying. The lack of clear benchmarks for performance inter- comparison impedes the ability of new research to build construc- tively on previous work.

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