

Quality of Five Thai Mango Cultivars (*Mangifera indica* L.) Using a Solar Drying System

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ABSTRACT

Solar drying is a simple but efficient method to preserve fruits even in remote areas where the lack of sufficient infrastructure constrains successful fresh marketing. Dried mangoes are a promising and healthy snack product for regional as well as export markets. The climatic conditions during the peak mango season in Thailand offer best opportunities for solar drying. Five untreated Thai mango cultivars, i.e., 'Kaew', 'Okrong', 'Chok Anan', 'Nam Dokmai' and 'Rad' were investigated for their suitability for solar drying. A solar tunnel dryer type 'Hohenheim' with photovoltaic-powered fans were used for the drying process which was finished within one sunny day. Nutritive and sensory quality aspects such as β -carotene content, provitamin A, colour, texture and flavour were evaluated. The cultivars 'Kaew' and 'Nam Dokmai' showed best results for all quality characteristics.

Key words: Mango cultivars, *Mangifera indica* L., Solar drying, Quality, β -carotene, Provitamin A

INTRODUCTION

The mango fruit (*Mangifera indica* L.) is one of the most important seasonal fruits in Southeast Asia. With an annual harvest of 1.25 million tons of fresh mangoes, Thailand is one of the main producers in Asia 2000 (De la Cruz Medina and Garcia, 2003). Among over 100 native mango cultivars in Thailand, only some are of commercial interest. The main harvest period is limited to about three months per year during the hot and dry season in Thailand, March to May. The lack of adequate storage facilities and an insufficient marketing structure lead to high post-harvest losses of these perishable fruits. In addition, overproduction and diseases cause low prices for fresh fruits and increase the demand for appropriate preservation methods of the fresh mango flesh. Processed mango products are fast gaining markets and commanding better prices than other tropical fruits. Major markets for dried mangoes in 1998 were Malaysia, Japan, Singapore, Hong Kong and The Netherlands.

Germany is one of the major import countries for canned mangoes (De la Cruz Medina and Garcia, 2003) but the import of other dried tropical fruits is increasing.

Focussing on a second problem besides the improvable fruit marketing in the region, the vitamin A-deficiency, which is widespread in Southeast Asia and a severe risk especially for infants and children younger than 5 years, should be mentioned in this context. Malnutrition and limited intake of vitamin A and provitamin A cause several serious health problems, mostly during child- and motherhood. Beside the well-known night-blindness and blindness, the weakening of the immune system and keratinisation of mucous membrane is followed by high morbidity and mortality rates among young children (Stephensen, 2001).

Mangoes can be classified as provitamin A-rich fruits. Depending on cultivar, the carotenoid content of mangoes ranges from 800 to 11,000 $\mu\text{g}/100\text{g}$ (Nanjundaswamy, 1997). About 50 to 80% of the total carotenoids are available as β -carotene (Mercandante and Rodr'guez Amaya, 1998). For dietary carotenoid mixtures, it is generally acknowledged that in terms of vitamin A, 6 μg of β -carotene is converted into 1 μg of retinol. The daily intake of retinol equivalent (RE) for healthy adults and children under six years old is 800 and 500 RE, respectively, (FAO, 1988). Besides the great relevance of carotenoids as provitamin A in developing countries, the importance of these micro-nutrients is additionally proved more and more as natural antioxidants, protecting human against certain types of cancer and cardiovascular diseases (Byers and Perry, 1992).

In Thailand and other Southeast Asian countries, osmotically pre-treated and sulphite treated mangoes are dried in cabinet dryers, mostly powered by gas burners at 50 to 60°C for 18 to 25 h. This results in high energy consumption and dried, sugared fruit pieces with low micronutrient but remarkable sulphite contents.

The present study was aimed at the suitability of solar drying for preserving fresh, untreated mangoes and retaining most of the natural, valuable β -carotene in the fruit flesh. Comparing the product quality concerning nutritive and sensory aspects, the most suitable mangoes among five typical polyembryonic Thai cultivars were revealed.

MATERIALS AND METHODS

Raw materials and drying processes

Three Thai mango cultivars, 'Kaew', 'Okrong' and 'Chok Anan' were purchased from the local market. Two others, cvs. 'Nam Dokmai' and 'Rad' were obtained from Prapat Farm at Maejo near Chiang Mai. Green mature fruits were allowed to reach a degree of approx. 75 to 80% full ripeness, according to Mahayothee et al., (2004). Moisture contents (w. b.) of the fresh mangoes were in the range of 82 to 85%. Fruits were cut with a common slicer into 8 mm-thick pieces. In the morning, the slices were spread out onto the drying area of the solar tunnel dryer, type 'Hohenheim', and were dried until a final moisture content (w. b.) of 14 to 16%. The complete processing for drying untreated mango slices is shown in Figure 1.

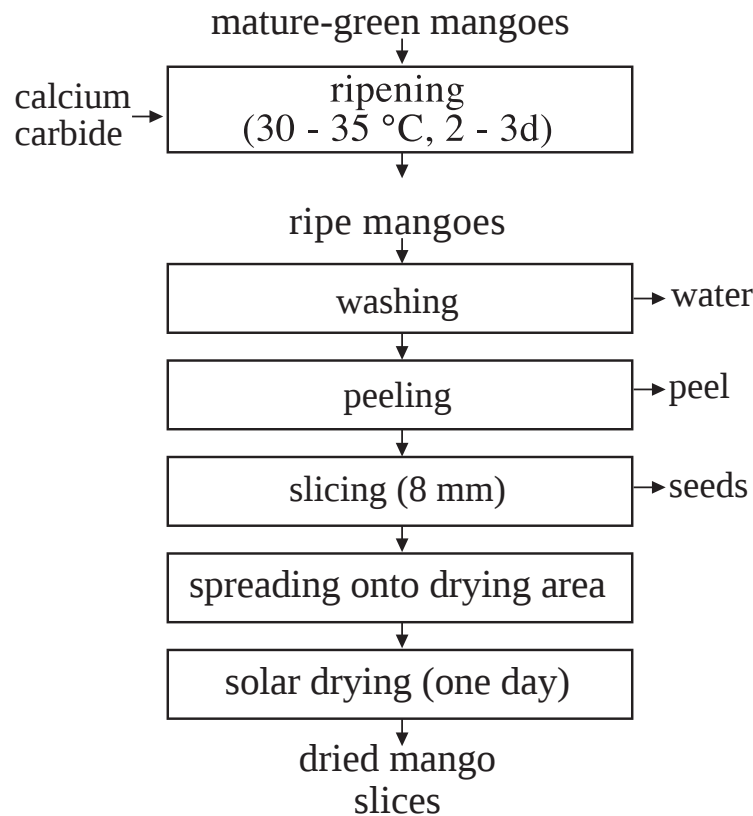


Figure 1. Flow chart of processing untreated dried mango slices.

The solar tunnel dryer (Figure 2) comprised a plastic sheet-covered flat plate collector (width 2 m, length 6.5 m) and a drying tunnel (width 2 m, length 9 m). It was arranged to supply hot air directly to the drying tunnel, using three fans powered by a 53 W solar cell module. Thus, the dryer could be used in rural areas where no supply of electricity is available from grid. The solar collector was connected directly to the drying tunnel without any additional air ducts. Plastic foam sandwiched between two parallel metal sheets was used as a back insulator for both the collector and the drying tunnel. This insulator also functioned as the structure of the dryer. The top surface of the insulator in the collector was painted black to absorb solar radiation. The collector and the drying tunnel were covered with a transparent UV-stabilised PE plastic sheet which was fixed to the collector frame, using reinforced plastic clamps. One side of the sheet of the drying tunnel was fixed to a metal tube, allowing the sheet to be rolled up and down for loading and unloading the dryer. For the drying tunnel, a wire mesh was placed on top of the insulators. A sheet of plastic net on which the mango slices to be dried were spread, was placed onto the wire mesh. This arrangement allowed the drying air to flow around the whole surface of the mango slices. Both collector and drying tunnel were installed on

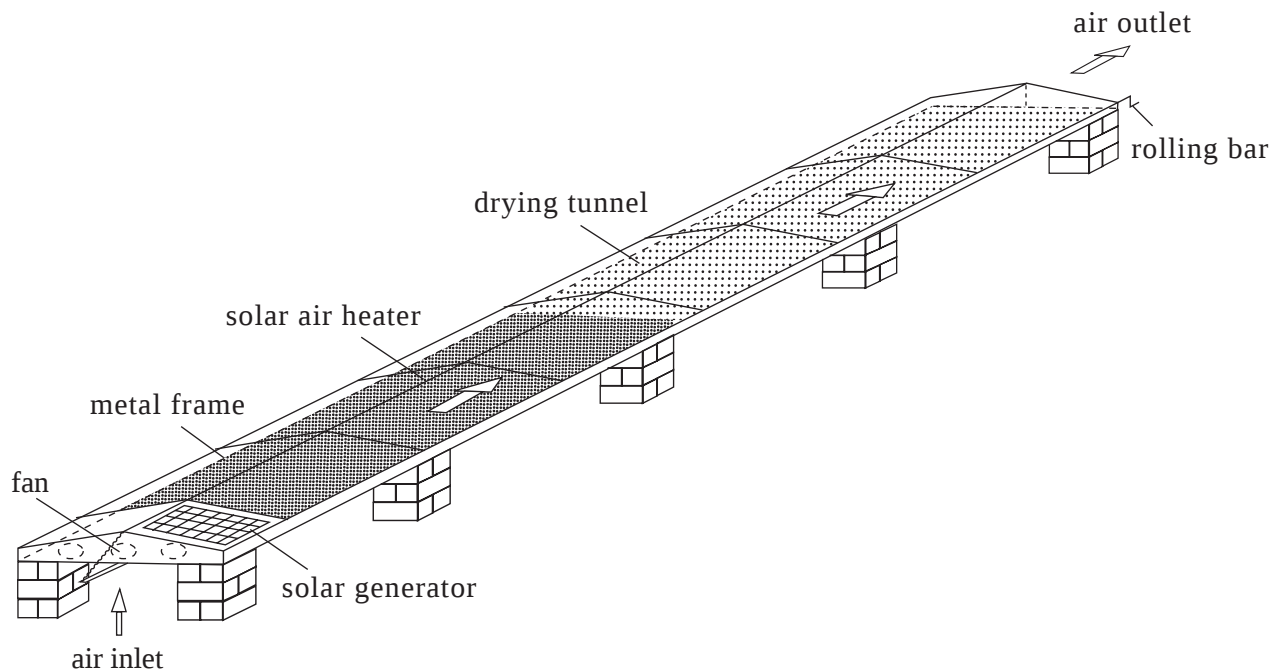


Figure 2. The solar tunnel dryer, type Hohenheim, according to Schirmer et al. (1996).

concrete block structures (Schirmer et al., 1996). The instrumentation of the solar tunnel dryer allowed the continuous measurement of crucial drying and weather conditions. Some exemplars were summed up in Figure 3 for two individual days. Drying trials were performed from end of March until middle of May 2001. Ambient air temperature (ϑ_i), drying air temperature (ϑ_d) and internal fruit temperature (ϑ_f) were measured by thermo couple, solar radiation (E_s) by pyranometer (Kipp & Zonen, Netherlands) and relative humidity of the ambient air (φ_i) by hygrometer (Rotronic, Germany). The data were recorded by datalogger (Hewlett Packard, USA). Thermo couples were situated at shadowed positions, drying temperatures were means of 3 measurements directly above the drying good in the middle of the drying tunnel, internal fruit temperatures were means of 2 measurements and sensors were situated in the centre of the slices.

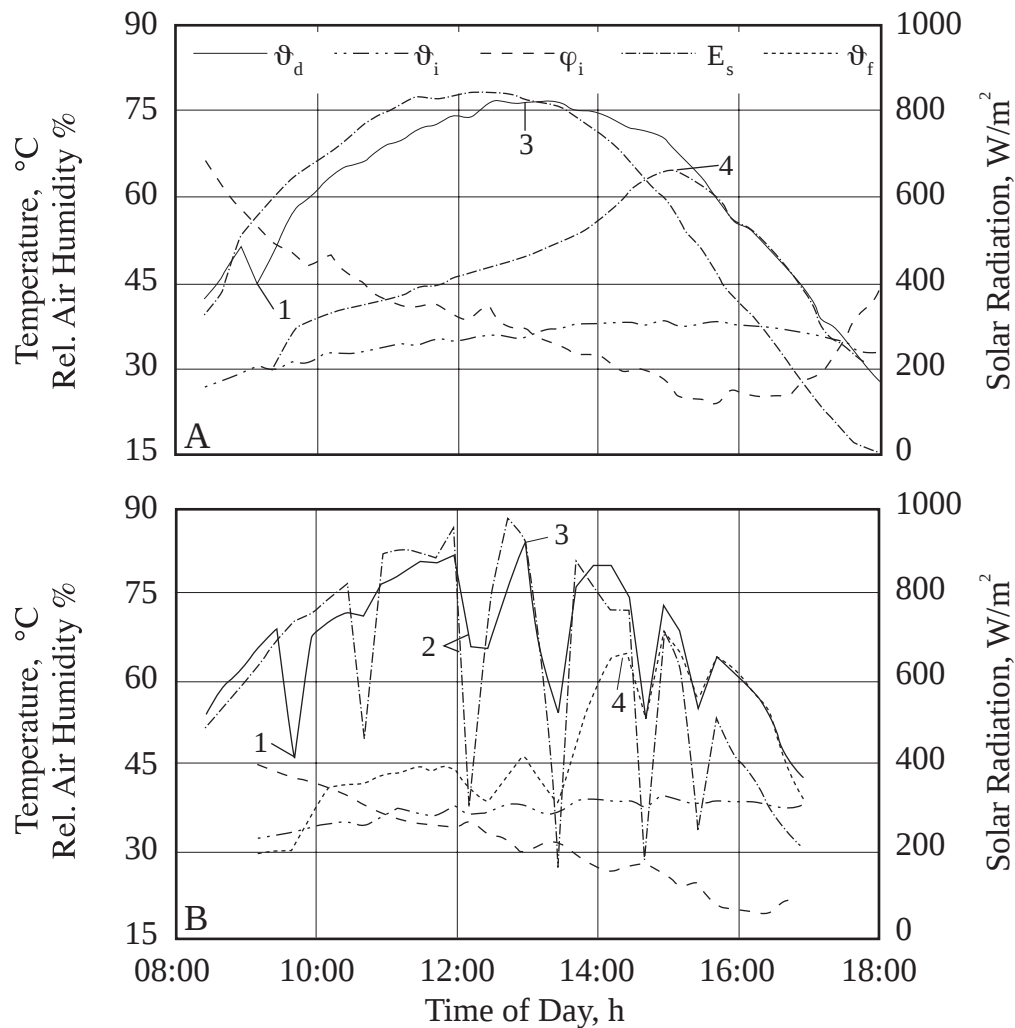


Figure 3. Solar drying conditions during a typical sunny (A) and typical cloudy (B) day. Legends see text. 1, opening the dryer for loading; 2, clouds shadowing the dryer; 3, maximum radiation (E_s) and drying temperature (θ_d) at high noon; 4, significant increase of internal fruit temperature (θ_i) indicating early drying end.

Quality evaluation

In accordance with one of the main quality criteria of dried fruit products for consumers, colour was evaluated by chroma-meter (Minolta, Japan) using the CIE-L*a*b* uniform colour space (CIE-Lab), where L* indicated lightness, a* indicated green (-) to red (+) and b* blue (-) to yellow (+) values. Numerical values of a* and b* were transformed to hue angles hab and colour chromaticity C* (Abbott, 1999).

The nutritional quality was evaluated by HPLC determination of the all-*trans*- β -carotene content corresponding to dry weight (DW) (Pott et al., 2003). Built stereoisomers are known to offer less retinol equivalents (RE) than the all-*trans* form (Rodríguez Amaya and Tavares, 1992). Therefore vitamin A values were calculated based only on the all-*trans*- β -carotene content.

Following the prevailing sensory tests for snack products and sweets of the Deutsche Landwirtschaftsgesellschaft (DLG, 1999) a valuation test with 5-point-scale was used for sensory evaluation. Before tasting the dried mango slices, two trained panels, Thai (n=12) and German (n=9), set a certain evaluation factor for the parameters 'appearance/colour', 'texture' and 'aroma/taste', individually. The sum of the evaluation factors was 20. For evaluating quality parameters as well as climatic conditions, at least two drying batches with similar drying conditions were done for each cultivar. When clouds or even rain influenced drying time or quality, dried samples were rejected.

RESULTS AND DISCUSSION

Drying process

The sunny and hot months in Thailand, March, April and May, with high ambient air temperatures and constant solar radiation offer best weather conditions for solar drying. In contrast to the stationary medium-temperature drying process in a conventional cabinet or tray dryer, the unsteady solar drying process will depend on changing weather conditions. Figure 3 shows typical conditions for a typical sunny (A) and typical cloudy day (B) in April 2001. Opening the drying area for filling and starting the drying process in the morning was followed by a decrease of drying temperature (1). Clouds, even when they shadowed the dryer only for a short time, led to a sudden but massive decrease of solar radiation followed by a severe decrease of the drying temperature (2). Between 10:00 and 15:00 o'clock, drying temperatures were mostly higher than 60°C. At high noon usually the temperature raised up to 75°C (3). Such high temperatures were ideal for drying mango products and other insensitive goods (Pott et al., 2000). For heat-sensitive products, e.g., medicinal herbs, drying temperatures should be reduced to achieve optimum product quality (Spirovska et al., 2002). This can be done either by shadowing the solar air heater or the drying area of the tunnel dryer. The significant increase of internal fruit temperatures (4) indicated the early drying end. For mango slices, one sunny day was sufficient to finish the drying process. Filling half of the drying area led to a drying time of approx. 6 h. A complete filling of the dryer, with about 50 kg of fresh mango slices, took approx. 10 h. Thus, more than 2.75 kg of mango slices of 8 mm thickness were dried per square metre per day.

Colour and nutritive value

Comparing the five mango cultivars of interest, concerning browning reactions, colour and β -carotene retention (Figure 4), it becomes obvious that browning reactions were negligible because of the retained high hue angles (h_{ab}). Additionally, the cultivars 'Chok Anan', 'Kaew' and 'Rad' showed the most intensive colour as revealed by high chromaticity values (C^*). After drying, the range of β -carotene retention with reference to dry weight (DW) was 50 to 70%. The absolute contents depended mostly on cultivar differences. Thus, the cultivars 'Nam Dokmai' and in particular 'Kaew' showed the highest contents after drying. Calculating the provitamin A value based on the all-trans- β -carotene content of the dried mango slices according to the FAO (1988), dried 'Nam Dokmai' offered 330 RE, 'Chok Anan' 230 RE, 'Kaew' 950 RE, 'Rad' 390 RE and 'Okrong' only 65 RE per 100 g edible portion, respectively. Hence, β -carotene content in 150 g and 240 g of dried mango, cv. 'Nam Dokmai', would be equivalent to the daily requirement of vitamin A for healthy children and

adults, respectively. For the cultivar 'Kaew', the data were even more promising, i.e., 55 g and 85 g respectively. Therefore, untreated dried mango slices can be classified as very-provitamin A-rich food. Determining the provitamin A value of traditional, osmotic pre-treated mango slices, cv. 'Kaew', the loss of β -carotene caused by treatment processes and sugar gain got obvious. Ripe, osmotic-treated mango slices, cv. 'Kaew', retained only 280 RE per 100 g edible portion.

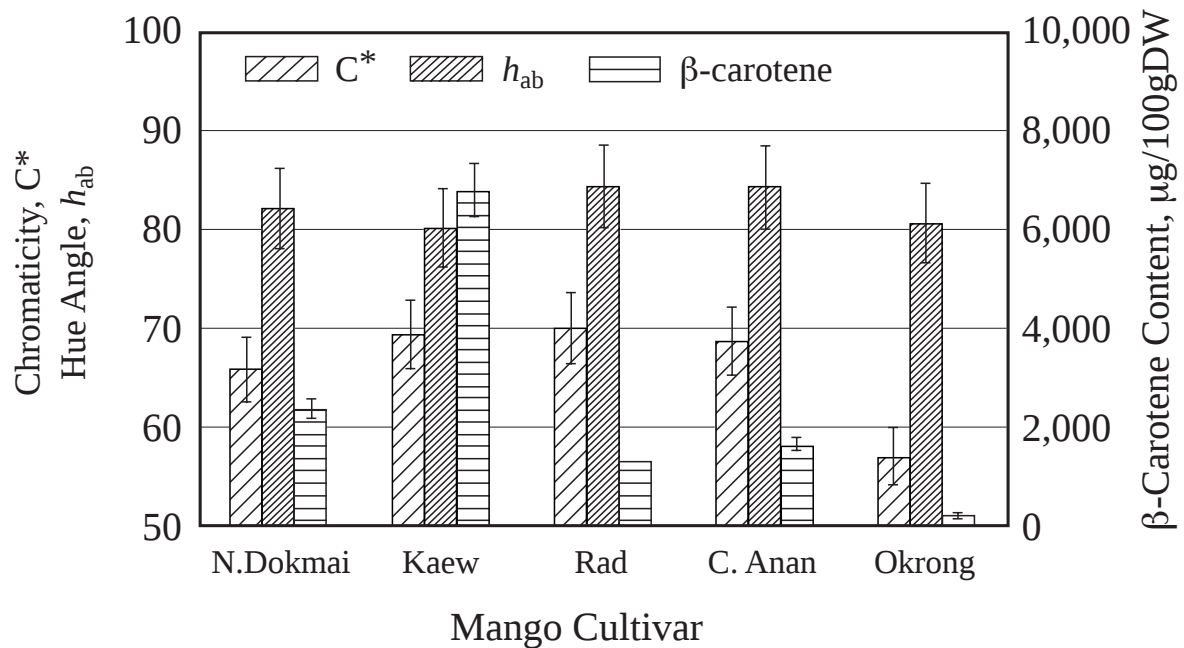


Figure 4. Colour and β -carotene content of five solar dried Thai mango cultivars. DW: Dry weight.

Sensory evaluation

In a preliminary study, a comparison between osmotic pre-treated and untreated dried mango slices, the commercial pre-treated were rejected by the Thai as well as by the German panellists (Büher, 2000). But recently, significant differences between the Thai and the German panel were shown, deciding their preferences among the three parameters 'appearance/colour', 'texture' and 'aroma/taste'. The sum of the parameter evaluation was 20. While the Thais scored the 'appearance/colour' with 7, 'texture' with 5 and 'aroma/taste' with 8, the Germans did not care in a similar extent about the appearance of the dried mango slices. But on the other hand, they classified the taste with a greater importance and with a significant gap to both other evaluation factors. Their evaluation was 4, 6 and 10 for 'appearance/colour', 'texture' and 'aroma/taste', respectively. This shows a probable cultural effect between the expectations of both panels concerning the acceptance of dried fruits. The final results of comparing the sensory quality of the five mango cultivars are shown in Figure 5. The significant difference between both panels with regard to general acceptance of dried mango slices is noticeable. The German panelists gave better scores on the whole, at least a

half score higher than the Thais. Meanwhile, the preferences for certain cultivars were corresponding. Both panels preferred the cultivars 'Nam Dokmai' and 'Kaew', while the cvs. 'Rad', 'Chok Anan' and 'Okrong' did not reach scores better than '3'. In agreement with the results for colour, 'Okrong' was rejected because of the appearance of the slices. 'Chok Anan' was too fibrous with a flat aroma. 'Nam Dokmai' and 'Kaew' convinced, especially the German panelists, because of their intensive, bright colour, smooth texture and delicious aroma and taste. In general, the Thai panelists found defects especially with regard to the texture and the insufficient sweetness of dried mango slices. Sweetening by gentle pre-treatments considering nutritive quality should be considered for optimising sensory quality for Thai consumers (Konsue et al., 2002).

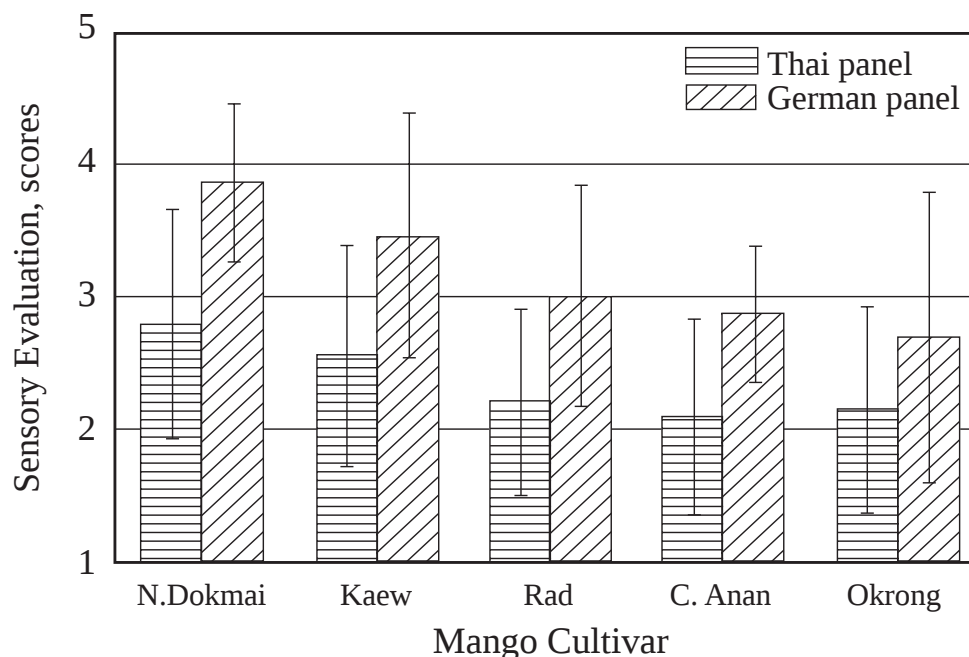


Figure 5. Sensory evaluation of five solar dried Thai mango cultivars.

CONCLUSION

For the production of dried mango slices, the solar tunnel dryer type 'Hohenheim' was successfully introduced. Drying process for untreated mango slices could be finished during one day in Thailand's hot season, March to May. The dried Thai mango cultivars 'Nam Dokmai' and 'Kaew' had the best nutritive as well as sensory quality. Thais as well as Germans preferred their appearance, texture and flavour, while 'Chok Anan' and 'Okrong' were rejected. The dried products offered an excellent source for vitamin A. Eighty-five g of dried mangoes, cv. 'Kaew', would be sufficient for the daily requirement of provitamin A in healthy adults. The sensory results revealed that untreated dried mango slices were promising snack products in Germany. For Thai consumers, an optimisation concerning texture and sweetness by gentle pre-treatments might be considered.

ACKNOWLEDGEMENTS

The authors thank the Deutsche Forschungsgemeinschaft (DFG MU 582/3-2) and the National Research Council of Thailand (NRCT) for financial support. We are grateful to the Department of Food Technology, Silpakorn University, for providing laboratory facilities for the β -carotene extraction.

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