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Quality improvement of non-sulphited mango slices by drying at high temperatures

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Abstract

An optimum drying routine for producing non-sulphited mango slices has been developed. The interaction of essential drying parameters (air temperature, air velocity, dew point, slice thickness and drying time) on water activity (a_W) and browning was determined. Microbiological stability of the dried product was achieved at a moisture content of 17% wet base (w.b.) corresponding to $a_W = 0.6$. Browning was monitored by the red colour shade of the product (CIE-Lab chromaticity coordinate a^*). Drying air temperature and drying time were shown to be the primary factors influencing product colour and a_W. In contrast to common practice, drying for about 6 h at elevated air temperature (80 °C), instead of 50 or 60 °C for a longer time, was optimal, since significant colour changes of the mango slices were not observed even without the use of any chemical or thermal pre-treatment. Moreover, at increased temperature, drying time was considerably shortened from about 9 h to 6 h, resulting in significant extension of the drying capacity.

Keywords: *Mangifera indica* L.; Drying; Water activity; Quality; Colour

Industrial Relevance: The suggested process concept for dried mango slices based on high-temperature drying is of utmost significance for the international marketing of dried fruit products. Chemical pre-treatments such as sulphitation often used to minimise quality deficiencies could be avoided. Sulphitation has been recently under critical consideration with respect to allergen labelling of foodstuffs implemented by EU-Member States in November 2004 (Directive 2003/89/EC) [Directive 2003/89/EC. Official Journal of the European Union, 25.11.2003, pp. L308/15 – 18 (http://europa.eu.int/eur-lex/pri/en/oj/dat/2003/l_308/l_30820031125en00150018.pdf)]. Export quality was improved and the drying process simplified, improving the utilisation of drying capacities. Particularly referring to an application of the technology in small- and medium-sized enterprises with limited investment possibilities, the suggested novel drying procedure in mango processing aimed at the optimisation of well-established simple drying methods instead of choosing technically more sophisticated technologies.

1. Introduction

The mango fruit (*Mangifera indica* L.) is one of the most important seasonal fruits of tropical and subtropical countries. Since industrial capacities for the processing of highly perishable mangoes into storable products are limited due to seasonal over-production of the fruits, drying of excess and partly defected mangoes is a promising preservation technique, meeting the processing requirements of small- and medium-size producers (de la Cruz Medina & Garcia, 2003; Fellizar, 1994). Beside traditional sun drying by direct solar radiation, solar dryers and conventional overflow dryers are presently used by small-scale enterprises to reduce the water activity. According to common practice for preservative-free as well as for sulphited mangoes, drying air temperature ranges between 50 and 60 °C. During sun and solar drying, even lower maximum temperatures are reached. Consequently, drying usually needs at least 20 h (Candelaria & Raymundo, 1994; Chavasit, Pisaphab, Sungpuag, Jittinandama, & Wasantwisut, 2002; Kameni, Mbofung, Ngnamtam, Doassem, & Hamadou, 2003), resulting in low

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drying capacities or high investments, respectively. Observed quality deficiencies of the dried fruits caused by these long-term processes were mainly discolouration, such as browning or bleaching, and cracked or scorched products (Kameni et al., 2003; Walker & Wilhelm, 1995), while insufficient drying limits the shelf life of the product due to microbial spoilage. Browning of non-sulphited fruits during drying is typically caused by both enzymatic and non-enzymatic transformations, whereas the non-enzymatic Maillard reaction predominantly occurs during storage of dried products (Krokida & Maroulis, 2000). Therefore, approaches to improve the quality of dried fruits generally involve thermal, chemical and osmotic pre-treatments such as blanching, sulphitation and osmotic dehydration (Jayaraman & Das Gupta, 1992; Madamba & Lopez, 2002; Nijhuis, Torringa, Muresan, Yuksel, Leguijt, & Kloek, 1998; Sagar & Khurdiya, 1999; Welti, Palou, López Malo, & Balseira, 1995). Beside the suppression of microbial growth, all pre-treatments aim at thermal or chemical inactivation of detrimental enzymes, chiefly of polyphenol oxidase (PPO), and at inhibition of the Maillard reaction (Wedzicha, Bellion, & German, 1994) by controlling pH, water activity, and reactive carbonyl compounds, respectively. The high-caloric, sugary dried fruit products, obtained by osmotic dehydration, often exceed maximum sulphur dioxide contents, and therefore, international quality standards are not met. Additionally, the labour-intensive application of pre-treatments contributes to prolonged processing procedures, causing significant vitamin losses. Consequently, masking of colour deficiencies, which result from carotenoid degradation, by applying synthetic food colourings is a common practice.

Therefore, the aim of this study was to investigate systematically suitable drying procedures without pre-treatments, abandoning the use of sulphur dioxide, in order to meet quality requirements and consumers' acceptance. To distinguish between unsuitable and suitable drying conditions, product colour was considered the primary quality criterion. A wide range of drying air temperatures, 30 to 90 °C, was applied, considering dew point, velocity of drying air, slice thickness and drying time as further drying parameters. Instead of the classical "one-variable-at-a-time" approach based on plotting the weight loss against drying time with stepwise variation of the drying parameters, or a highly resource-consuming traditional matrix approach (complete factorial plan), a statistical problem solving approach, that is, a fractional factorial plan, was chosen to explore the experimental space while studying many variables by use of a small number of observations (Dey & Mukerjee, 1999; Haaland, 1989). Hence, possible interactions among the variables could also be studied. Such factorial experiments have wide applications in many diverse scientific areas. To identify the most suitable drying procedures and to evaluate the various existing ones, the objective of the present experimental design was to display the important variables and to narrow their best settings down for further optimisation. Therefore, the drying experiments were performed according to a D-optimal design for 5 factors, covering the range of usual drying procedures. Because of the putative benefit of high-temperature drying, which should allow fast initial reduction of water activity and early enzyme inactivation, drying at elevated air temperatures was included in this study. Furthermore, extension of drying capacities was a further objective of the present investigation.

2. Material and methods

2.1. Raw material

Fresh mangoes, cv. 'Kent', from Ivory Coast, were purchased at the wholesale market in Stuttgart, Germany. Using another mango variety than those applied by Mahayothee, Neidhart, Mühlbauer, and Carle (2004), optimum ripeness for drying was reached after 5 instead of reported 2 days of postharvest ripening at 25 ± 2 °C and 50–70% relative humidity. In the raw material used for processing, contents of soluble solids and titratable acids were 17.5 ± 1°Brix and 0.9 ± 0.15 g/100 g, respectively, resulting in a sugar/acid ratio of 20.9 ± 4.6. The pH of the fresh mesocarp was 3.7 ± 0.12. Fresh fruits were washed, manually peeled and sliced, using an electric food-slicer MAS 9101 (Bosch, Munich, Germany). The thickness of the mango slices was varied from 5 to 15 mm. To ensure homogeneous drying, the shape of slices was standardised by using a template of 60×30 mm.

2.2. Drying experiments

Drying experiments with 17 mango slices each were performed in a laboratory overflow dryer, described in detail by Guarte, Mühlbauer, and Kellert (1996), and Häuser (1995). The dryer was equipped with control assemblies for temperature, humidity and velocity of the drying air (Fig. 1), which allowed to expand process conditions. The mango slices were completely exposed to the drying air by spreading the fresh product on a stainless steel mesh (mesh size 10×10 mm). Drying air temperature (± 0.2 °C), relative humidity (± 1%), air velocity (± 0.05 m/s), and sample weight (± 0.2 g) were automatically recorded at 10 min intervals.

2.3. Experimental design

According to the objective of this study, a wide range of drying conditions, being typical for sun, solar and high-temperature drying, were investigated, with respect to their effect on hygienic food safety and browning. Quality evaluation was thus based on water activity and product colour as the most crucial parameters. Sufficiently low water activity was the prerequisite for product safety and stability,