DRYING KINETICS OF BANANA (*Musa* spp.)

ADEWALE O. OMOLOLA, AFAM I. O. JIDEANI AND PATRICK F. KAPILA

SUMMARY

*Research focus and interest on banana (*Musa *spp.) in recent times has been due to its nutritional and economic importance. Banana is a major fruit crop in the tropics and subtropics, and has contributed largely to the economies of many countries. Dessert bananas are popular in modern westernized diets due to its nutritional potential. Banana drying has become necessary in order to reduce microbial activity and product spoilage, and to extend storage life. Knowledge of the drying kinetics is essential for the control and optimization of drying process, any subsequent or further processing and quality of final product. Furthermore, the application of adequate pretreatment(s) before drying banana helps keep the fruit from darkening during drying and storage, speeds up the drying operation and minimizes the effects of the operation on some quality parameters of banana. In this review we examine the drying kinetics of banana with regards to pretreatments applied to the fruits prior to drying, overview drying models for the description of drying characteristics and summarize drying methods and moisture transport properties during drying.*

Banana (*Musa* spp.) is a major fruit crop in the tropics and subtropics and it makes a vital contribution to the economies of many countries. Dessert bananas have become very popular in modern westernized diets. They are popular for their flavor, texture and convenience value, being easy to peel and eat. Bananas make a useful contribution to the Vitamins A, C and B_6 content of the diet, and are an important and immediate source of energy often eaten by sports people during competitions (Robinson and Sauco, 2010). They are also cholesterol free and high in fiber. A medium sized banana contains 280kJ, which is more than deciduous or citrus fruits (Robinson and Sauco, 2010). They are chiefly eaten raw as a dessert fruit, because in the ripe state they are sweet and easily digested. Bananas have therapeutic values in many special diets. Ripe mashed banana is an excellent food for babies due to easy digestibility, mineral, and vitamin content (Ganesapillai *et al.*, 2011). For elderly people, the fruit can be consumed in large quantities without being fattening or causing digestive disturbances.

Banana is low in sodium, contains very little fat and no cholesterol. Therefore, it is useful in managing patients with high blood pressure and heart diseases (Robinson, 2006; Robinson and Sauco, 2010). Banana has the potential of neutralizing free hydrochloric acid, suggesting its use in peptic ulcer therapy. A fully ripe banana mixed with milk powder is especially recommended for ulcer patients. It is a rich source of energy. That is why it is consumed throughout the world in one form or the other (Ganesapillai *et al.*, 2011). Research focus and interest on banana in recent time has been due to its nutritional and economic importance. Common foods obtained from banana are presented on Table I.

Drying is the removal of moisture from a food material with a view of reducing microbial activity and product spoilage, and extending storage life. Knowledge of drying kinetics of banana is essential for the control and optimization of the banana drying process, any subsequent or further process and quality of final product (Demirel and Turhan, 2003). Recent and past studies on drying characteristics of banana in different forms includes whole fruit (Nogueira and Park, 1992; Queiroz and Nebra, 2001; Dandamrongrak *et al.*, 2002; Sousa and Marsaioli, 2004; Silva *et al.*, 2013), slices (Sankat and Castaigne, 1992; Sankat *et al.*, 1996; Demirel and Turhan, 2003; Leite *et al.*, 2007; Abano and Sam-Amoah, 2011; Ganesapillai *et al.*, 2011) and chunks (Mowlah *et al.*, 1983; Garcia *et al.*, 1988). This paper reviews the drying kinetics of banana with regards to pretreatments followed prior to drying, mathematical models used for the description drying behavior and the moisture transport mechanism during drying.

Effect of Pretreatments on Drying Kinetics of Banana

Common pretreatments applied to fruits prior to drying operation include blanching, lemon juice, ascorbic

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TABLE I
COMMON PRODUCTS OBTAINED FROM BANANA

Banana Products	References
Yoghurt	Aurore *et al.* (2009)
Jam	Espiard (2002)
Muffins and confectionaries	DAFF (2011); Juárez-García *et al.* (2006)
Beer and wine	Carreño and Aristizábal (2003)
Chips	Carreño and Aristizábal (2003), Lemaire *et al.* (1997), Anyasi *et al.* (2013)
Infant foods	Ganesapillai *et al.* (2011)
Fruit bar	Mohapatra *et al* 2011, Anyasi *et al.*, 2013
Noodles and pasta	Anyasi *et al.* (2013)

TABLE II
COMMON PRETREATMENTS FOR BANANA

Pretreatment	References
Ascorbic acid	Demirel and Turhan (2003); Abano and Sam-Amoah (2011); Thuwapanichayanan *et al.* (2011)
Lemon juice	Abano and Sam-Amoah (2011)
Salt solution	Abano and Sam-Amoah (2011)
Honey dip	Abano and Sam-Amoah (2011)
Citric acid	Demirel and Turhan (2003); Sousa and Marsaioli (2004)
Sodium metabisulphite	Demirel and Turhan (2003)
Ultrasound	Azoubel *et al.* (2010)
Blanching	Dandamrongrak *et al.* (2002)
Chilling	Dandamrongrak *et al.* (2002)
Freezing	Dandamrongrak *et al.* (2002)

acid, sulfuring, honey dip, salt solution and osmotic pretreatment, ethyloleate, NaOH, olive oil, skin puncturing, and K_2CO_3 (Pangavhane *et al.*, 1999; Lewicki, 2006; Vasquez-Parra *et al.*, 2013). Table II contains a list of pretreatments as used by various researchers prior to banana fruit drying operation.

Pretreating fruits prior to drying is essential due to its benefits. Pretreating helps keep light-colored fruits from darkening during drying and storage; it speeds the drying of fruits and minimizes the effects of drying operation on some quality parameters of fruits (Susan and Williams, 1993; Abano and Sam-Amoah, 2011; Licciardello *et al.*, 2012). Studies have shown that pretreating with an acidic solution or sodium metabisulfite dip also enhances the destruction of potentially harmful bacteria during drying, including *Escherichia coli* O157:H7, *Salmonella* spp. and *Listeria monocytogenes (Di Persio, 2004)*. The paragraph below summarizes studies on the effect of drying pretreatments on the drying characteristics of banana as investigated by various researchers.

Effects of different pretreatments on drying characteristics of banana slices as conducted by Abano and Sam-Amoah (2011) revealed a minimum rehydration ratio of 1.215 for ascorbic acid treated slices and a maximum rehydration ratio of 1.716 for lemon juice treated samples. They concluded that lemon juice treated dried banana will reconstitute more moisture when exposed to air. Effect of ultrasound pretreatment on banana (cv Pacovan) drying kinetics under a fixed bed dryer at two different temperatures (50 and 70ºC) and $3.0 m \cdot s^{-1}$ air velocity investigated by Azoubel *et al.* (2010) revealed that moisture diffusivities increased with increasing temperature and with the application of ultrasound, while process time was reduced, which is an indication of an economy of energy, since air drying is cost intensive. The effects of four pretreatments (blanching, chilling, freezing, and combined blanching and freezing) on the drying rate and quality of bananas were investigated by Dandamrongrak *et al.* (2002). They reported that the initial drying rate was highest for the blanched treatment and the two pretreatments involving freezing resulted in the shortest drying times. The blanched sample was preferred in terms of color while the frozen samples exhibited extensive browning. The texture and flavor were significantly ($P<0.05$) reduced in all samples that involved blanching and/or freezing. Demirel and Turhan (2003) studied the air-drying behavior of untreated, and sodium bisulphite and ascorbic/citric acid treated Dwarf Cavendish and Gros Michel banana slices between 40 and 70ºC. They reported that pretreatments and increasing temperature decreased browning while pretreatments and temperature did not affect the shrinkage.

Factors Influencing Drying Kinetics

Drying kinetics is the description of the changes of moisture content of the material during drying. It can be expressed as a drying curve or drying rate curve. A drying curve is usually obtained experimentally by plotting the free moisture content *vs* drying time. This plot can be converted into a drying rate curve by calculating the derivative of the curve over time. Generally, factors influencing drying rate of agricultural products include drying air temperature, relative humidity, drying air flow velocity and composition of a food product. At a constant temperature, the moisture content of food changes until it comes into equilibrium with water vapor in the surrounding air. This is termed equilibrium moisture content. Figure 1 represents the sorption isotherm for a typical food product. Apart from the general factors, other factors such as shape, size, surface area of food product and the drying method used (Table III) could also influence the drying rate of agricultural products. The effects of the mentioned factors on the drying characteristics of banana as observed by various researchers are captured in the following paragraph.

Pereira *et al.* (2007) in their study on effect of microwave power, air velocity and temperature on the final drying of osmotically dehydrated bananas observed that increasing the microwave power increased the drying rate, thus making the drying time shorter. However, higher microwave power also caused temperature runaway leading to charring on the dried product; air flow cools the product surface and improves product quality by reducing charring. Ganesapillai *et al.* (2011) studied the drying kinetics of banana (*Nendran* spp.) under microwave, convective and

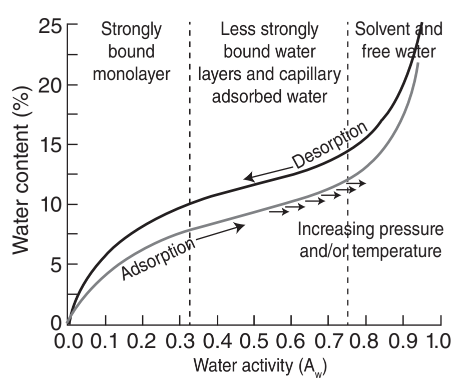

Figure 1. Sorption isotherm for a typical food product. Source: www1.lsbu.ac.uk/water/water_activity.html

TABLE III
DRYING METHODS FOR BANANA FRUIT

Drying Method	Reference
Spouted bed	Bezerra *et al.* (2013)
Kiln	Baini and Langrish (2007; 2008)
Fixed bed	Azoubel *et al.* (2010)
Freeze	Pan *et al.* (2008)
Cabinet tray	Silva *et al.* (2013); Demirel and Turhan (2003)
Heat pump	Dandamrongrak *et al.* (2002)
Microwave	Sousa and Marsaioli (2004); Ganesapillai *et al.* (2011)
Oven	Leite *et al.* (2007); Abano and Sam-Amoah (2011); Ganesapillai *et al.* (2011)
Combined microwave-convective	Ganesapillai *et al.* (2011)

combined microwave-convective process; they reported that microwave drying resulted in a substantial decrease in the drying time with quality product when dried at higher power (300W) level compared to other processes. Drying of bananas assisted by microwave energy at air temperatures from 25 to 55ºC revealed that drying time ranges from 200-290min (Sousa and Marsaioli, 2004). Silva *et al.* (2013) reported a drying time of 1200 and 3265min at air temperatures of 70 and 40ºC, respectively, for whole bananas. The effect of stepwise changes in drying air temperature on drying kinetics and product color in batch drying of banana pieces in a two stage heat pump dryer, as investigated by Chua *et al.* (2001), showed that by employing stepwise-varying drying air temperature with appropriate starting temperature and cycle time, it was possible to reduce significantly the drying time to reach the desired moisture content with improved product color. The effects of various operating parameters, i.e., drying medium temperature and pressure, on the drying kinetics and heat transfer behavior of banana as well as the energy consumption was investigated by Nimmol *et al.* (2007), who found that low-pressure superheated steam drying and far-infrared radiation (LPSSD–FIR) and combined far-infrared radiation and vacuum drying (VACUUM-FIR) took a shorter drying time compared to LPSSD at all drying conditions. Specific energy consumption of the vacuum pump was much higher than that of the far-infrared radiator or electric heater while specific energy consumption of LPSSD-FIR and VACUUM-FIR were lower than that of low-pressure superheated steam drying LPSSD at all drying conditions.

Drying Models for the Description of Drying Kinetics of Banana

Drying of agricultural materials usually occurs under two drying regimes, namely falling and constant rate period. Studies conducted on drying kinetics of banana by various researchers (Drouzas and Schubert, 1996; Dandamrongrak *et al.*, 2002; Demirel and Turhan, 2003; Ganesapillai *et al.*, 2011) revealed that drying of banana usually takes place under the falling period and that diffusion mechanisms (movement of moisture from a region of higher concentration to a region of lower concentration) is the dominant physical mechanism prevailing during moisture removal process in bananas. However, drying of banana could also occur under the two above mentioned drying regimes in a single drying operation. For instance, Mowlah *et al.* (1983) reported a constant rate period followed by a falling rate period during drying of banana dices at 60ºC and relative humidity of 9%. Drying kinetics and quality attributes of low-fat banana slices dried at high temperature, as investigated by Prachayawarakorn *et al.* (2008), revealed that the drying rate evolution occurred in three drying regimes, i.e., warming-up and two falling rate periods.

The thin layer drying characteristics of most agricultural products, which includes banana, could be described using drying models. These drying models are of two main groups, including the empirical models (Turhan *et al.*, 2002; Diamante *et al.*, 2010; Kaleta and Gornicki, 2010; Mundada *et al.*, 2011; Silva *et al.*, 2013, 2014a) and diffusion models (Karim and Hawlader, 2005; Nguyen and Price, 2007; Silva *et al.*, 2012a, b, 2013, 1914a; Darvishi *et al.*, 2013). According to Aguerre and Suárez (2004) diffusion models, unlike the empirical models, include the diffusion coefficient, which reflects a possible physical phenomenon that may occur during drying. Diffusion has often been described as one of the transport mechanisms for moisture transfer during drying, but the underlying basis of using the diffusion model for fitting the drying of fruits has not been fully justified, although descriptions and comparisons of various diffusion concepts and their applications are available (Chen, 2006). Common drying models available in the literature are presented on Table IV. Apart from the use of these models to describe the thin layer drying of agricultural products, they have also been suggested for the design of effective drying equipment and optimization of the drying process (Darvishi *et al.*, 2014). Furthermore, they can be used to describe the heat penetration during drying when hot air is used. In this case heating relies on the diffusion equation, which involves the drying rate in the energy balance (Karim and Hawlader, 2005; Mariani *et al.*, 2008; Silva *et al.*, 2014a).

Drying models that have been used by various researchers for the description of the thin-layer drying of banana are presented on Table V. Silva *et al.* (2014a) used several empirical models to simulate the thin layer drying of whole bananas at temperatures of 40, 50, 60 and 70ºC. Their results showed that Page and Silva *et al.* models were the best models to describe the drying kinetics of whole bananas. Baini and Langrish (2007) in their study on choosing an appropriate drying model for intermittent and continuous drying of bananas observed that the diffusion model, which

TABLE IV
DRYING MODELS FOR THE DESCRIPTION OF DRYING CHARACTERISTICS OF AGRICULTURAL MATERIALS

Model	Equation	References
Page	$MR = \exp(-kt^n)$	Lahsasni *et al.* (2004)
Henderson	$MR = a \exp(-kt)$	Doymaz (2009)
Modified Henderson	$MR = a \exp(-kt) + b \exp(-gt) + c \exp(-ft)$	Ganesapillai *et al.* (2011)
Logarithmic	$MR = a \exp(-kt) + c$	Togrul and Pehlivan (2002)
Wang and Singh	$MR = 1 + at + bt^2$	Miranda *et al.* (2009)
Diffusion	$MR = a \exp(-kt) + (1-a) \exp(-kbt)$	Ganesapillai *et al.* (2011)
Verma	$MR = a \exp(-kt) + (1-a) \exp(-gt)$	Ganesapillai *et al.* (2011)
Two term	$MR = 1 \exp(-kt) + u \exp(-gt)$	Lahsasni *et al.* (2004)
Two term exponential	$MR = a \exp(-kt) + (1-a) \exp(-kat)$	Doymaz (2009)
Midilli *et al.*	$MR = c \exp(-kt(t^n)) + bt$	Midilli *et al.* (2002)
Silva *et al.*	$MR = e^{-at-b\sqrt{t}}$	Silva *et al.* (2013)

MR: moisture ratio; a, b, c, k, g, h, l, u and n: model constants; t: time.

TABLE V
DRYING MODELS FOR THE DESCRIPTION OF DRYING KINETICS OF BANANA

Variety	Model	References
Cavendish, Cavendish cv. nanica	Page	Dandamrongrak *et al.*(2002); Silva *et al* (2013)
Cavendish	Two- term	Dandamrongrak *et al.* (2002)
Dwarf Cavendish, Gross Michel, nanicao	Diffusion	Baini and Langrish (2007); Demirel and Turhan (2003); Sousa and Marsaioli (2004)
Cavendish cv nanica	Silva *et al.*	Silva *et al.* (2013)
Nendran spp.	Midilli *et al.*	Ganesapillai *et al.* (2011)

includes the variation of moisture content and temperature throughout the banana in its solution, describes the drying kinetics of banana well for both continuous and intermittent drying. They concluded that the diffusion model is suitable for predicting the relaxation processes that occur when the drying conditions are interrupted, such as in intermittent drying. Ganesapillai *et al.* (2011) studied the drying kinetics of banana (*Nendran* spp.) under microwave, convective and combined microwave-convective process, and observed that MD (moisture diffusivity) resulted in a substantial decrease in the drying time with quality product when dried at higher power (300W) level compared to other processes. Furthermore, they reported that drying of the banana variety under the selected drying processes took place in the falling rate period, an indication that moisture removal from the banana was accomplished through diffusion mechanism. They concluded that the Midilli *et al.* model describes the drying kinetics of the banana variety compared to other drying models. Sousa and Marsaioli (2004) also observed that the drying of whole ripe banana of the Nanicao variety under microwave energy took place in the falling rate period, with diffusion mechanism being responsible for the moisture removal process. They, however, concluded that the drying process fitted well to a simplified diffusion model.

Relevant statistical parameters are normally used to select the best drying equation/model expressing drying curves of agricultural products, including bananas, and also to determine the consistency of the fits. The coefficient of determination R^2 is usually used to select the best equation expressing the drying curves of the samples. In addition to the R^2, parameters such as the reduced chi square value (χ^2), root mean square error (RMSE), mean bias error (MBE), and t-value are also usually employed to determine the consistency of the fit. The basis for the determination of the best fit or model is usually the highest values of R^2 and the lowest values of χ^2, RMSE, MBE and t-values (Ganesapillai *et al.*, 2011; Silva *et al.*, 2014a). The statistical parameters could be calculated using Eqs. 1-4.

$$\chi^2 = \sum_{i=1}^{N}(MR_{exp,i} - MR_{pre,\ i})^2 \quad (1)$$

$$RMSE = (\frac{1}{N}\sum_{i=1}^{N}(MR_{pre,i} - MR_{exp,\ i})^2)^{\frac{1}{2}} \quad (2)$$

$$MBE = \frac{1}{N}\sum_{i=1}^{N}(MR_{pre,i} - MR_{exp,\ i}) \quad (3)$$

$$t - value = \sqrt{[\frac{(n-1)MBE^2}{RMSE - MBE}]} \quad (4)$$

where MR_{exp}: experimental moisture ratio, MR_{pre},i: predicted moisture ratio, n: number of constants, and N: number of observations.

Moisture Diffusivity in Banana during Drying Process

Diffusion in solids during drying is a complex process that may involve molecular diffusion, capillary flow, Knudsen flow, hydrodynamic flow, or surface diffusion (Marinos-Kouris and Maroulis, 2006). Effective moisture diffusivity is a term used to describe the migration or diffusion of moisture in agricultural products during drying operation and it is said to be a function of material moisture content and temperature, as well as of the material structure (Abano and Sam-Amoah, 2011). According to Zogzas *et al.* (1996) diffusivity values fall between 10^{-13} and $10^{-6}m^2\ s^{-1}$ while most values (92%) fall within 10^{-12} and $10^{-8}m^2{\cdot}s^{-1}$. Drying kinetics and quality attributes of low-fat banana slices dried at high temperature as investigated by Prachayawarakorn *et al.* (2008) revealed that the effective diffusion coefficient of banana increased with a decrease in moisture content until a certain moisture content, after which the diffusivity decreased. The influence of drying temperatures on the moisture diffusivity and quality attributes of the dried banana slices in terms of volatile compound, shrinkage, color, texture and microstructure was investigated by Thuwapanichayanan *et al.* (2011), who showed that the drying rate of banana slices occurred in two sub-drying periods, first and second falling rate periods. The effective diffusivity estimated by the optimization technique was found to decrease sharply with moisture content in the first falling rate period and changed slightly in the second falling rate period. Air drying of Dwarf Cavendish and Gross Michel banana slices by Demirel and Turhan (2003) revealed that effective moisture diffusivity increased with increasing temperature between 40 and 70ºC in the untreated samples, while it increased between 40 and 60ºC, and decreased at 70ºC in the pretreated samples probably due to case hardening and starch gelatinization above 60ºC. Modeling microwave drying kinetics and moisture diffusivity of banana (Mabonde variety) showed that effective moisture diffusivity of Mabonde banana variety increased with increasing microwave power (Omolola *et al.*, 2014).

The theoretical determination of effective moisture diffusivity of banana using the solution to Fick's second law has been widely used by various researchers (Doymaz, 2009; Thuwapanichayanan *et al*., 2011; Silva *et al*., 2014a; Omolola *et al*., 2014). Eqs. 5 to 7 summarize the solution of Fick's second law of diffusion, where MR: moisture ratio, D_{eff}: effective moisture diffusivity ($m^2{\cdot}s^{-1}$) and L: half-thickness (m) of banana slices

$$MR = \frac{8}{\pi^2}\sum_{n=0}^{\infty}\frac{1}{(2n+1)^2} \exp(-\frac{\pi^2(2n+1)^2}{4L^2}D_{eff}t) \quad (5)$$

Eq. 5 is based on the assumption that the moisture diffusivity is constant, the banana slices represent infinite slab geometry and the initial moisture distribution is uniform (Demirel and Turhan, 2003; Abano and Sam-Amoah, 2011; Thuwapanichayanan *et al.*, 2011). It could further be simplified to a straight line equation:

$$\ln(MR) = \ln\left(\frac{8}{\pi^2}\right) - \left(\frac{\pi^2 D_{eff}}{L^2}t\right) \quad (6)$$

The plot of experimental drying data in terms of ln (MR) against time gives a straight line with a negative slope (φ) of

$$\varphi = \frac{\pi^2 D_{eff}}{L^2} \qquad (7)$$

A two-dimensional numerical solution in generalized coordinates of the diffusion equation with boundary condition of the third kind, obtained through the finite volume method for the description of moisture diffusivity in whole bananas has been extensively discussed by Silva *et al.* (2014b).

However, the determination of effective moisture diffusivity of agricultural products, including banana, during drying could also be determined experimentally. Experimental methods for effective moisture diffusivity determination include concentration-distance curves, permeation methods, sorption kinetics, electrospin resonance, nuclear magnetic resonance, radiotracer methods and drying techniques that include regular regimes and simplified methods (Crank and Park, 1968; Assink, 1977; Schoeber and Thijssen, 1977; Luyben, 1980; Naesens *et al.*, 1981; Windle, 1985; Hendrickx *et al.*, 1986; Coumans and Luyben, 1987; Gros *et al.*, 1987; Moyne *et al.,* 1987; Eccles *et al.*, 1988; Marinos-Kouris and Maroulis, 2006).

Conclusion

Understanding drying kinetics of banana with regards to mathematical modeling of the drying behavior and moisture migration or transport mechanism is important for the description of drying behavior, design of effective drying equipment, optimization of drying process and description of heat penetration mechanism during drying process. Several drying models are available in the literature for the description of thin layer drying kinetics of agricultural products out of which models such as page, two-term, diffusion, Silva *et al.* and Midilli *et al.* adequately describe the drying kinetics of some banana varieties. Furthermore, relevant and adequate pretreatment is essential and required prior to drying of bananas as this result in a good quality dried banana product in terms of color, microbiological and shelf stability and reduction in drying time, thereby reducing energy consumption during drying.

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CINÉTICA DEL SECADO DE BANANAS (*Musa* spp.)

Adewale O. Omolola, Afam I. O. Jideani y Patrick F. Kapila

RESUMEN

*El enfoque e interés de las investigaciones recientes sobre bananas (*Musa *spp.) se ha debido a su importancia nutricional y económica. Estas especies son un cultivo mayor en los trópicos y subtrópicos, y han contribuido en buena medida a la economía de muchos países. Las bananas son populares como postre en las dietas modernas occidentalizadas por su potencial nutritivo. El secado de la banana se ha hecho necesario a fin de reducir la actividad microbiana y prevenir la pudrición, y para extender el tiempo de almacenamiento. El conocimiento de la cinética de secado es esencial para el control y la optimización del proceso de secado, de cualquier procesamiento ulterior y de la calidad del producto final. Además, la aplicación de pretratamiento(s) adecuado(s) antes del secado de la banana ayuda a mantener la fruta sin oscurecer durante el secado y almacenamiento, acelera la operación de secado y minimiza los efectos de la misma en algunos parámetros de calidad de la banana. En esta revisión se examina la cinética de secado de la banana en relación a los pretratamientos aplicados a las frutas antes del secado, se resumen los modelos para la descripción de las características del secado y los métodos de secado, así como las propiedades de transporte durante el secado.*

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RESUMO

*O enfoque e interesse das investigações recentes sobre bananas (*Musa *spp.) devem-se à sua importância nutricional e econômica. Estas espécies são um cultivo maior nas áreas tropicais e subtropicais, e tem contribuído em boa medida na economia de muitos países. As bananas são populares como sobremesas nas dietas modernas ocidentalizadas por seu potencial nutritivo. A secagem da banana tem sido necessária para reduzir a atividade microbiana e prevenir o apodrecimento, e para estender o tempo de armazenamento. O conhecimento da cinética de secagem é essencial para o controle e a optimização do processo de secagem, de qualquer processamento ulterior e da qualidade do produto final. Além disso, a aplicação de pré-tratamento(s) adequado(s) antes da secagem da banana ajuda a manter a fruta sem escurecimento durante a secagem e armazenamento, acelera a operação de secagem e minimiza os efeitos da mesma em alguns parâmetros de qualidade da banana. Nesta revisão é examinada a cinética de secagem da banana em relação aos pré-tratamentos aplicados às frutas antes da secagem, são resumidos os modelos para a descrição das características da secagem e os métodos de secagem, assim como as propriedades de transporte durante a secagem.*