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Mathematical Modelling of Thin Layer Dried Cashew Kernels

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ABSTRACT

In this paper mathematical models describing thin layer drying of cashew kernels in a batch dryer were presented. The range of drying air temperature was 70 – 110°C. The initial moisture content of the cashew kernels was 9.29% (d.b.) and the final moisture content was in the range of 3.5 to 4.6% dry-basis. Seven different thin layer mathematical drying models were compared according to their coefficients of determination (R^2) mean square error (MSE) and mean relative deviation modulus (P) to estimate drying curves. The effects of the drying air temperature and time on the drying model constants and coefficients were predicted by multiple regression analysis using linear and non-linear type models. The results have shown that among the models, the Page model was found to be the best for describing the drying behaviour of cashew kernels with R^2, MSE and P values of 0.9830, 0.00311 and 5.046 respectively.

Keywords: Modelling, cashew kernel, thin layer, drying, moisture loss.

Introduction

Cashew (*Anacardium occidentale*) is a tropical tree crop widely distributed throughout the tropics. The primary products of cashew nuts are kernels, which are used in confectionery, and CNSL, which is an important industrial raw material for resin manufacture (ITDG, 2002). Harvested cashew nut is processed into kernel by cleaning, soaking, steaming/roasting, shelling/cracking, separation, drying, peeling, grading, dehumidification and packaging.

Presently, cashew nut production has flourished with the current production level put as 30,000 metric tonnes. Despite all these, cashew is still a very important industrial and export cash crop yet to be fully exploited by Nigerian farmers and industrialists (Oluka, 2001; NEPC, 2004) having abandoned the industry after the discovery of petroleum.

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Cashew nut can be processed into kernel by two methods according to the type of heat treatment given to the nuts. These are (i) steaming where raw nuts are heated with steam and allowed to cool and dry for a day to make shelling easy and thus reduce breakage and (ii) roasting method where the cashew nuts are soaked in water to condition to a moisture content of 7 – 10% (Ohler, 1979; Oluka, 2001) then roasted in an oil bath at a controlled temperature of 180 – 185°C (Acland, 1977). Roasting the nuts releases the CNSL and the shell becomes brittle and easy to crack. Steaming method is more advantageous over roasting because the kernels produced are not scorched or brittled as their moisture content is about 10% while for roasting it is about 6% (Ohler, 1979). Also, steaming preserves phenolic constituents in the CNSL as roasting removes it by evaporation. These phenolic constituents are used in applications such as brake and clutch linings, adhesives, vanish, paint and epoxy resins.

Shelling of cashew nut and removal of testa from kernels are the two major operations in cashew nut processing. The shell of the roasted cashew nut is removed manually or with the help of gadgets. However, the most critical step in cashew processing is the removal of testa which requires that the shelled cashew kernels are dried in convective dryers for 6 to 8 h. This allows easy detachment of testa and then it is removed manually by special knives made of metal, bamboo or wood. Microbial stability in storage and industrial application or other processing require cashew kernel to have a moisture content of 5% w.b, so artificial drying became an important step of the industrial processing of cashew kernels. Dyring may impact product quality, yield and the entire process economics (Algood *et al.*, 1993; Palacios *et al.*, 2004).

Thin layer drying models for both semi-theoretical and empirical were used. The thin layer model considered for semi-theoretical are Henderson and Pabis model, Lewis model, the two term model, Page model and modified Page model. For empirical models, models considered are Wang and Singh model and Thompson model. All the models were used to describe drying process during drying of cashew kernels. The models were evaluated based on mean square error (MSE), correlation coefficient (R^2), and the mean relative deviation (P) modulus (Lomauro *et al.*, 1985; Madamba *et al.*, 1996; Palipane and Driscoll, 1994).

The aims of the present study are:

- To study the effect of drying temperature and time on the drying kinetics of the cashew kernel samples in a Mitchel batch dryer.
- To fit the drying curves with some mathmatical models.

Materials and Methods

The cashew nuts used for these experiments were collected from the University of Agriculture Abeokuta (UNNAB) cashew plantation. Cashew nut samples were steamed in an autoclave (Dixon Surgical Instrument LTD, Model 3T19T) at a pressure of 7.93 x 105 N/mm^2 and temperature of 121^{o}C for 30 min, and allowed to cool for 24 h (Raman *et al.* (2002). The nuts were shelled using FIIRO cashew nut sheller and the kernels separated from the shells. Whole kernels were separated from the broken and cracked ones. All whole kernels were put in sealed polythene and stored in a refrigerator set at 4^{o}C until used.

The kernels were dried in a batch dryer (heated air dryer, Model 008404/631) at a temperature range of 70^{o}C to 110^{o}C for 3 – 7 h. Drying of cashew kernels started with an initial moisture content of 9.29% (d.b.) and were dried to a final moisture content of 3.5 – 4.6% (d.b.) after 7 h.

Mathematical modelling

The thin layer drying model usually used in describing dying process in agricultural materials fall into three categories (Akpinar and Bicer, 2006), namely theoretical, semi-theoretical and empirical (Midilli *et al.*, 2002; Panchariya *et al.*, 2002). The first takes into account only internal resistance to moisture transfer while the other two considered only external resistance to moisture transfer between the air and product (Bruce, 1985; Parti, 1993; Ozedimir and Devres, 1999; Akpinar and Bicer, 2006). The most widely investigated is the Fick's second law of diffusion. Drying of many products such as rice (Ece and Cihan, 1993) and hazlenut (Dermitas *et al.*, 1998) has been successfully predicted using Fick's second law. Semi-theoretical models offer a compromise between theory and ease of use (Fortes and Okos, 1981). Simplifying general series solution of Fick's second law or its modification derived semi-theoretical models. However, they are only valid within the temperatute range for which they are developed. Among the semi-theoretical models used are Henderson and Pabis, Lewis, two term model, Page model and modified Page model. Emprical models derived a direct relationship between average moisture content and drying time. They neglect the fundamentals of the drying process and their parameters have no physical meaning. Therefore, they cannot give clear accurate view of the important processes occurring during drying although they may describe the drying curve for the conditions of the experiments (Ozdemir and Devres, 1999). Among them, the applicability