

Low-cost solar drying of mango slices: a two-season comparison with open sun drying

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Abstract

Post-harvest losses of mango reach forty percent in the peak season, and open sun drying, the usual remedy, is slow and exposes the fruit to dust and insects. We built a mixed-mode solar dryer from locally available materials and compared it with open sun drying over two seasons, drying 5 mm slices and measuring moisture content, colour and vitamin C every two hours. The dryer reached a safe moisture content in 11 hours, against 23 hours in the open sun. Dried slices kept 68 percent of their vitamin C, against 41 percent, and showed less browning. The dryer cost the equivalent of 85 US dollars to build. A dryer that a local workshop can build halves drying time and keeps more of the fruit's value, which makes drying practical for smallholder farmers.

Keywords: post-harvest loss, food preservation, drying kinetics, vitamin C retention, smallholder farming

Introduction

Mango is among the most widely grown fruits in the tropics, and in the peak season up to forty percent of the harvest is lost before it is eaten [1]. Drying extends shelf life from days to months and needs no cold chain. Most smallholder farmers dry fruit in the open sun, which is free but slow, and exposes the fruit to dust, insects and rain [2].

Solar dryers shorten drying time and protect the product, but commercial units cost more than most farmers can pay [3]. This paper asks whether a dryer built in a local workshop, from materials sold in any market town, can match them. We describe the dryer, compare it with open sun drying over two seasons, and report its cost.

Materials and methods

The dryer

The dryer is of the **mixed-mode** type: air is heated in a glazed collector of 2 m² and rises through a chamber of six trays, which also receives direct sun through a clear cover. It was built from three materials, all bought in the nearest market town:

- timber, for the frame;
- blackened roofing sheet, for the absorber;
- greenhouse plastic, for the glazing.

Drying runs

Ripe mangoes of one variety were peeled and cut into slices 5 mm thick. Each run followed the same steps:

1. Weigh 6 kg of slices onto the trays of the dryer, and 6 kg onto an open rack beside it.
2. Weigh both lots every two hours.
3. Stop when the slices reach a moisture content of 10 percent, which is safe for storage.

Each treatment was repeated six times in each of two seasons, giving $n = 12$ runs. Moisture content was found by oven drying [4].

Drying model

The moisture ratio at time t was calculated as

$$MR = \frac{M_t - M_e}{M_0 - M_e} \quad (1)$$

where M_t , M_e and M_0 are the moisture content at time t , at equilibrium and at the start. The drying curves were described by the thin-layer model

$$MR = \exp(-kt) \quad (2)$$

in which k is the drying constant, in hours⁻¹. It was fitted to the readings of each run by least squares, and the fit was judged by the root mean square error

$$\text{RMSE} = \sqrt{\frac{1}{N} \sum_{i=1}^N (MR_{\text{pred},i} - MR_{\text{obs},i})^2} \quad (3)$$

over the N readings of a run. The fit was done with the short script below.

```
import numpy as np
from scipy.optimize import curve_fit

def thin_layer(t, k):
    """Moisture ratio after t hours, for a drying constant k."""
    return np.exp(-k * t)

hours = np.arange(0, 26, 2)
(k, _) = curve_fit(thin_layer, hours, moisture_ratio)
rmse = np.sqrt(np.mean((thin_layer(hours, k) - moisture_ratio) ** 2))
print(f"k = {k:.3f} per hour, RMSE = {rmse:.3f}")
```

PYTHON

Vitamin C was measured by titration, and colour with a handheld colorimeter.

Results

Drying time

The dryer reached the safe moisture content in 11 hours, against 23 hours in the open sun (Table 1). The difference held in both seasons. The drying constant was $k = 0.25 \text{ h}^{-1}$ in the dryer and $k = 0.12 \text{ h}^{-1}$ in the open sun, and the model followed the readings closely in both (Figure 1), with an RMSE below 0.03.

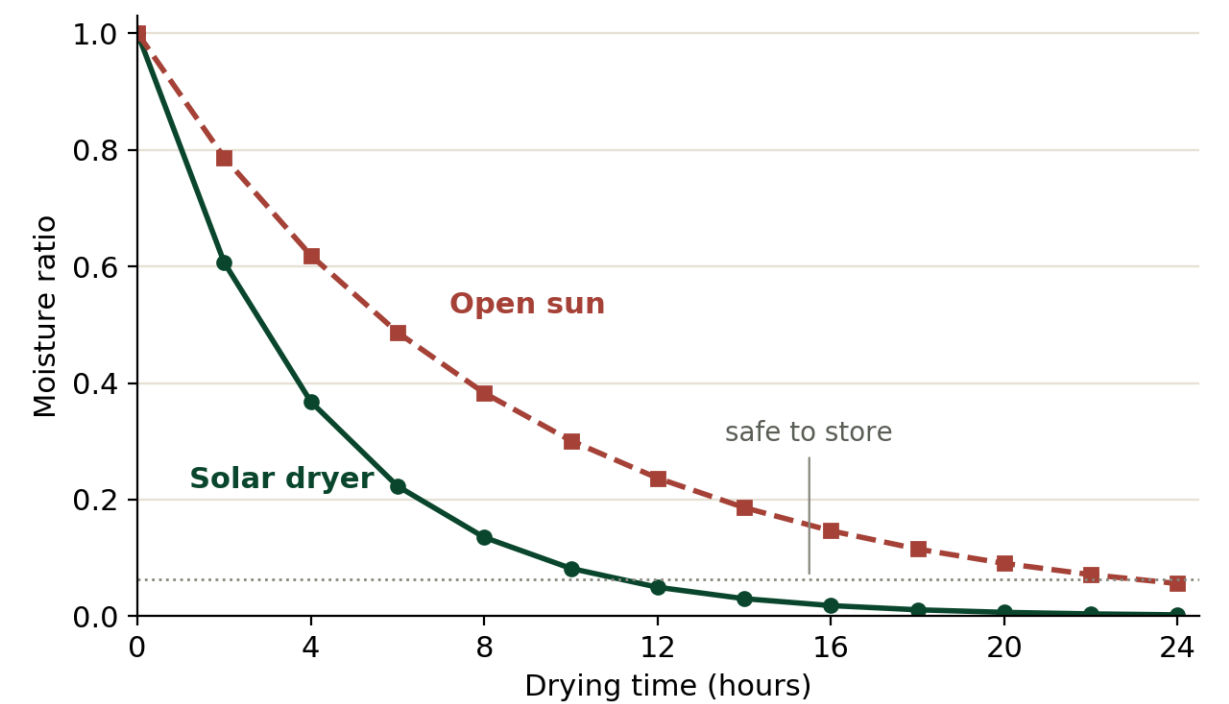


Figure 1. Moisture ratio of mango slices against drying time, in the solar dryer and in the open sun. Points are means of twelve runs, and the lines are the fitted model.

Air in the chamber was 14 to 22 °C warmer than outside during the middle of the day.

Quality

Table 1. Drying time and quality of mango slices, mean of twelve runs. Values in brackets are one standard deviation.

Measure	Solar dryer	Open sun
Time to 10% moisture (hours)	11 (1.2)	23 (2.6)
Vitamin C retained (%)	68 (4)	41 (6)
Colour change, total difference	9.1 (1.0)	17.4 (2.2)
Slices spoiled or soiled (%)	1	8

Slices from the dryer kept more of their vitamin C and changed colour less. One slice in a hundred was lost to soiling in the dryer, against eight in the open.

Discussion

The dryer halved drying time. That is close to what has been reported for commercial mixed-mode dryers [3], [5], at about a sixth of their price. Faster drying is also the likely reason for the better retention of vitamin C, which is destroyed by long exposure to heat and light [2].

The materials cost the equivalent of 85 US dollars, and a carpenter built the dryer in three days. At local prices for dried mango, a farmer drying 6 kg a day recovers that cost in *one season*. As one of the farmers who took part put it:

With the old rack I lost a day's fruit every time it rained. Now I close the door and go home.

Limitations

The work was done at one site and with one variety. Drying time will be longer in more humid places. The greenhouse plastic lasted two seasons and will need replacing, which is not counted in the cost.

Conclusion

A solar dryer that a local workshop can build halves the drying time of mango slices and keeps more of their vitamin C and colour than open sun drying. Its cost is within reach of a group of smallholder farmers. Trials in more humid regions, and with other fruits, should follow.

References

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