UNIVERSITI PUTRA MALAYSIA

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By

KEK SIOK PENG

Thesis submitted to the School of Graduate Studies, Universiti Putra Malaysia in Fulfilment of the Requirements for the Degree of Master of Science

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

MODELLING, OPTIMISATION, AND ULTRASOUND PRE-OSMOTIC TREATMENT OF GUAVA DRYING

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Chairperson : Assoc. Prof. Ir. Chin Nyuk Ling, PhD

Faculty : Faculty of Engineering

The drying behaviour and quality attributes of guava slices were investigated through modelling, optimisation, and ultrasound pre-osmotic conventional hot-air drying. Modelling studies of drying kinetics and quality attributes are presented using theoretical and statistical models by varying temperature from 55 to 75 ℃ and slice thickness from 3 to 9 mm. The quality of dried fruit was measured for its water activity, colour, vitamin C, and texture. The superposition technique with Midilli-Kucuk model showed efficiency in modelling the drying process with R^2 = 0.9991. The second-order polynomial equations adequately described the quality of dried guava with regression coefficient, R^2 > 0.7. Drying time was a good function of temperature and thickness (P < 0.001); water activity, colour, and vitamin C showed strong dependence on temperature (P < 0.1); while texture was mainly influenced by its thickness (P < 0.005). The optimum drying temperature of 70 ℃ at slice thickness of 6 mm was determined using the desirability function method. Simultaneous modelling using the theoretical and statistical drying models provides information on water diffusion and evaporation with the drying responses and factors.

With the optimised slice thickness, 6 mm used in subsequent experiments, the effects of ultrasound pre-osmotic treatments on guava slices with indirect sonication using an ultrasonic bath system and direct sonication using an ultrasonic probe system were investigated. Pre-treatments in three osmotic solution concentrations of 0, 35, and 70 °Brix using ultrasonic bath at power from 0 – 2.5 kW for immersion time ranging for 20 – 40 minutes or using the ultrasonic probe at amplitude from 0 – 35% for immersion time of 6 – 20 minutes were investigated. Water loss, solid gain, weight reduction and colour change significantly increased ($P < 0.0005$) with ultrasound power or ultrasound amplitude, immersion time, and osmotic solution concentration. Indirect sonication with ultrasonic bath at 1.75 kW and 60 minutes of immersion time with 70 °Brix osmotic solution contributed to a highest water loss of 34.34%, solid gain of 8.85%, weight reduction of 24.17% and acceptable colour change when compared to the direct sonication with ultrasonic probe.

The effect of optimum ultrasound pre-osmotic treatment at osmotic solution of 0, 35, and 70 °Brix prior to the hot-air drying at optimum drying temperature of 70 °C on the transport properties and quality attributes of dried guava was studied. The application of ultrasound pre-osmotic treatment prior to hot-air drying was able to reduce the drying time by 33.3%, increased the effective diffusivity by 34.5%, reduced the dried fruit colour changes by 37.9%, decreased the vitamin C contents by 32.5%, and resulted to the hardness of 430.1 g – 469.6 g, which was comparable to the fresh guava. The use of ultrasound in fruit drying is recommended to improve the drying process and the dried product quality.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

PERMODELAN, PENGOPTIMASIAN, DAN PRA-RAWATAN OSMOTIK BERULTRABUNYI BAGI PENGERINGAN JAMBU BATU

By

KEK SIOK PENG

Ogos 2012

Pengerusi : Prof. Madya Ir. Chin Nyuk Ling, PhD

Fakulti : Fakulti Kejuruteraan

Sifat tingkah laku pengeringan dan sifat kualiti kepada kepingan jambu batu telah dikaji dengan kajian-kajian permodelan, pengoptimasian, dan pra-rawatan osmotik berultrabunyi konvensional pengeringan udara-panas. Kajian permodelan untuk sifat kinetik pengeringan dan sifat kualitinya adalah berdasarkan model teori dan statistik bagi suhu daripada 55 hingga 75 ℃ dan ketebalan kepingan daripada 3 hingga 9 mm. Aktiviti air, warna, vitamin C, dan tekstur telah diukur sebagai kualiti buah-jambu batu kering. Teknik superposisi dengan model Midilli-Kucuk menunjukkan kecekapan dalam permodelan proses pengeringan dengan mencapai R^2 = 0.9991. Persamaan polinomial tertib kedua telah berjaya menggambarkan kualiti jambu batu kering dengan pekali regresi, R^2 > 0.7. Masa pengeringan memberi banyak kesan kepada suhu dan ketebalan (P < 0.001); aktiviti air, warna dan vitamin C menunjukkan pergantungan yang kuat kepada suhu (P < 0.1); manakala tekstur terutamanya adalah dipengaruhi oleh ketebalan (P < 0.005). Nilai optimum bagi suhu pengeringan dan ketebalan kepingan adalah pada 70 ℃ dan 6 mm selepas ditentukan dengan menggunakan kaedah fungsi keinginan. Pemodelan serentak

menggunakan teori dan statistik amat diperlukan untuk memberikan kefahaman terhadap proses resapan air dan pengewapan air bersama dengan responden pengeringan dan faktor-faktornya.

Eksperimen seterusnya dijalankan dengan menggunakan ketebalan hirisan yang dioptimumkan iaitu 6 mm sebagai ketebalan sampel. Kesan-kesan pra-rawatan osmotik berultrabunyi terhadap kepingan jambu batu telah dikaji dengan sonikasi tidak langsung yang menggunakan sistem rendaman ultrasonik dan sonikasi langsung yang menggunakan sistem kuar ultrasonik. Eksperimen pra-rawatan telah dikaji dalam ketiga-tiga kepekatan larutan osmotik, iaitu 0, 35, dan 70 °Brix dengan menggunakan rendaman ultrasonik pada kuasa 0 – 2.5 kW untuk masa rendaman sebanyak 20 – 40 minit dan pada masa yang sama, eksperimen juga dijalankan dengan menggunakan kuar ultrasonik pada amplitude 0 – 35% untuk masa rendaman, 6 – 20 minit. Kehilangan air, perolehan gula, pengurangan berat dan perubahan warna telah ditingkatkan dengan ketara ($P < 0.0005$) dengan kuasa ultrasonik atau amplitud ultrasonik, masa rendaman, dan kepekatan larutan osmotik. Sonikasi tidak langsung dengan sistem rendaman ultrasonik pada 1.75 kW dan 60 minit masa rendaman untuk kepekatan larutan osmostik pada 70 °Brix telah menyumbangkan kehilangan air yang tertinggi sebanyak 34.34%, perolehan gula yang tertinggi sebanyak 8.85%, pengurangan berat yang tertinggi sebanyak 24.17% dan perubahan warna yang boleh diterima berbanding dengan sonikasi langsung dengan kuar ultrasonik.

Kesan-kesan pra-rawatan osmotik berultrabunyi pada optimum untuk ketiga-tiga kepekatan larutan osmotik, iaitu 0, 35, dan 70 °Brix sebelum pengeringan udara-

panas pada suhu optimum, iaitu 70 ℃ terhadap sifat pengangkutan dan sifat kualiti jambu batu kering telah dikaji. Aplikasi pra-rawatan osmotik berultrabunyi dalam pengeringan udara-panas telah mengurangkan masa pengeringan sebanyak 33.3%, meningkatkan kemeresapan sebanyak 34.5%, mengurangkan perubahan warna bagi jambu batu kering sebanyak 37.9%, menurunkan kandungan vitamin C sebanyak 32.5%, dan mencapai kekerasannya iaitu 430.1 g – 469.6 g yang setanding dengan jambu batu segar. Penggunaan ultrabunyi dalam proses pengeringan buah-buahan amat digalakkan untuk meningkatkan proses pengeringan dan juga kualiti-kualiti produk kering.

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I certify that a Thesis Examination Committee has met on 27 August 2012 to conduct the final examination of Kek Siok Peng on her thesis entitled **"Modelling, Optimisation and Ultrasound Pre-osmotic Treatment of Guava Drying"** in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U(A) 106] 15 March 1998. The Committee recommends that the student be awarded the degree of Master of Science.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of **Master of Science**. The members of the Supervisory Committee were as follows:

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DECLARATION

I declare that the thesis is my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or at any other institution.

KEK SIOK PENG

Date: 27 August 2012

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