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Meat drying in a hot and humid climate using convection type solar dryers

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Abstract *Two types of solar dryer were examined for use in the drying of meat strips under hot, humid climatic conditions. The solar cabinet dryer proved to be more effective than the solar tent dryer in the rate of moisture reduction. Long raw material preparation time resulted in the poor integration of samples into the first drying cycle. Pretreatment of the strips by immersion in 5% sodium chloride solution conferred no advantage in drying rate.*

Keywords: meat drying, sun drying, solar cabinet dryer, solar dryers, solar tent dryer.

Introduction

Sun drying has been traditionally used in developing countries for the preservation of small quantities of product. The technique requires little expense or expertise and can give an acceptable shelf-stable product in warm dry climates. The process has limitations when applied in the more humid tropics, where reduced rates of moisture loss may lead to increased drying times and risk product spoilage. Solar dryers will reduce drying times, reduce product spoilage and offer some protection against insect infestation. Other quality attributes, however, may be reduced.

This paper concerns the improvement of meat drying technology in the humid tropics using solar dryers. A number of simple, low-cost dryer designs are available, based on a drying chamber consisting of a polythene sheet covered framework (Doe *et al.* 1977). These designs differ in the site and type of solar collector (Brenndorfer *et al.* 1985). Two types of solar dryer were evaluated in this trial: the solar tent dryer (STD) consisted of a combined drying and collecting chamber; the solar cabinet dryer (SCD) featured a separate solar collecting chamber.

These units were compared with exposed ambient drying of meat strips suspended 1 m above ground level. Trim and Curran (1983) reported that pretreatment with salt was necessary in order to prevent spoilage during the drying of fish under humid (>75% relative humidity) conditions and that brine immersion rather than dry

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salting gave a better quality product. The comparative trials described here were carried out on meat strips with or without pre-immersion in 5% (w/v) brine.

Materials and methods

Solar dryers

The 4 m^3 STD was based on the design of Doe *et al.* (1977); air was introduced through two 0·4 m^2 openings covered by 2 mm nylon mesh (5% surface area of 0·36 mm gauge transparent polythene sheet), which were sited at base level, and vented through two 0·125 m^2 openings at each end of the tent apex. The 4·5 m^2 tent base area, painted black, served as the solar collector; the dryer was elevated 0·86 m above ground level to improve air circulation.

The SCD was similar to that described by Exell (1980), in which the air was ducted through a separate 0·3 m^3 solar collector (2 m^2 black base area) into the 1·5 m^3 chamber (black base area 1·25 m^2), air being vented through a 1 m high black polythene-covered chimney fitted to the apex of the dryer.

Raw material preparation

Within 2 h of slaughter, beef topside *(semimembranosus)* was trimmed of connective tissue and fat (residual fat 3·5%, dry weight basis) and cut into strips 150 × 10 × 10 mm or 150 × 20 × 20 mm (length × width × breadth) with their longest axis parallel to the muscle fibre direction. Some strips were pre-treated by immersion in 5% w/v sodium chloride solution at 1:2 (meat to brine) infusion ratio at 25 °C for 2 h. Ten to fifteen meat strips were hung on hooks welded to a single 1 m rod; eight rods were fitted in layers in each dryer giving a meat weight to collector area ratio of 0·25 kg/m^2.

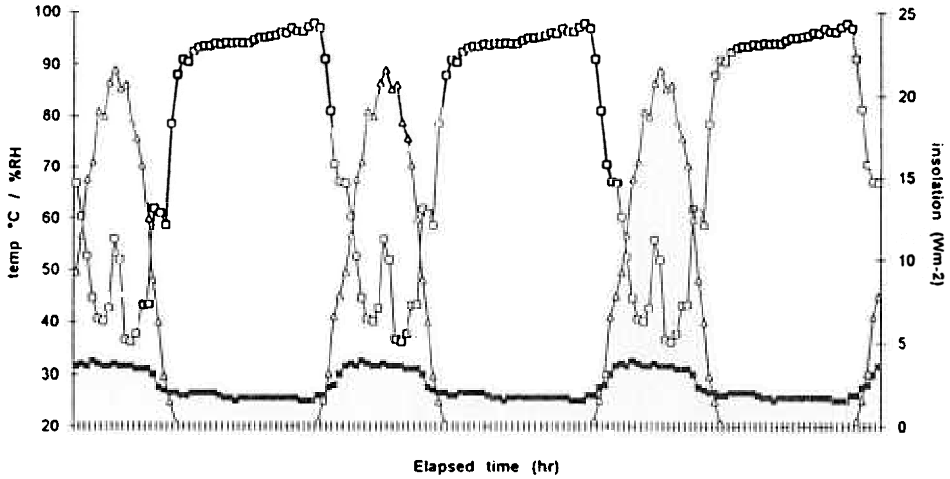


Figure 1. Ambient environmental conditions during drying cycles. ■ Temperature; □ relative humidity (%); △ insolation

Drying runs

Drying runs were carried out in the open in January/February in Accra, Ghana. Daytime temperatures were typically at max. 33 °C (unshaded) with a relatively low relative humidity (min. 35%); at night the temperature fell to about 23 °C and relative humidity, increased to almost 100% (Figures 1, 2). Wind speeds over the trial were consistently below 4 m/s. Dryers were loaded approximately 4 h after sunrise and drying was continued over a 3 day period. Weight loss was recorded by weighing whole rods at 4–8 h intervals. Moisture content was determined on one-third of the total whole strips held on separate rods (20 g sample dried at 103 °C for 8 h) and water activity was determined on the same sample (1 g chopped sample measured on

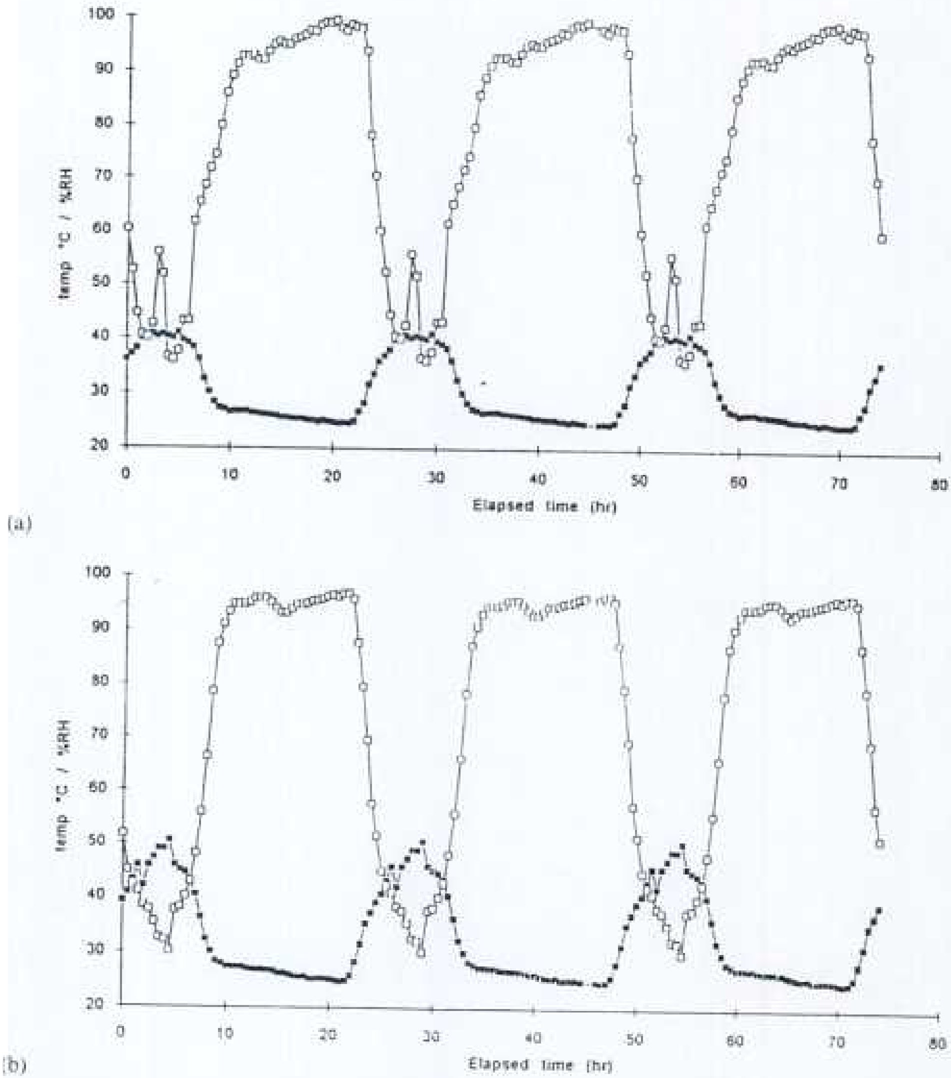


Figure 2. Environmental conditions in (a) the STD; (b) the SCD. ■ Temperature; □ relative humidity (%)

a Decagon XI water activity meter). Measurements of insolation (Kipp and Zone type CM11 solarimeter), ambient humidity, ambient and internal dryer temperatur were recorded on a Grant squirrel data logger.

Results and discussion

Weight loss from meat strips dried in ambient conditions is shown in Figure 3. Strip of 10 × 10 mm would be expected to complete drying (i.e. to <30% of the origin weight) in 35 h; this would be extended to at least 70 h in the larger (20 × 20 mm strips. Salt pre-immersion accelerated the initial rate of weight loss in both sizes o strips, although this advantage was not sustained, leading to a reduction in overal weight loss over the drying period. The crossover point (at which progressive weigh loss becomes less than that for raw material samples) for the 10 × 10 mm an 20 × 20 mm strips were 20 and 45 h respectively. These points coincided wit overnight periods in the first and second drying cycles.

Weight loss and associated changes were recorded for meat strips in both sola dryers for the 10 × 10 mm (Figure 4) and the 20 × 20 mm strips (Figure 5). Th 10 × 10 mm raw material strips lost 70% of their original weight in both the SCD an STD. More divergent results for weight losses were obtained for the 20 × 20 m strips; the rate and extent of weight loss was generally lower in the SCD. Th pretreatment of these strips with brine caused a further reduction in overall weigh loss although this was equivalent to strips dried under ambient conditions. Th

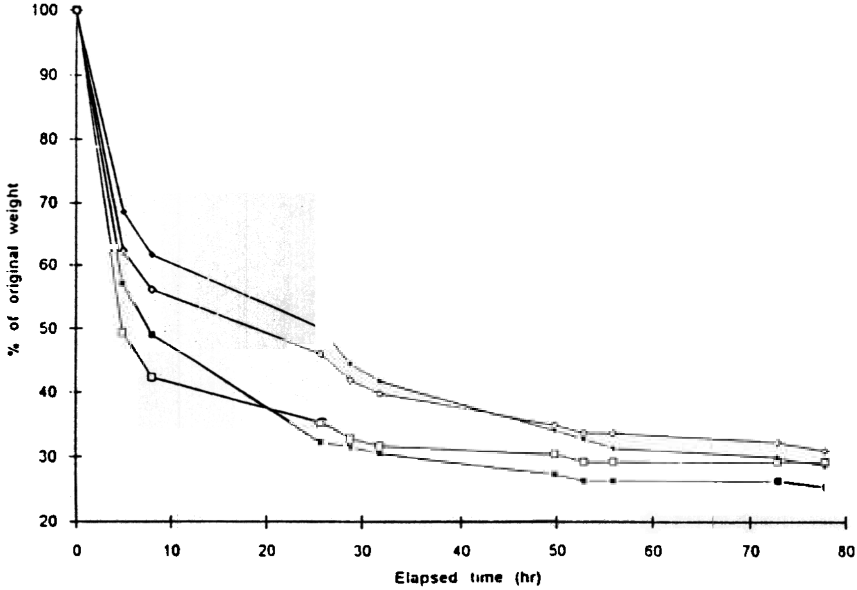
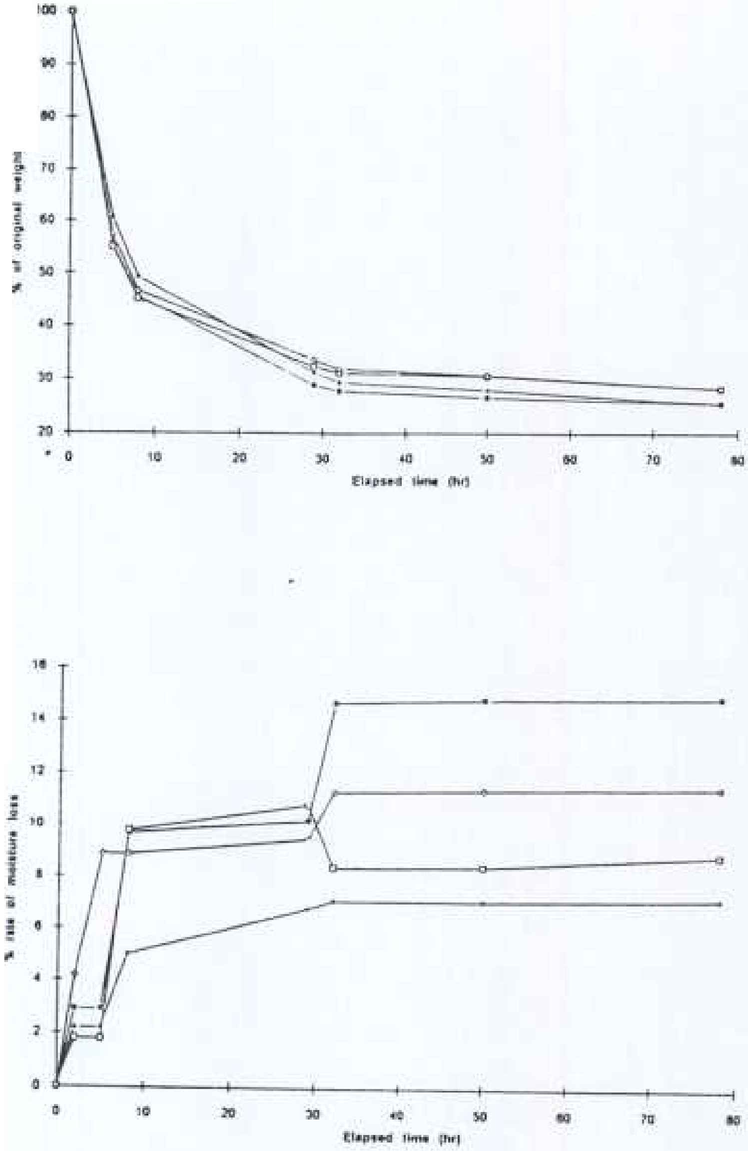
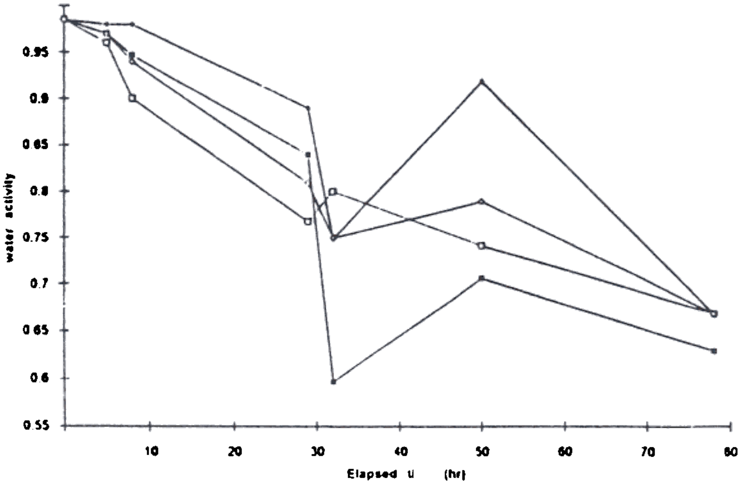


Figure 3. Weight loss of meat strips dried under ambient conditions. ■ 10 × 10 mm, raw; □ 10 × 10 m salted; ◆ 20 × 20 mm raw; ◇ 20 × 20 mm salted



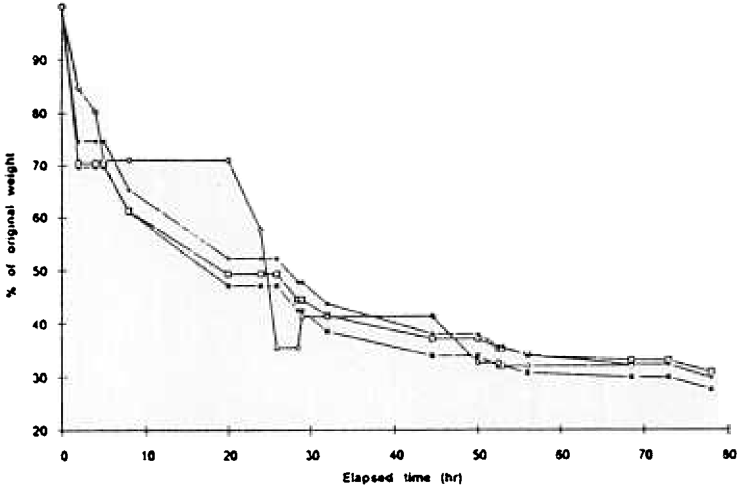
(b)

Figure 4. Weight loss (a), cumulative rate of moisture loss (b) and water activity (c) in 10 × 10 mm meat strips dried in the SCD and the STD. ■ Raw, SCD; □ salted, SCD; ◆ raw, STD; ◇ salted, STD



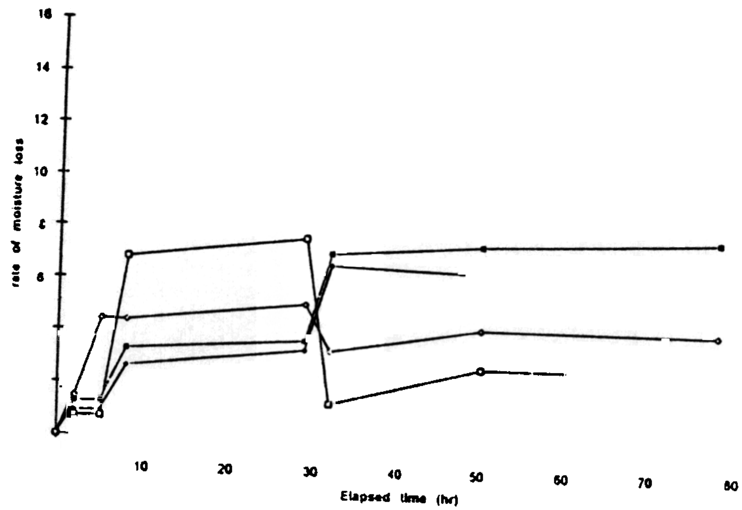
(c)

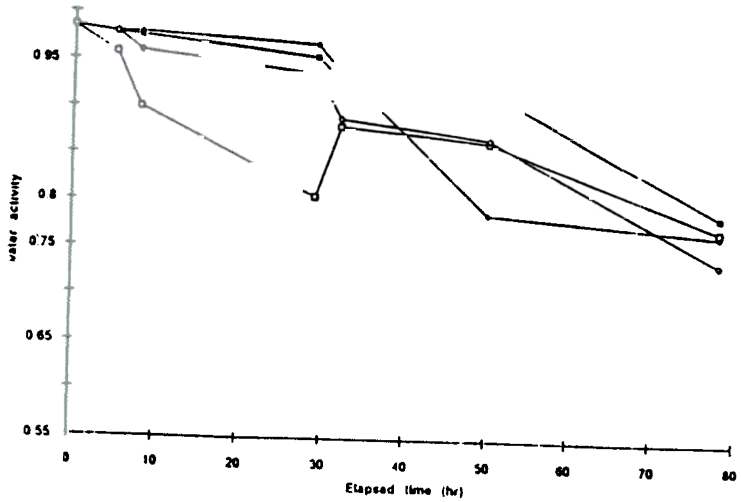
Figure 4. (continued)



(a)

Figure 5. Weight loss (a), cumulative rate of moisture loss (b) and water activity (c) in 20 × 20 mm meat strips dried in the SCD and the STD. ■ Raw, SCD; □ salted, SCD; ◆ raw, STD; ◇ salted, STD





(c)

Figure 5. (continued)

performance of both dryers was similar to that recorded for these units with brined or salted fish (*Xenomugil thoburni*), giving 35% of original weight after 35 h (Trim and Curran 1983), although the effect of not salting the fish was not reported.

Results for moisture loss suggested that the drying process could be divided into four distinct phases, reflecting in part changes in ambient conditions. The initial rate of moisture loss was rapid over the first 6-h period in all treatments, although the reduction in moisture in the raw material sample dried in the STD was noticeably slower. Brine pre-immersion appeared to accelerate the drying rate but had a limited effect under the higher temperature conditions in the SCD. Rates of moisture loss over the 6–24 h period were reduced in all treatments irrespective of dryer type as the samples equilibrated with the higher relative humidity overnight. Reduction in water activity over these early drying stages was in agreement with the steady decline anticipated from moisture loss.

Treatments diverged over the 29–32 h drying period, equivalent to the high temperature, low humidity conditions of the second drying cycle. The increase in the rate of moisture loss in the STD raw material and brined 10 × 10 mm strips was minimal, but a higher rate of moisture loss was observed in SCD 10 × 10 mm raw samples. A high rate of moisture loss was observed in both dryers for the 20 × 20 mm raw material; brined samples generally showed a relative reduction in rate of moisture loss in both dryers.

Drying over the last phase (32 h onwards) took place over the equivalent of two

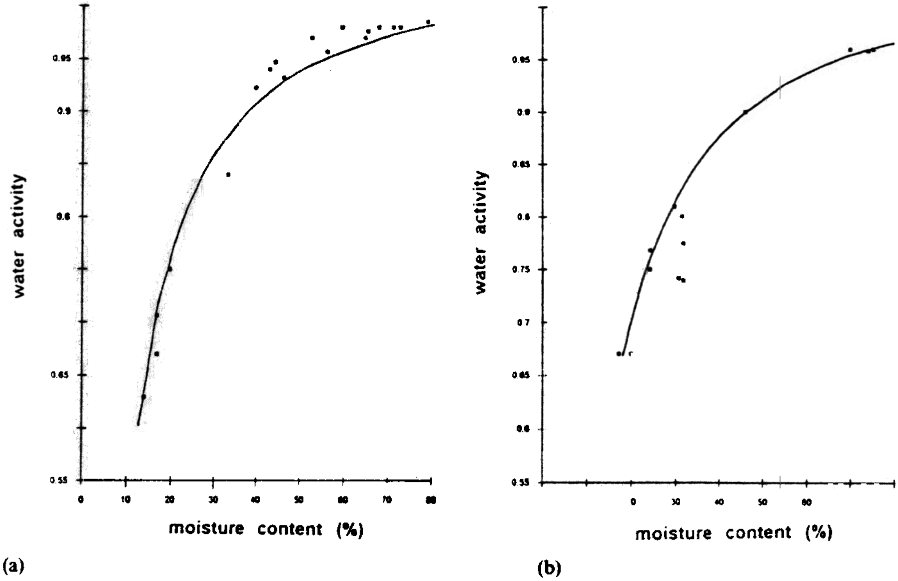


Figure 6. Relationship between water activity and percentage moisture content in raw (a) and salted (b) meat strips.

Table 1. Percentage moisture contents of end products removed from SCD and STD dryers after 70 h drying

Treatment	SCD	STD
Raw (10 × 10 mm)	16·2	18·4
Raw (20 × 20 mm)	28·5	24·8
Salted (10 × 10 mm)	19·1	20·4
Salted (20 × 20 mm)	33·1	28·9

further drying cycles. All treatments showed a consistent limited moisture loss over the period, irrespective of the dryer type or brine pre-immersion. Reduction in water activity was not consistent with moisture content, reflecting a decrease in sample homogeneity with respect to water distribution. Regression analysis of the overall moisture content and water activity data (Figure 6) gave a reciprocal relationship ($y = a + b/x$). Correlation coefficients for raw material ($r = 0{\cdot}86$; $P < 0{\cdot}001$) and salted material ($r = 0{\cdot}92$; $P < 0{\cdot}001$) confirmed the variation in sample composition and changes in distribution of water within the drying material.

End product analysis (Table 1) confirmed the advantage of small-diameter strips in producing a stable end product after 70 h drying. The SCD was marginally better than the STD in terms of overall moisture reduction; Trim and Curran (1983) reported a similar limited difference in dryer performance for fish. Interestingly, the SCD is less efficient in overall removal of moisture from the 20 × 20 mm strips, probably because of the case hardening effects of higher drying temperatures. Pre-treatment with brine resulted in a product with higher ultimate moisture content.

Conclusions

Conditions of high relative humidity will result in extended drying times, which may affect the quality of the dried product. This risk can be reduced by the use of narrow diameter meat strips and solar cabinet type dryers; immersion brining assists in the initial rate of moisture loss but has an inhibitory effect over a 70 h drying process. Other chemical means of product protection over the first two drying cycles should be investigated.

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