Influence of drying parameters on β-carotene retention in mango leather

Roberto C. GUARTE[a], Isabell POTT[b]*, Werner MÜHLBAUER[b]

[a] Department of Agricultural Engineering, College of Engineering and Agri-Industries, Leyte State University, Visca, Baybay, Leyte 6521-A, Philippines

[b] Institute for Agricultural Engineering in the Tropics and Subtropics, Hohenheim University, 70593 Stuttgart, Germany

pott@ats.uni-hohenheim.de

* *Correspondence and reprints*

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Abstract — Introduction. Dried mango slices are a common snack product in Southeast Asian countries. Mashing the carotenoid-containing mango flesh and drying the puree to mango leather is a promising alternative to utilise even over-mature or small fruits and fruits with irregular size as low-cost raw materials. Within the study, the impact of blanching and air temperature (40–90 °C) on drying time and quality was investigated. **Materials and methods**. Drying tests were conducted using a laboratory dryer, which allowed continuous measurement of the drying rate. The quality of the mango leather was evaluated in terms of colour (CIE-Lab) and β-carotene content (HPLC). The formation of 13-*cis*-β-carotene isomer was used to indicate thermal β-carotene degradation. **Results and discussion**. Blanching degraded the β-carotene content, reduced drying time (–20%) and decreased browning reactions. Optimum drying conditions in terms of drying time, colour and β-carotene retention were determined at 80 °C. The all-*trans*-β-carotene content was maintained at 75% and no decrease in colour saturation (*C**) was observed. As a result, it is expected that 80 °C is sufficient to inactivate carotenoid oxidising enzymes without showing significant negative thermal effects on β-carotene degradation. Higher temperatures led to severe β-carotene losses. Lower temperatures increased drying times, caused discolouration and decreased the β-carotene retention. **Conclusion**. With a provitamin A activity of (600 to 650) retinol equivalents (RE), mango leather is a promising source of provitamin.

Philippines / mangoes / postharvest losses / postharvest technology / fruit pulps / hot air drying / carotenoids / quality

Influence des paramètres de séchage sur la conservation de β-carotène dans la pâte de mangue.

Résumé — Introduction. Les tranches sèches de mangue sont un produit commun de grignotage dans les pays d'Asie du Sud-Est. Le broyage de la chair de mangue contenant des carotenoïdes et le séchage de la purée obtenue pour produire de la pâte de mangue est une voie prometteuse pour utiliser des fruits réguliers trop mûrs ou petits, ou des fruits de calibre irrégulier en tant que matières premières peu coûteuses. Dans notre étude, l'impact du blanchiment et de la température de l'air (40–90 °C) sur le temps et la qualité de séchage a été étudié. **Matériel et méthodes**. Des essais de séchage ont été effectués à l'aide d'un dessiccateur de laboratoire qui a permis de mesurer en continu le taux de séchage. La qualité de la pâte de mangue obtenue a été évaluée en termes de couleur (CIE-Lab) et de son contenu en β-carotène (HPLC). La formation de l'isomère 13-*cis*-β-carotène a été utilisée pour suivre la dégradation thermique du β-carotène. **Résultats et discussion**. Le blanchiment a affecté la teneur en β-carotène, réduit le temps de séchage (–20%) et diminué les réactions de brunissement. Les meilleures conditions de séchage en termes de temps de séchage, de couleur et de conservation de β-carotène ont été déterminées pour 80 °C. La teneur en all-*trans*-β-carotène a été maintenue à 75 % et aucune diminution de la saturation de couleur (*C**) n'a été observée. En conséquence, une température de 80 °C devrait être suffisante pour inactiver les enzymes d'oxydation des carotenoïdes sans montrer d'effets thermiques négatifs significatifs sur la dégradation du β-carotène. Des températures plus élevées ont mené à des pertes graves en β-carotène. De plus basses températures ont augmenté les temps de séchage, ont causé de la décoloration et ont diminué la conservation de β-carotène. **Conclusion**. Avec une activité de la provitamine A de (600 à 650) équivalents de rétinol, la pâte de mangue est une source prometteuse de provitamine.

Philippines / mangue / perte après récolte / technologie après récolte / pulpe de fruits / séchage par air chaud / caroténoïde / qualité

1. Introduction

The mango fruit (*Mangifera indica* L.) is one of the most important seasonal fruits in the tropics. With an annual harvest of about 1 Mt of fresh mangoes, the Philippines are one of the main producers in Asia [1]. Carabao mango, the most important cultivar for local and export markets, is found in every region of the archipelago. The harvest period is limited to about 3 months per year during the hot and dry season. The lack of adequate storage facilities and insufficient marketing structures lead to high postharvest losses of the perishable fruits. In addition, over-production causes low prices for fresh fruits, and increases the demand for appropriate preservation methods for the fresh mango flesh [2].

On the other hand, vitamin A deficiency is widespread not only in Southeast Asia but in most of the developing countries where there is a severe risk of deficiency, especially for infants and children. Malnutrition and limited intake of vitamin and provitamin A cause several and serious health problems, mostly during child- and motherhood [3]. Although infant and child mortality was reduced by distribution of vitamin A supplements, mortality rates are still remarkable. Because of the high costs and the great logistical problems, supplementation campaigns are not recognised as an appropriate solution to solve the vitamin A deficiency [4]. Nevertheless, the intake of yellow and red fruits and vegetables is known to support the diet with provitamin A, in the form of vitamin A-active carotenoids [5]. The vitamin A deficiency, for instance, is less severe or negligible during the main season of mangoes in tropical countries and increases again during the off-season [6]. Besides the great relevance of carotenoids as provitamin A in developing countries, the importance of these micro-nutrients has been proved additionally as natural antioxidants, especially when consumed at nutritional doses and in combination, protecting humans against certain types of cancer and cardiovascular diseases [7, 8].

Mangoes can be classified as provitamin A-rich fruits. Depending on the cultivar, the usual carotenoid content of mangoes ranges from 800 to 9 200 µg per 100 g edible portion, whereas the Indian cultivar 'Alphonso' showed exceptionally high values of up to 11 000 $\mu g \cdot 100^{-1}$ g [9]. About (50 to 80)% of the total existing carotenoids is β-carotene [10]. Using the conversion factors for carotenoid mixtures from food propagated by the WHO [11] which are nowadays scrutinised in view of bioavailability [12], it is generally acknowledged that, in terms of vitamin A, 6 µg of β-carotene or 12 µg of mixed provitamin A-active carotenoids are converted into 1 µg of retinol. The recommended daily intake of retinol equivalent (RE) for healthy children under 6 years old is 400 RE. Considering the health status of infants and children in developing countries, an even higher supply should be taken into account [11, 13].

A potential source of provitamin A is dried products of ripe mango flesh which could be offered all year round. Dried mangoes, depending on the cultivar, contain up to 6 800 $\mu g \cdot 100\ g^{-1}$ β-carotene, which is equivalent to about 1 000 RE [14]. Dried mango slices or sticks are popular products in Southeast Asia and are consumed as snacks or sweets. For the processing of dried mango slices, intact and regular fruits of a sufficient size and a certain ripening status are required [15]. The fruits have to be cut manually and are commonly pre-dried osmotically in sugar solution with added preservatives. While slicing, the loss of fruit flesh located around the seed or flesh which is already too soft to cut properly usually reaches 30%, while losses caused by peeling are about 20%, additionally. Sliced mangoes are commonly dried in tray dryers with air temperatures of 60 °C or less. To reduce the power requirement of the fan, these dryers are operated in over-flow mode.

In contrast to the production of dried mango slices for which mangoes in a less advanced ripening stage are utilised [15], pureed mango flesh from ripe and fully-ripe fruits can be used to produce so-called mango leather. Thus, it appears that, due to the advanced natural ripening process, the flesh contains a higher amount of natural sugar and carotenoids, but the activity of endogenous oxidising enzymes increases [16]. Besides the lower purchase price of irregularly shaped and over-ripe fruits, processing is less labour-intensive. The

removal of the pulp from the seed can be mechanised by the use of pulping machines. Compared with the production of sliced mangoes, the processing losses are negligible. The pureed pulp is usually blanched before drying. The commercial processing of mango leather commonly used in the Philippines follows a specific flowchart (*figure 1*).

Despite certain advantages of the production of mango leather compared with the drying of sliced mangoes, the processing has never been investigated in detail. In particular, the optimal blanching and drying conditions as well as the β-carotene retention of mango leather have never been investigated.

The major objectives of this study were the determination of the impact of blanching as well as that of the drying air temperature on the colour and β-carotene content of the mango leather. During mashing, the mesocarp tissue is destroyed. Due to this decompartmentation of cell material, it is expected that enzymatic-catalysed degradation, mostly by lipoxygenase, reduces the carotenoid content while polyphenol oxidase simultaneously oxidises polyphenolic compounds into coloured, brown quinones. Furthermore, during blanching, a warm-up phase with an expected high activity of oxidising enzymes and the additional thermal stress influence the all-*trans*-β-carotene content. Besides degradation, a formation of *cis*-isomers can be observed. This isomerisation of the all-*trans*-β-carotene molecule, hereinafter referred to as β-carotene, into its 13-*cis* form is taken as an indicator for the thermal effect followed by further degradation [17]. Besides the effects of the drying process, the common blanching method was classified regarding β-carotene retention. Based on the outcome of the investigations, the optimum drying conditions for mango leather in terms of colour and β-carotene retention was identified.

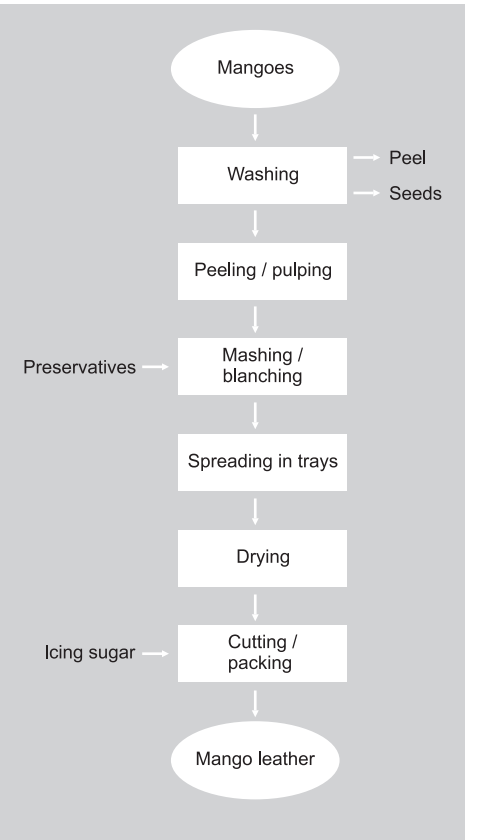

Figure 1.
Flowchart of common mango leather processing in the Philippines.

2. Materials and methods

2.1. Raw materials

Mature green harvested Philippine mangoes, cv. Carabao, were brought to Germany and stored at 15 °C for a maximum of 10 days to retard ripening and to extend storage life. Prior to drying, the fruits used in each experiment were ripened naturally at 30 °C for 2–3 days to reach a sugar/acid ratio of 50, with an average of 14.2 °Brix and 0.27 g titratable acid per 100 g fresh material. To produce the puree for mango leather production, the fruits were first washed and peeled manually; the mesocarp was separated from the seed and blended using an electric blender. For blanching, the pasty puree was heated in a cooking kettle using an electric stove until a temperature of 70 °C was reached for 2 min. During this period, the puree was continuously stirred to maintain the temperature and avoid burning.

2.2. Drying experiments

Fruit dryers are commonly operated in the over-flow mode. Thus, the fruit slices are fully exposed to the drying air (*figure 2a*).

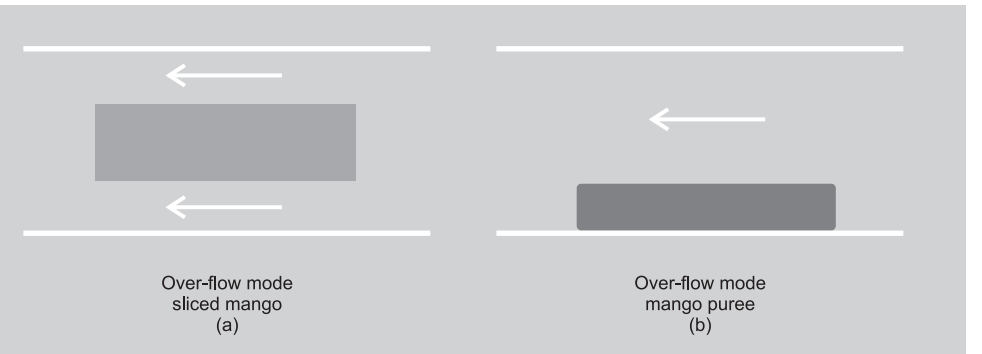

Figure 2.
Drying of mango leather in the over-flow mode.

Mango leather should also be dried preferably in the over-flow mode. Due to the pasty structure, the mango leather either has to be spread in a thin layer on a tissue or on a metal sheet. Compared with the drying of mango slices, only the upper layer of the puree is exposed to the drying air (*figure 2b*). Therefore, internal moisture transfer is caused by osmotic forces from the lower layer of the puree to the surface with a simultaneous heat transfer in the opposite direction.

The drying experiments were carried out using a laboratory overflow-dryer developed at the Institute of Agricultural Engineering in the Tropics and Subtropics at Hohenheim University (Stuttgart, Germany) [18]. It maintained a wide range of drying air conditions, definable with high accuracy. The laboratory dryer consists of an airflow, humidity and temperature control assembly (*figure 3*). For the drying experiments, an 8-mm-thick layer of mango puree was evenly distributed on a stainless food tray measuring 32 cm × 32 cm × 1 cm.

The drying air temperatures varied in the range of 40 °C to 90 °C at 10 K intervals. Drying air temperature, relative humidity, air velocity, atmospheric conditions and instantaneous weight of the sample were measured continuously and recorded automatically at 10-min intervals. For each temperature, both blanched and unblanched purees were used. The air velocity was kept constant at 1 $m \cdot s^{-1}$. A dew-point of 25 °C was maintained in all experiments to simulate tropical drying conditions. Drying was finished when

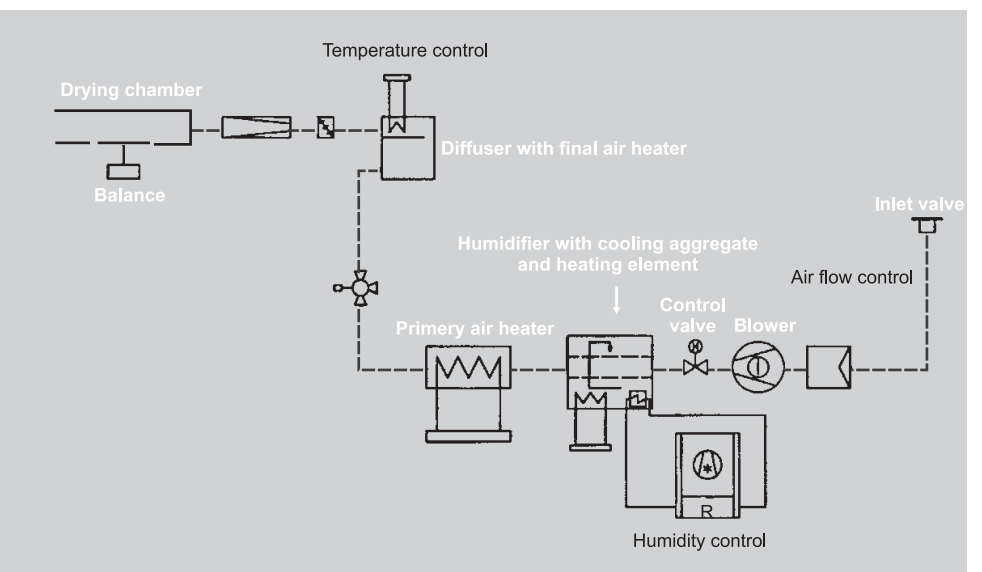

Figure 3.
Scheme of the over-flow lab-dryer [16].

the desired final moisture content of 14% wet basis was reached. This moisture content is equivalent to the hygienically safe water-activity of a_w = 0.6.

2.3. Quality evaluation

To determine the stage of ripeness and to characterise the quality of the raw materials, total soluble solids (TSS) and total titratable acid (TTA) were measured according to the German food law LmBG § 35 [19]. The water content of the fresh as well as of the dried material was measured using the Karl-Fischer titration method [20].

In accordance with one of the main quality criteria for dried fruit products, colour was evaluated using the CIE-*L*a*b** uniform colour space (CIE-Lab), where *L** indicates the lightness, *a** indicates chromacity on a green (–) to red (+) axis, and *b** chromacity on a blue (–) to yellow (+) axis. Numerical values of *a** and *b** were transformed to the hue angle α and the colour saturation *C** [21].

The nutritional quality of the dried material was evaluated by determination of the β-carotene content. Product samples for β-carotene and 13-*cis* stereoisomer analysis were extracted as described by Pott *et al.* [14] and measured by HPLC as described by Breithaupt [22]. The YMC C30 reversed-phase column (Schermbeck, Germany) was kept at 35 °C. The UV absorbance of the carotenoids was recorded at 450 nm (DAD).

3. Results and discussion

3.1. Raw materials

During mango processing, losses caused by peeling and pulping were minimised (*table I*). Therefore, more than 75% of the fresh fruits were used for drying mango leather. Blanching reduced the initial moisture content from (84.3 to 81.7)% (wet base) because of evaporation during the heating process.

The attractive natural colour of the mango mesocarp can be affected by enzymatic and non-enzymatic browning reactions. Both are expected during the drying and blanching process. Due to consumers' demands, browning of the product should be minimised.

Table I.
Characteristics of fresh mangoes, cv. Carabao, used for drying experiments.

Materials considered	Weight (g)	Fraction (%)	Standard deviation
Whole fruits	346.3	100.0	9.1
Mesocarp (puree)	262.5	76.2	2.5
Peel (exocarp)	43.8	13.4	1.5
Seed (endocarp)	36.0	10.5	1.3
Moisture content (unblanched puree)	–	84.3 (wet base)	0.7
Moisture content (blanched puree)	–	81.7 (wet base)	0.1

However, no visible colour changes caused by the blanching process could be observed. Lightness *L** was 53.6 and 54.2, hue angle α was 89.8 and 91.9, and colour saturation *C** was 42.0 and 40.7 for unblanched and blanched puree, respectively. In consideration of standard deviations of 0.6 to 1.7, differences were not significant and caused by slight raw material distinctions. Thus, colour conditions of untreated and blanched puree were similar before the drying process.

In contrast, untreated purees contained an average of 6500 (± 650) µg all-*trans*-β-carotene per 100 g dry weight, while, after blanching, only 3400 (± 240) µg all-*trans*-β-carotene per 100 g dry weight was retained. The loss was equivalent to a retention rate of 52%. Due to an increased 13-*cis* isomerisation from 200 (± 80) µg all-*trans*-β-carotene·100 g^{-1} dry weight in untreated puree to 310 (± 7) µg all-*trans*-β-carotene·100 g^{-1} dry weight in blanched puree, an additional thermal degradation could be assumed.

On the curve showing a chromatographic separation of carotenoids of untreated and blanched mango puree, cv. Carabao, the peaks of all-*trans*-β-carotene and 13-*cis*-β-carotene can be observed (*figure 4*). Further peaks in the chromatogram were mixtures of different carotenoids, mostly without any vitamin A activity, such as violaxanthin [23, 24].

3.2. Drying characteristics

The drying characteristics of mango leather dried at different temperatures were significantly influenced by drying temperature (*figure 5*).

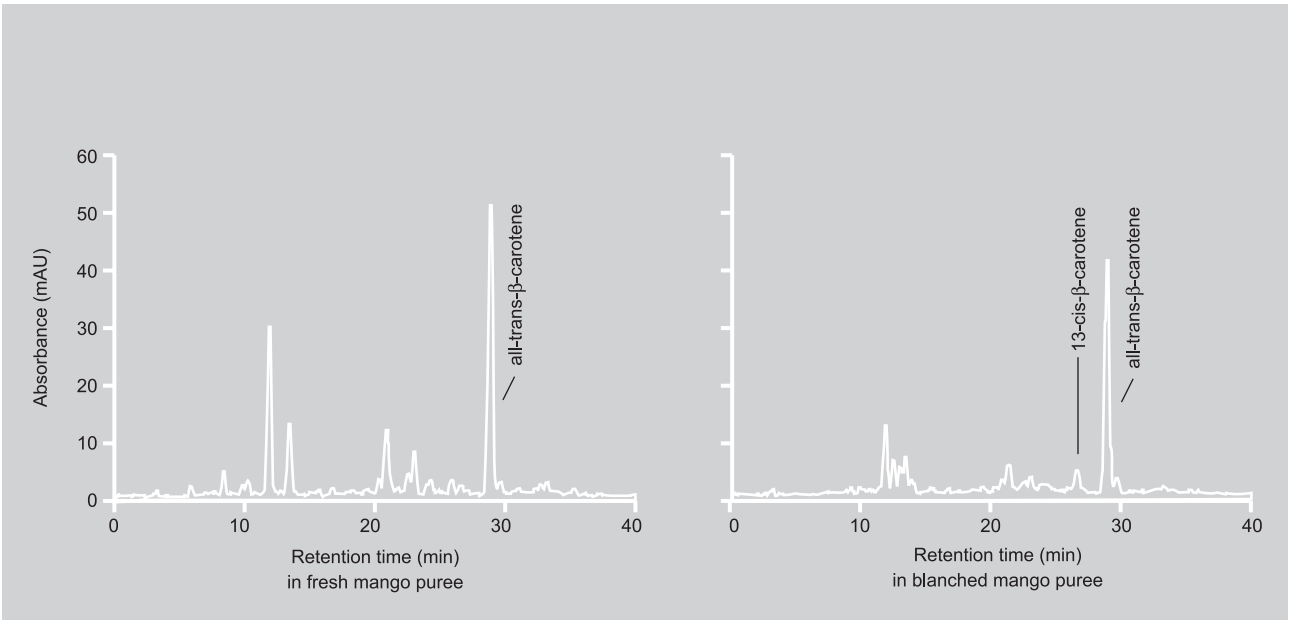

Figure 4.
HPLC chromatogram (DAD, 450 nm) of a carotenoid extract of fresh and blanched mango puree, cv. Carabao.

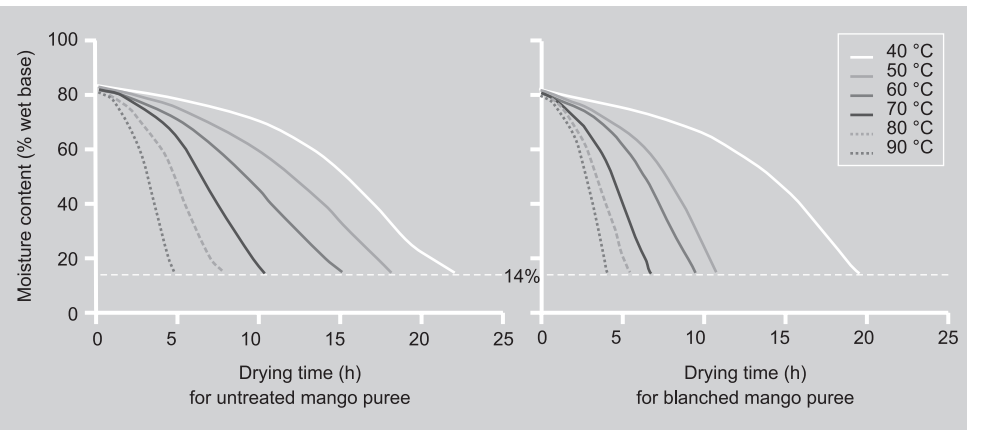

Figure 5.
Drying characteristics of untreated and blanched mango leather at different drying air temperatures (dew point 25 °C, air velocity 1.0 m·s^{-1}).

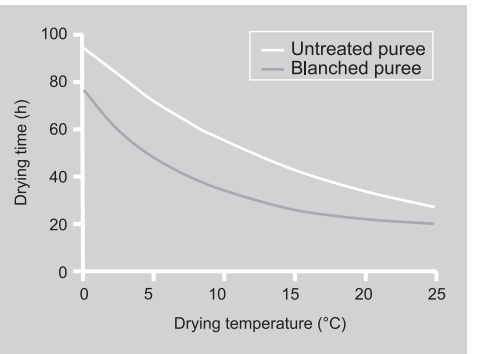

Figure 6.
Drying time to reach a moisture content of 14% for untreated and blanched mango leather at different temperatures (dew point 25 °C, air velocity 1.0 m·s^{-1}).

The drying times for mango leather to reach a moisture content of 14% (wet base) were significantly affected by the drying temperature and the thermal pre-treatment (*figure 6*). Drying time decreased exponentially with increasing temperature. The average drying time to reach 14% (wet base) from an initial 84.3% (wet base) for untreated puree was (22.5, 18.5, 15.2, 10.5, 8.0 and 4.8) h at (40, 50, 60, 70, 80 and 90) °C, respectively. Due to the reduction of the initial moisture content, the drying time of blanched puree was reduced. Besides

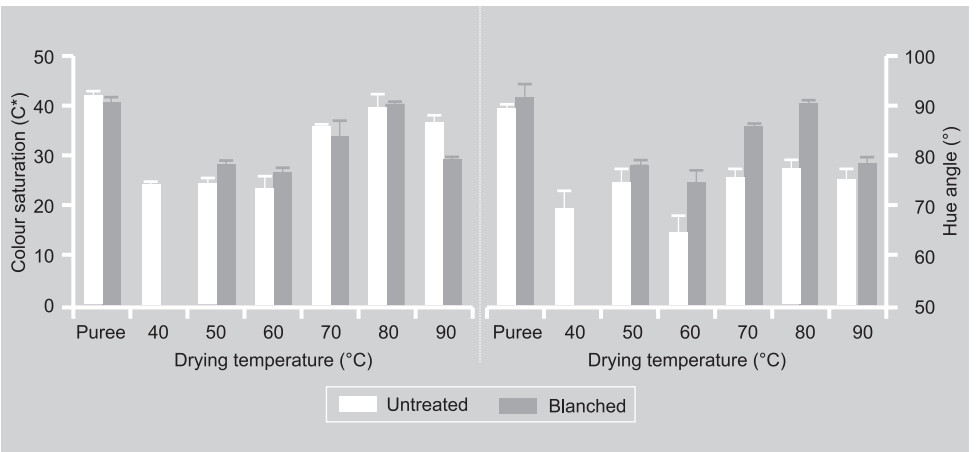

Figure 7.
Influence of different drying temperatures on the colour of untreated and blanched mango leather, cv. Carabao (dew point 25 °C, air velocity 1.0 $m \cdot s^{-1}$).

this, diffusion was additionally forced by a higher initial puree temperature of about 60 °C. The differences in drying time of unblanched and blanched puree were particularly remarkable at low drying temperatures. Drying mango leather with unblanched puree at (60 and 50) °C therefore needed more than a 50% longer drying time compared with blanched puree. For a drying temperature of 40 °C, this remarkable discrepancy could not be detected. The visible variation in drying time for blanched mango leather at 40 °C was tolerated since all manageable process parameters were checked and a different ripening stage could be held responsible for this disagreement. Drying mango leather at 60 °C and above shortened drying time to less than 12 h even for untreated puree. For drying conditions below 60 °C, blanching is favoured to shorten the drying time and to avoid microbiological and enzymatic activity. Especially for the common unsteady solar drying process, where temperatures alternate, dependent on solar radiation between ambient temperatures and about 70 °C [25], blanching shortened the drying time. Nevertheless, the additional blanching process before drying amounts to higher energy and labour costs.

3.3. Colour

Besides the reduction of drying time, the thermal inactivation of quality-affecting enzymes, such as polyphenol oxidase (PPO) and lipoxygenase (LOX), as well as the prevention of microorganism growth, is the main reason for blanching before drying. In this way, the maintenance of colour and vitamins, improving product quality, is expected.

When comparing the colour changes of untreated and blanched puree with the raw materials, e.g. the puree colour, the best mango leather colour was gained at 80 °C (*figure 7*). At this temperature puree blanching had no effect on colour changes, but untreated mango leather showed browning and a little decrease in colour saturation (C^*). Drying below 70 °C was followed by a severe loss of C^* and decreasing hue angles (α) showed browning caused by long drying times at low temperatures.

Analysis of the colour values indicated that drying temperatures below 70 °C and extending drying times were contrary to producing acceptable mango leather colours. However, drying mango puree at 80 °C produced favourable colours. Blanching helped to reduce browning reactions when drying at low temperatures. This refers to polyphenol oxidase (PPO) activity that is mainly responsible for colour changes by converting polyphenolic compounds into coloured quinones. PPO activities in the fresh mesocarp were mainly defined by cultivar and ripening status [16]. In accordance with preceding investigations higher temperatures than 70 °C were needed to inactivate PPO efficiently [26].

Thus, considering mango leather colour, a drying temperature of 80 °C is recommended.

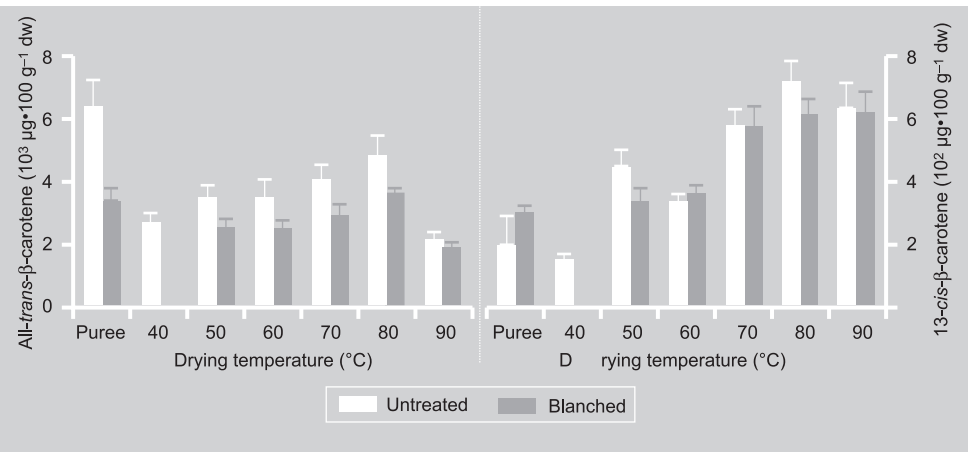

Figure 8.
All-*trans* and 13-*cis*-β-carotene content in mango leather processed from untreated and blanched mango puree, cv. Carabao, at different drying air temperatures (dew point 25 °C, air velocity 1.0 m·s^{-1}).

In terms of browning, blanching the puree before drying was shown as a slight advantage and, additionally, drying time is reduced from (8 to 5.5) h as described before.

3.4. β-carotene degradation

The average values of the all-*trans*-β-carotene content of mango leather, processed from both untreated and blanched mango puree, cv. Carabao, and dried at different drying temperatures showed that optimum β-carotene retention proceeded at 80 °C (*figure 8*). At this juncture, for untreated puree, 75% of the original amount was preserved. A temperature of 90 °C was followed by a retention rate of less than 35%. Furthermore, medium temperatures of (70 to 40) °C showed a linear increase in β-carotene degradation. Comparable with the early thermal PPO inactivation followed by favourable product colours after drying at high temperatures, it is hypothesised that the elevated drying air temperature was responsible for the early inactivation of lipoxygenase, too. In the temperature range of (50 to 60) °C and at 40 °C, only (55 and 42)% of the β-carotene content could be retained, respectively. This supported the earlier mentioned hypothesis of enzymatic carotene degradation. The lower the drying temperature, the longer mango mesocarp cells were exposed to optimum enzyme activity temperatures, which are reported to be in the range of 25–40 °C [27].

Blanching led to the loss of 50–60% of β-carotene. Thus, blanching is not only labour- and energy-consuming but also means an increased degradation rate for provitamin A. Therefore, it is unnecessary for the proposed drying process with high air temperatures, and the mentioned slight product browning should be acceptable.

By estimating the provitamin A content of unblanched mango leather only by calculating the all-*trans*-β-carotene content, the mango leather dried at 80 °C still had a vitamin A activity of (600 to 650) RE·100 g^{-1}. Hence, according to the FAO [11], the β-carotene content of (70 and 130) g mango leather, cv. Carabao, would be equivalent to the daily requirement of vitamin A for children and adults, respectively.

3.5. 13-*cis* isomerisation

The most vitamin A-active carotenoid all-*trans*-β-carotene is partly converted to its *cis*-stereoisomers during processing. The formation of 13-*cis* isomers is then mainly formed by thermal heat treatment [28], followed by a probable reduction of vitamin A activity [29]. Fruits and vegetables also contain a natural amount of isomers [14, 30]. Here, the 13-*cis* isomer content of ripe mango flesh, cv. Carabao, was about 200 (± 80) µg·100 g^{-1} dry weight. During the drying experiments, there was an increase in 13-*cis* isomerisation (*figure 8*). A significant formation of 13-*cis* isomers in unblanched

mango leather was proved firstly for drying temperatures from 50 °C onwards, where the isomerisation was doubled. Secondly, from 70 °C onwards the isomerisation rate was tripled for the dried unblanched puree. According to these results, thermal effects on carotenoid structure were shown with drying temperatures from 50 °C and higher, while β-carotene degradation processes were most evident at (40 and 90) °C. Hence, while drying mango leather, both enzymatic- and thermal-induced destruction of carotene took place.

Blanching increased the β-carotene isomerisation rate in the undried puree and showed in consequence the remarkable thermal influence of the blanching process on β-carotene. After drying, the isomerisation rates for blanched puree were doubled from 70 °C onwards and reached comparable amounts of 13-*cis*-β-carotene to those of unblanched puree.

Drying with temperatures between (70 and 90) °C is equivalent to a predominant thermal degradation of provitamin A. Only with 90 °C was a severe loss observed. At (50 and 60) °C, thermal degradation was only proved with regard to a slightly augmented 13-*cis* isomerisation rate, but β-carotene losses were more severe compared with those at higher drying temperatures. With 40 °C degradation increased, even without any sign of isomerisation. Thus, degradation in this low temperature range was assumed to occur by enzymatic reactions leading to serious reduction of provitamin A compared with temperature effects. Therefore, air temperatures lower than 80 °C should be prevented, and also blanching is unnecessary for the use of tray dryers.

For solar drying processes which are often used for drying mango products [31], it is recommended to use as high a temperature as possible to shorten tha drying time and to retain as much as possible of the provitamin A [32]. So, drying during the hot and dry season is urgently needed. Nevertheless, more than about one-half of the natural β-carotene content could be preserved in the temperature range of (40 to 70) °C with drying of untreated or blanched mango puree. To finish the drying within one sunny day and to ensure a high hygienic status, it is recommended to blanch the puree before drying.

4. Conclusion

With an average provitamin A activity of (600 to 650) RE, mango leather is a suitable source of vitamin A and should be considered as a solution for preventing vitamin A deficiencies in tropical countries. Mango leather can be easily produced from fresh and ripe mango flesh and, in our studies, even solar drying methods were successful successful [33].

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Influencia de los parámetros de secado en la conservación de β-caroteno en la pasta de mango.

Resumen — Introducción. Las rodajas secas de mango son un producto común de picoteo en los países del sudeste asiático. La trituración de la piel de mango que contiene carotenoides así como el secado del puré obtenido para producir la pasta de mango es una vía prometedora para utilizar como materias primas poco costosas tanto los frutos regulares demasiado maduros o pequeños, como los frutos de calibre irregular. En nuestro estudio, se estudió el impacto del blanqueo y de la temperatura del aire [(40–90) °C] en el tiempo y en la calidad de secado. **Material y métodos**. Se efectuaron algunas pruebas de secado con la ayuda de un desecador de laboratorio que permitió medir continuamente el tipo de secado. La calidad de la pasta de mango obtenida se evaluó según su color (CIE-Lab) y su contenido en β-caroteno (HPLC). La formación del isómero 13-*cis*-β-caroteno se utilizó para seguir la degradación térmica de β-caroteno. **Resultados y discusión**. El blanqueado afectó el contenido en β-caroteno, redujo el tiempo de secado (–20%) y disminuyó las reacciones del ennegrecimiento. Se determinó 80 °C para las mejores condiciones de secado en términos de tiempo de secado, de color y de conservación de β-caroteno. El contenido en all-*trans*-β-caroteno se mantuvo en 75% y no se observó ninguna disminución de la saturación de color (*C **). Consecuentemente, una temperatura de 80 °C debería ser suficiente para inactivar las enzimas de oxidación de los carotenoides sin mostrar efectos térmicos negativos significativos en la degradación de β-caroteno. Otras temperaturas más elevadas acarrearon graves pérdidas de β-caroteno. Otras temperaturas más bajas aumentaron el tiempo de secado, causaron la decoloración y disminuyeron la conservación de β-caroteno. **Conclusión**. La pasta de mango es una fuente prometedora de provitamina y posee una actividad de la provitamina A de (600 a 650) equivalentes de retinol.

Filipinas / mango / pérdidas postcosecha / tecnología postcosecha / pulpa de frutas / secado por aire caliente / carotinoides / calidad