DRYING MACADAMIA NUTS BY HOT AIR COMBINED WITH MICROWAVES AS COMPARED TO THE CONVENTIONAL HOT AIR PROCESS

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The macadamia tree (*Macadamia integrifolia* Maiden & Betche) belongs to the botanical family Proteaceae and is indigenously from the Australia tropical forests. Macadamia nuts are considered to be one of the tastiest among other nuts of worldwide commercialization. The nut is a rich source of fat, of quality comparable to that of olive oil, which explains why macadamia culture rapidly became profitable.

The most critical stage of macadamia nut processing concerns drying the kernels, as a minimum quality standard can only be achieved under specific controlled conditions, otherwise there is a deterioration of the nut and devaluation of the kernel quality. According to Toledo Piza (2000), the conventional way of drying macadamia nuts being practiced by the processors, either in Brazil or in the rest of the producing countries, uses a storage silo as a dryer, applying hot air under automatically controlled temperature, the whole operation taking up to six days to be accomplished. The processing involves three drying stages, of two days each, at air temperatures of 40^{o}C, 50^{o}C and 60^{o}C, respectively, when the macadamia's moisture content drops from a starting value of 8 to 10% (db) to 3.5% (db) [kernel at 1.5%db].

This work aimed at verifying the feasibility of producing dried macadamia nuts by applying microwaves to assist the hot air drying process, towards reducing the drying time, increasing industrial yield and quality of kernels compared to those of the conventional processes. Another specific objective of this study was to analyze and model the drying kinetics of the macadamia nuts processed with microwaves.

Two drying operations were studied, one conventional by hot air, carried out in an industrial macadamia processing plant based on a method described by Xavier et al. (2002), another combining microwave and hot air, developed within an adapted microwave domestic oven (900W), carried out at the Applied Microwave Laboratory (LMA), located at the DEA/FEA/UNICAMP, as described by Silva and Marsaioli (2003). In addition to the original adaptation, the microwave oven was also equipped with a temperature control system, based on measuring the product temperature inside the oven by an infrared sensor, feeding the signal to a digital controller, which switches a solid state relay to command the on/off operation of the magnetron generating microwaves. Macadamia nuts at 8 to 11% (db) moisture content were provided for both drying operations from the same pre-processed lot, coming from a farm where the industrial plant is located (Estância Macadamia, Dois Córregos, SP).

For the microwave operation, an experimental design was established for testing samples by using several combinations of drying air temperatures (58 to 62^{o}C) and product temperatures (64 to 68^{o}C), for a total number of seven tests. The air velocity was fixed at 0.3 m/s. The microwave power was set at a value smaller than 300 W, compatible with the desired range of the controlled product temperatures.

The main response for both processes was drying time (hr). Other responses to be considered will be peroxide value (PV) and oxidative stability (OSI) indexes of the product, being measured during a six months storage period of the packed dried kernels. The dried samples were weighed and packed into low-density polyethylene bags and sealed under vacuum.

The microwave assistance caused a significant drying time reduction from 144 hours (conventional method) to 4.5-5.5 hours, both processes referred to the final in-shell nut moisture content of 3.5%(db) [kernel at 1.5%db].

The theory of water migration by diffusion, based on the Fick's second law, was considered in studying the drying kinetics. Assuming the macadamia nut being represented by a sphere, an equation (1) was used, according to Crank (1975), who proposed its use for products of this geometry:

$$MR = \frac{M_t - M_e}{M_0 - M_e} = \frac{6}{\pi^2}\sum_{n=1}^{\infty}\frac{1}{n^2}\exp\left[-\frac{n^2 D_{ef}\pi^2}{R^2}t\right] \qquad (1)$$

where M_t (%,db) is the average product moisture at the time t (min); M_e (%,db) is the product equilibrium moisture; M_0 (%,db) is the product initial moisture; D_{ef} (m^2/min) is the effective diffusivity and R (m) is the radius of the sphere. The effective diffusivity was calculated by using equation (2):

$$k = \frac{D_{ef}\pi^2}{R^2} \qquad (2)$$

On applying these equations to the results obtained during the drying operation of the macadamia nuts with the microwaves, it was possible to model the drying kinetics for all experiments. The values of the effective diffusivity ranged from 1.35×10^{-7} to $0.97 \times 10^{-7} m^2$/min.

It can be concluded that is perfectly possible to dry macadamia nuts by applying the energy of microwaves, because the drying times were much shorter than the time taken in the conventional hot air drying process. Also, the proposed method of applying microwaves during the drying process has been shown to be efficient in preserving the natural quality of the macadamia nuts in comparison to the conventional drying process.

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