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OPTIMUM STRATEGIES FOR DRYING FRUITS WITH HIGH SUGAR CONTENT

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ABSTRACT

Important factors which affect decision when drying agricultural products are normally quality, drying time or throughput and energy consumption. In this paper, a mathematical model for fruit tray dryers is presented. The accuracy of the model was tested with experimental results. Three kinds of fruit, namely: papaya glacé, pineapple glacé and local banana fruit were chosen for this study. It was concluded that the model predicted drying rate with fairly good accuracy. From both experimental and simulated results, conclusion for optimum drying strategies, i.e., drying air temperature, specific air flow rate and fraction of air recycled could be drawn as follows: product qualities were acceptable up to the drying air temperature not exceeding 65°C, for typical sizes of papaya glacé, pineapple glacé and banana fruit, specific air flow rate and fraction of air recycled were 35 kg/h-kg dry matter and 65 %, 11 kg/h-kg dry matter and 75 %, and 10 kg/h-kg dry matter and 85%, respectively. In addition, drying time and specific energy consumption increased along with the size of drying products.

Key words : fruit drying, fruit glacé, drying strategy, mathematical model.

INTRODUCTION

Dry fruits become more and more popular at present. Among them are pineapple glacé, papaya glacé, mango glacé, banana fruit, etc. Fruit drying is an effective and cheap method for preventing produces from spoilage. Products from fruit drying are even more important due to their high potential of export.

Fruit glacé is usually prepared by cutting fresh fruit into small pieces, dipping in a solution of $CaCl_2$ and leaching in hot water or steaming and cooling suddenly with water, then dipping it in sugar solution which starts at a low concentration of about 40° Brix and is increased by 10° Brix each day up to about 70° Brix to which sodium metabisulfite is added at a concentration of 0.1 %. (w/w) (see details in references 1,2,3). Processed fruit is then dried, usually on trays in cabinet or tunnel dryers. Variables which affect the performance of drying (measured in terms of product quality, drying time or throughput and energy consumption) are drying air temperature, air flow rate and fraction of air recycled.

Processing of dry banana fruit is much simpler compared to the fruit glacé. Ripe bananas are peeled and dried in open air or in cabinet dryers (see details in references 4, 5).

The objective of this paper is to review selected research and development work on drying of fruits with high sugar content and to recommend optimum drying strategies.

MATHEMATICAL MODEL

To investigate optimum drying strategies only from experimental work is the most difficult task or is almost impossible due to the labour intensive during the experiments and the difficulty of controlling some parameters such as ambient temperature and relative humidity, initial and final moisture content of drying products, etc. A mathematical model is therefore necessary to be used as a key tool for the investigation of optimum drying strategies. The model employed in references 2 and 3 is explained in brief as follows:

Figure 1 shows the diagram of a drying system and the control volumes drawn for writing equations of energy and mass balances. Exhaust air can be partly recycled. It is first mixed with fresh air and then heated up to the controlled temperature before entering the drying cabinet in which the drying process occurs. From application of the principle of energy and mass conservation for all control volumes, equations for the calculation of air properties and energy consumption could be derived. To simplify the model, it was assumed that thermal equilibrium exists between the drying air and the product (see reference 2).

To calculate the moisture content of drying product, it is necessary to have a drying equation for a piece of fruit. A moisture diffusion equation is usually accurate for the fruits with high sugar content. The diffusion equations for pineapple glacé, papaya glacé, and banana fruit are available in references 2, 3 and 6 respectively.

To obtain the solution of the model, it is necessary to use a microcomputer. The equations were solved by iteration[2,3,6].

RESULTS FROM SELECTED STUDIES

Experimental Results

Most of the experimental results of drying fruits with high sugar content[2,3,6] showed that the qualities in terms of colour and other appearance such as surface softness, etc., were acceptable as compared with the products available in local markets, up to the drying temperature not exceeding 65°C. Sulfur dioxide content and sugar content of the product after drying were in the acceptable range according to the standard of the Ministry of Industry, Thailand. Vitamin C could not be found in any of the samples tested.

Experimental results also indicated that specific energy consumption (MJ/kg water evaporated) increased along with specific air flow rate (kg/h-kg dry matter) but decreased when fraction of air recycled increased. Energy consumption tended to decrease at higher drying temperature.

Simulation Results

Conclusion for optimum strategies can not be drawn only from the experimental results. Therefore, the mathematical model was employed to simulate drying process. The results obtained from the model was found to be agreeable with the experimental results[2,3,6]. During the drying simulation, the following assumptions were made: the initial moisture content was fixed, the final moisture content was around 21-22 % dry basis for fruit glacé and 50 % dry-basis for banana fruit, papaya glacé was in 0.005 m cubes and pineapple glacé was in short hollow cylinders with inner diameter of 2 cm, outer diameter of 6 cm and thickness of 1 cm.

Simulated results of papaya glacé, pineapple glacé and banana fruit are shown in Figures 2, 3, 4 respectively. It can be concluded that there were an optimum specific air flow rate and an optimum fraction of air recycled. Specific energy consumption is the lowest at the optimum conditions. The energy was divided into electricity for the fan and thermal energy for heating the air. The electricity consumed was less than 5 % of the total energy. Figures 5 and 6 show the effect of fraction of air recycled on the corresponding drying time at different specific air flow rate for pineapple glacé and banana fruit respectively. It was found that the drying time remained nearly constant up to a certain value of fraction of air recycled which was a little bit less than the previous optimum one. If both drying time and specific energy consumption were taken into consideration, the optimum specific air flow rate and fraction of air recycled for pineapple glacé drying should be about 11 kg/h-kg dry matter and 75 % and about 10 kg/h-kg dry matter and 85 % respectively for banana fruit. For drying much smaller size such as papaya glacé, optimum specific air flow rate should be much higher, about 35 kg/h-kg dry matter.

Simulated results also indicated that drying time and specific energy consumption increased along with the size of drying product. Higher ambient temperature and lower ambient relative humidity were favourable to the improvement in the drying performance.

CONCLUSION

From the studies of drying of fruits with high sugar content[2,3,6], significant conclusion could be drawn as follows:

1. Product qualities were acceptable up to the drying air temperature not exceeding 65°C.

2. There were optimum specific air flow rate and fraction of air recycled for different sizes and drying products. At the optimum operating conditions, specific energy consumption and drying time were near to the minimum. For typical sizes of papaya glacé, pineapple glacé and banana fruit, specific air flow rate and fraction of air recycled were as follows: 35 kg/h-kg dry matter and 65 %, 11 kg/h-kg dry matter and 75 %, and 10 kg/h-kg dry matter and 85 %, respectively.

3. Drying time and specific energy consumption increased along with the size of drying products.

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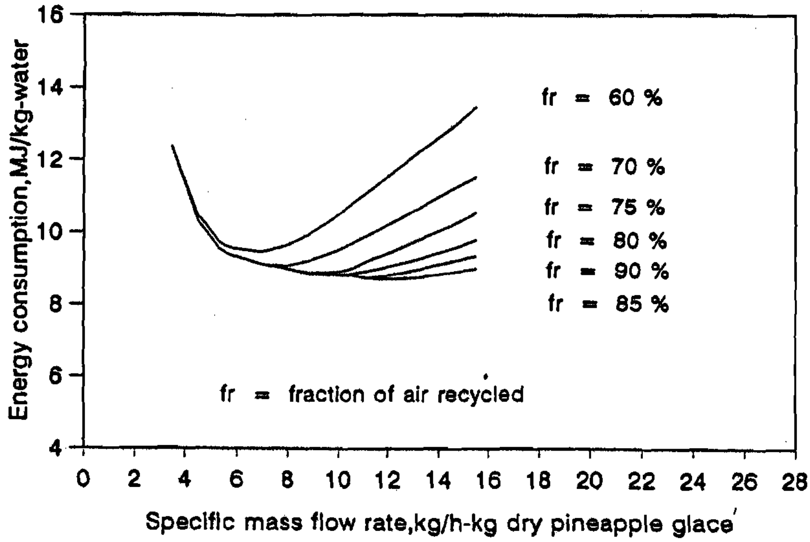

Figure 3. Simulated energy consumption of pineapple glacé drying at 65°C (in hollow cylinders, 1 cm thick).[2]

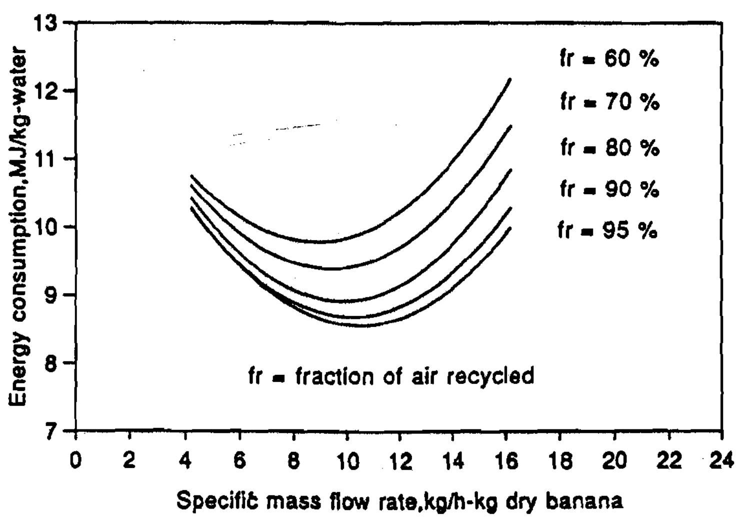

Figure 4. Simulated energy consumption of banana fruit drying at 60°C.[6]

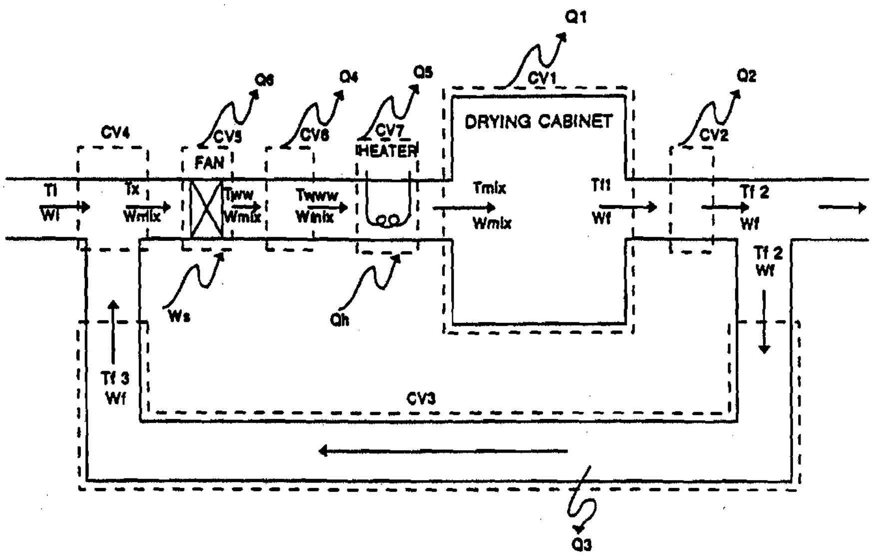

Fig. 1. Control volume.

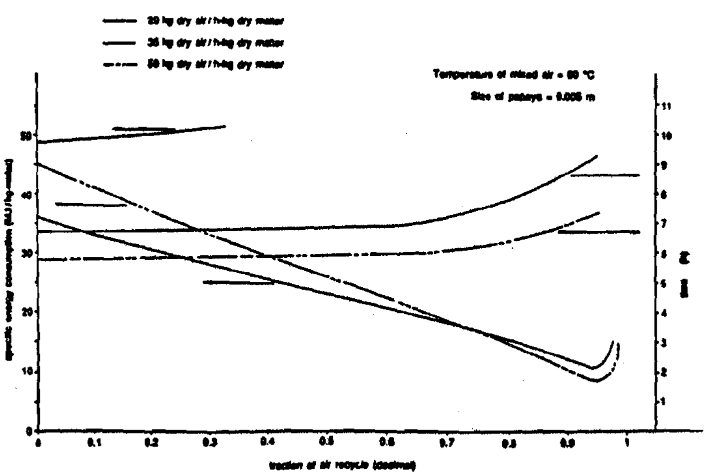

Figure 2. Simulated energy consumption of papaya glacé drying at 60°C (in cubes, 0.5 cm).[3]

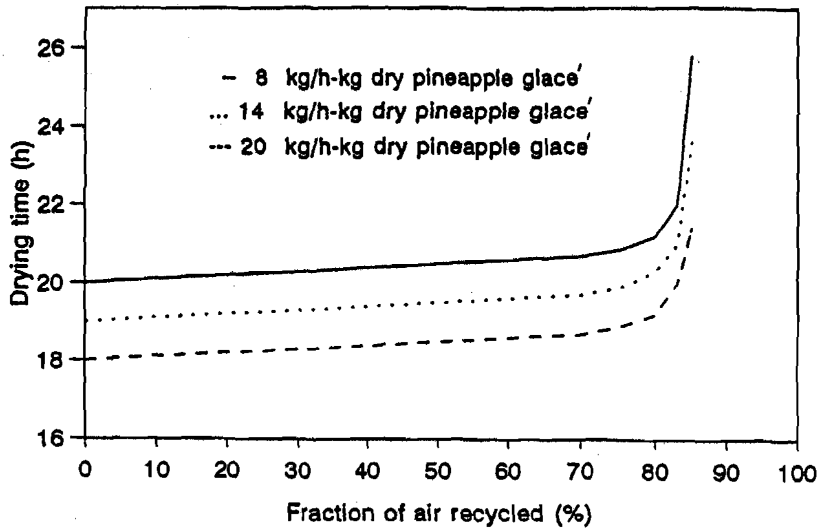

Figure 5. Simulated drying time of pineapple glacé drying at 65°C (in hollow cylinders, 1 cm thick).[2]

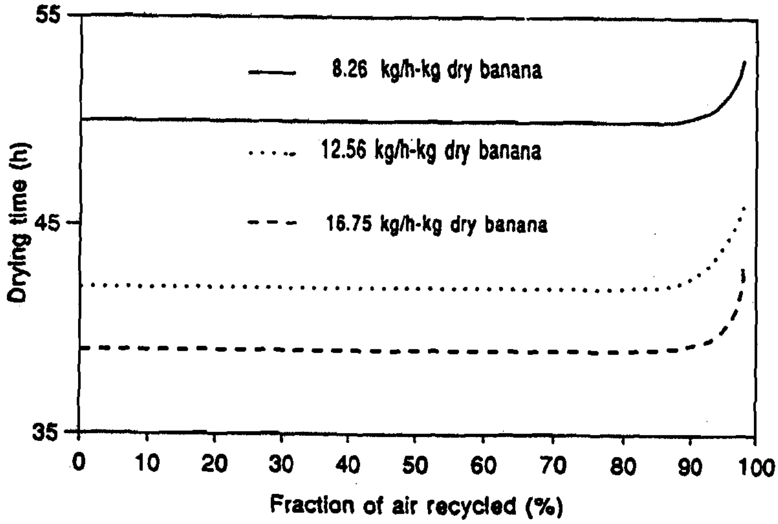

Figure 6. Simulated drying time of banana fruit drying at 60°C.[6]