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Drying Kinetics of Gum Karaya (*Sterculia urens*) Using Convective Air Dryer

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Authors' contributions

This work was carried out in collaboration between both authors. Author JS managed the literature searches, performed the experiment and wrote the first draft of the manuscript. Author BS managed the analyses of the study along with proof reading of the final draft of the manuscript. Both authors read and approved the final manuscript.

Original Research Article

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ABSTRACT

The present study was aimed to investigate the drying kinetics of gum karaya (*S. urens*). Three grades of gum (I, II, III) were dried using a cabinet-type convective dryer. Particle size equivalent to US Sieve size-6 and air temperatures of 50, 60 and 70℃ were used for the drying experiments. The experimental drying data was fitted to Page's model to predict the drying kinetics. Investigations with constant air velocity revealed that for grade-I gum, drying rate constant (k) varied between 0.2744-0.3742 (h^{-1}), for grade-II gum between 0.3208-0.4439 (h^{-1}) and for grade-III gum between 0.4098-0.4639 (h^{-1}). The dimensionless number (n) was always more than 1 and minimum value of the Coefficient of determination (R^2) was 0.967. Increase in air temperature enhanced drying process and drying rate. For each particular temperature, the values of drying rate constant were minimum for grade-I, maximum for grade-III and intermediate for grade-II gum.

Keywords: Gum karaya; convective hot air drying; drying kinetics; Sterculia urens.

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1. INTRODUCTION

Gum Karaya (GK), also called sterculia gum, is a dried exudate of *Sterculia urens* tree and other species of Genus *Sterculia*, which belong to the Family *Sterculiaceae* [1]. Exudate gums are the oldest natural gums and among the numerous commercially important tree exudates from India, gum karaya is ranked first [2]. However, in terms of its share in the world-wide market, it ranks second only to Gum Arabic which is the most popular exudate gum [3]. Food and Drugs Administration in the USA listed gum karaya as 'generally recognized as safe' (GRAS) for food applications [4]. The Food and Agricultural Organization (FAO), Rome, had recognised Sterculia gum as food additive [5]. In the early 1900s, it was marketed to be used as an adulterant or alternative to gum tragacanth (*Astragalus gummifera*) [6]. India is the largest producer of gum karaya and holds monopoly over its production and export. The gum is found to be contaminated with microbes during conditioning and handling. Le-Cerf et al. [7] in their study reported 5×10^4 microbes per gram of gum sample. Gum karaya successfully passed toxicological [8,9], teratological [10,11] and mutagenic [12] tests carried out by different workers. Gum karaya is a heteropolysaccharide of galactose, rhamnose, galacturonic acid and glucuronic acid containing 60% neutral sugars and 40% acidic sugars [13].

The wide range of applications of gum karaya in the food and pharmaceutical industries has been mentioned by various workers. In bakery, karaya gum is used to prolong the shelf-life of products, to improve the water holding capacity as emulsifier and to increase the dough stability as foam stabilizer [14]. In plant tissue culture, it has recently been used as solidifying agent for *In vitro* regeneration of plantlets from nodal explants [15] and shoot tips of rough lemon (*Citrus jambhiri* Lush.) [16]. In cosmetics, it has been used in hair dressing lotions and finger wave lotions [17]. Gum karaya has also been employed to produce essential-oil-intact patches of *Lavandula angustifolia* oil for aroma-therapeutic applications, essential oil delivery through the skin and other tropical applications [18].

Apart from a number of its various tested roles in pharmaceutical industry, some of its recent successful evaluations include: a) As matrix material in floating drug delivery tablets for verapamil hydrochloride (anti-hypertensive drug) with good floating capability and shorter floating lag time [19], b) As coating material for microcapsules prepared using karaya gum in combination with alginate for slow release of glipizide (hypoglycemic drug) over a long period of time [20], c) As release retardant in hydrogel prepared from modified sterculia gum with methacrylic acid (MAAc) for controlled delivery of ranitidine hydrochloride (anti-ulcer drug) [21].

In recent times, natural polymers are being used in various pharmaceutical and other applications because they are economical, readily available, non-toxic, biodegradable and biocompatible [22]. Drying is the process that is widely used to decrease the water activity in agricultural and food products. It reduces microbial activity thereby improve food stability. Open air sun drying results in contamination by dust and insects, therefore, most of the dryers used for agricultural products use electricity as preferred energy source [23]. The hot-air drying of food materials has advantages of controlled product quality achieved through proper hygienic conditions with reduced product loss [24]. The flavour and most of the nutritional values are preserved and concentrated through hot air drying [25]. However, optimization of the drying operations is mainly required to minimize the energy consumption during processing [26]; which leads to improved production of dried products [27]. Study on the drying kinetics of gum karaya using convective hot air has not been reported in literature and considering its wide use in different fields as a novel polymer, there is need to develop processing technique in order to store this important natural product of Indian origin for long durations. So the present study was planned with an aim to observe the effect of drying temperatures on drying characteristics of this gum.

2. MATERIALS AND METHODS

2.1 Collection of Samples

Fresh karaya gum was purchased from Girijan Cooperative Corporation Ltd. Visakhapatnam, India and stored in airtight polypropylene jars, sealed and tagged as (Grade I, II, III). Gum samples free from extraneous materials having particle size equivalent to US Sieve size-6 were used in this study (Fig. 1).

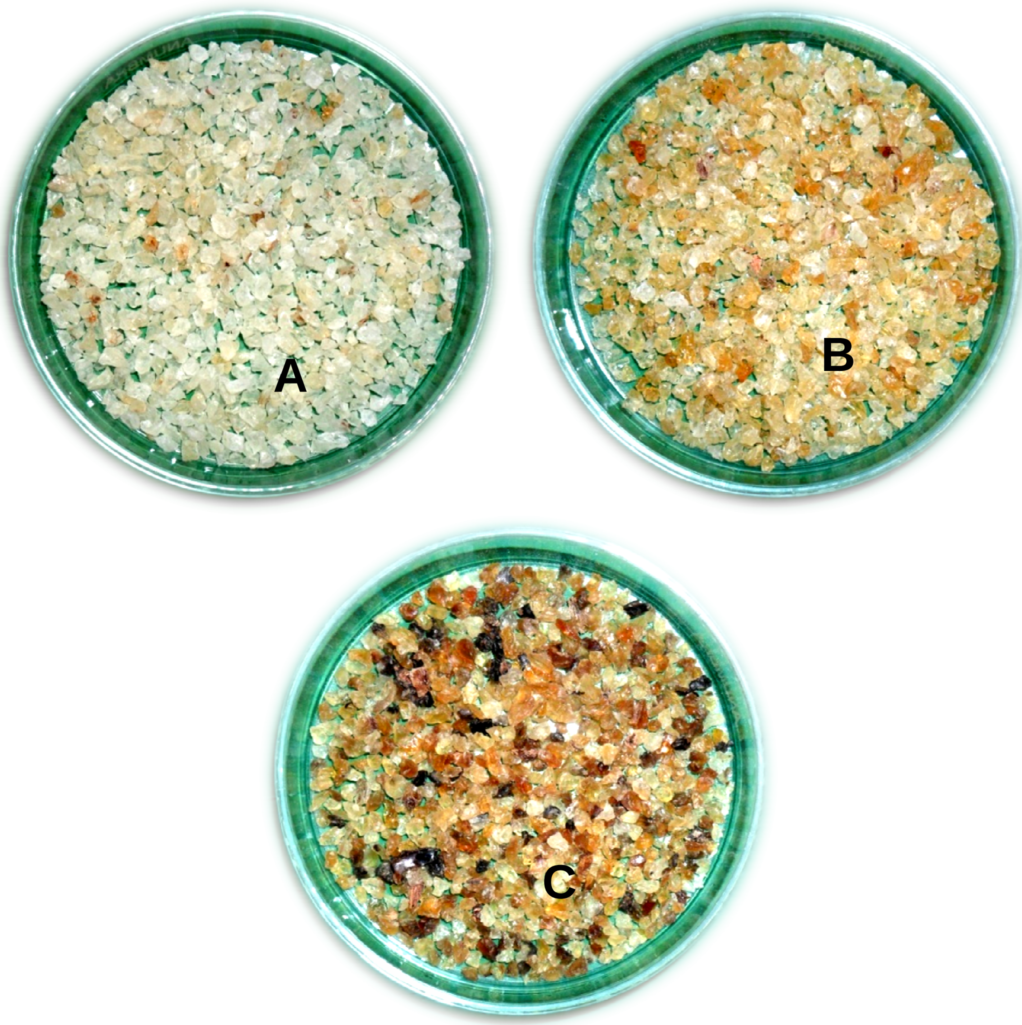

Fig. 1. Gum Karaya (*Sterculia urens*) grade-I (A), grade-II (B), grade-III (C)

2.2 Experimental

Gum karaya was dried on perforated trays in a cabinet dryer (*La Parmigana*, Italy) at 50, 60 and 70±1ºC respectively. The cabinet dryer used for drying was consisted of an electric fan for air circulation, digital thermostat with temperature control probe, heating unit and timer. To achieve internal temperature consistency, the dryer started about 1 hour before each drying run at respective drying temperatures. 25g of the gum samples were weighed and uniformly spread onto the perforated trays in a single layer. The loss in moisture was recorded using analytical balance (Shimadzu, model BL-220) at 15min. intervals for initial 2 hours and at 30min. intervals afterward till the weight became constant. The weight of gum before drying i.e. at zero drying time, was considered as the initial weight. The gum containing trays were taken out, weighed and placed back after each drying interval in about 30s to avoid any significant temperature variation in the dryer. Air velocity inside the dryer was kept constant during each drying run. All the experiments were repeated thrice and the average value was used to analyze the data.

2.3 Analytical

2.3.1 Initial moisture

Initial moisture content of gum samples were determined by drying at 105ºC till their constant weight as per AOAC (1984) standards [28], using thermostatically regulated universal oven. The moisture content was calculated as:

$$\%\ \text{moisture content (dry basis)} = \left(\frac{\text{amount of moisture loss}}{\text{weight of dried sample}}\right) \times 100 \tag{1}$$

The amount of moisture loss was calculated by taking the difference between the mass of the original sample and that of dried sample.

2.3.2 Modelling

The page’s thin layer drying model was used to describe the drying behavior of gum [29].

$$MR = \left(\frac{m_t - m_e}{m_o - m_e}\right) = \exp(-kt^n) \tag{2}$$

Where:

MR is the moisture ratio,
m_t is the moisture content at any given instant time t (% d.b.),
m_e is the equilibrium moisture content (% d.b.),
m_o is the initial moisture content (% d.b.),
k is the coefficient called drying rate constant,
t is time in hours and
n is the dimensionless constant

Equation (2) can be linearized as:

$$\ln[-\ln(MR)] = \ln(k) + n\ln(t) \tag{3}$$

The final moisture content achieved after drying was considered as equilibrium moisture content which was used for the calculation of drying ratio and further fitting of an appropriate model.

2.3.3 Data analysis

The drying data was analyzed using Microsoft excel software.

3. RESULTS AND DISCUSSION

Drying is an established technique in food processing [30]. Due to hygienic and economic considerations, heated air drying has been developed as an important newer technique [31]. Convective drying is considered as a simultaneous heat and mass transfer process where water is transferred by diffusion from interior of the material to the material-air interface and in turn from the interface to the outer atmospheric air by convection [32]. Temperature range of 37 to 71ºC effectively inactivates enzymes and kills bacteria, therefore suitably recommended for drying [33]. The use of high drying temperatures cause detrimental changes to the food materials [34]. The moisture content of gum karaya grade I, II & III as a function of drying time at 50, 60 and 70ºC air drying temperatures is shown in (Figs. 2a, b, c). All the drying curves showed two stages. During initial period of drying (first stage), the moisture content decreased rapidly and during later period (second stage), the moisture content decreased slowly with drying time. At higher temperatures the rate of moisture loss was higher and the total drying time was reduced with increase in the drying temperature. The drying time required to reduce the moisture content to any given level was temperature dependent, being highest at 50ºC and lowest at 70ºC. In this way, the drying temperature showed an important effect on drying time. The drying process enhanced with the increase in drying temperature, as the total moisture loss by drying at higher temperature was more than that of drying at lower temperature. The drying rate was minimum at lowest temperature (50ºC) and maximum at highest temperature (70ºC). The first 15min. of drying appeared as a rapid drying period irrespective of the temperature used, because the drying rates were highest during this period and as drying time proceed the drying rate decreased simultaneously at all temperatures. Similar trends have also been reported in hot air cabinet drying of gum kondagogu (*Cochlospermum gossypium*) [35].

For grade-I gum, the initial moisture content (IMC) of 27.38% (d.b.) was reduced to 12.33, 10.06, 6.13% (d.b.) at 50, 60, 70ºC drying temperatures respectively. The experimental repeat for grade-II gum having IMC value 24.68% (d.b.), the final moisture content (FMC) attained was 12.52, 10.57 and 6.81% (d.b.); whereas for grade-III gum with IMC value 22.10% (d.b.), the FMC attained was 10.74, 8.36 and 6.67% (d.b.) and the time spans for drying were of 270, 390 and 420min. The respective time spans for 50, 60, 70ºC drying temperatures were 330, 450, 420min. for grade-I; 300, 480 and 420min. for grade-II and 270, 390 and 420min. for grade-III gum.

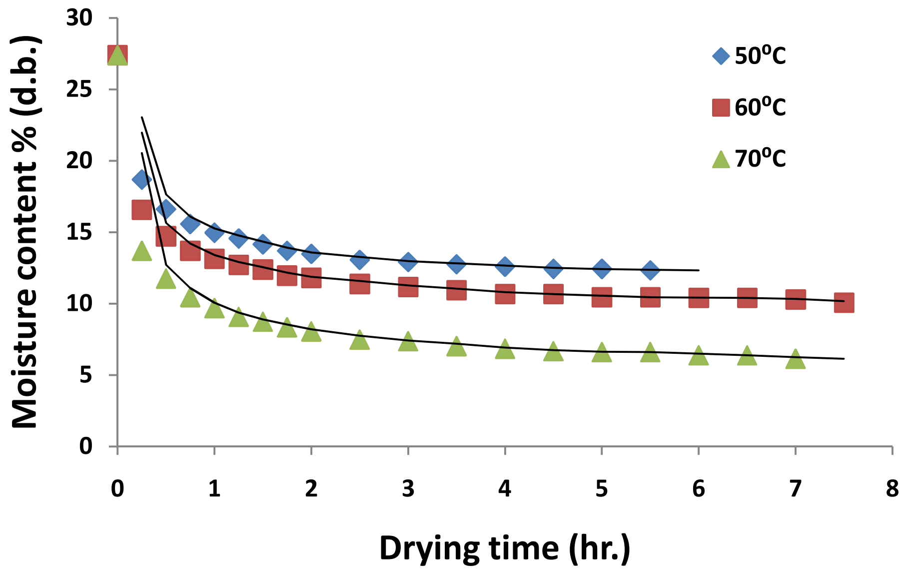

Fig. 2a. Drying curves for gum karaya grade-I

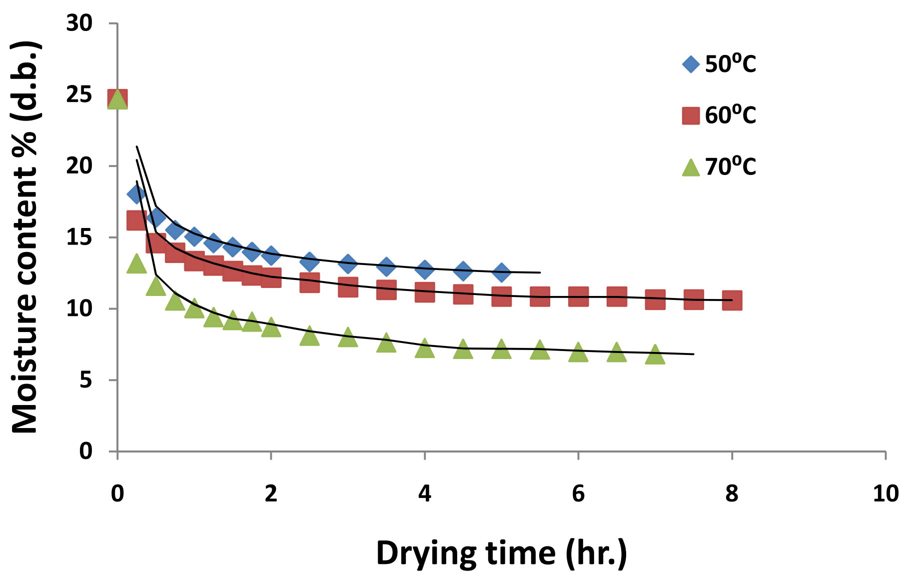

Fig. 2b. Drying curves for gum karaya grade-II

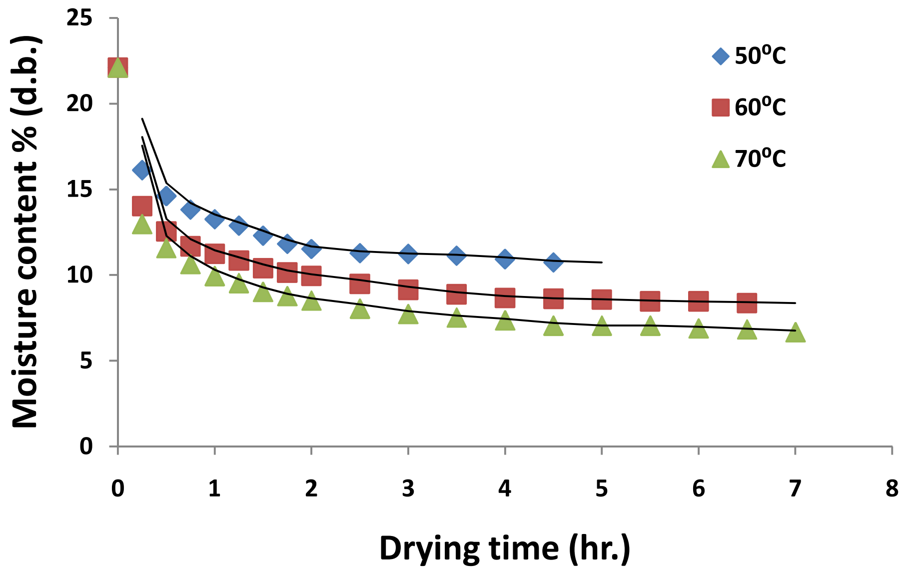

Fig. 2c. Drying curves for gum karaya grade-III

Table 1. Coefficients of page's model for hot air cabinet drying of gum karaya

Grade	Drying temperature (ºC)	Drying rate constant (*k*)	Dimensionless number (*n*)	Coefficient of determination (R^2)
	50	0.3742	1.693	0.985
Grade-I	60	0.2891	2.226	0.994
	70	0.2744	2.172	0.991
	50	0.4439	1.647	0.975
Grade-II	60	0.3953	1.888	0.967
	70	0.3208	2.038	0.972
	50	0.4639	1.603	0.984
Grade-III	60	0.4257	1.745	0.972
	70	0.4098	1.937	0.983

The drying of biological materials in the falling rate period is a diffusion-controlled process and may be represented by Fick's second law of diffusion. Various types of mathematical models have been used to describe drying of foodstuffs; ranging from theoretical models to purely empirical models [36,37]. Thin layer equations contribute to the understanding of heat and mass transfer phenomena in agricultural products [38]. Page's model has been widely used to describe the drying behavior of a variety of biological materials [39,40]. The values of coefficients of Page's model as determined are presented in (Table 1). For different drying temperatures from (50-70ºC), considering all the three grades, the overall variation in drying rate constant (*k*) value was between 0.2744-0.4639 (h^{-1}), and that of the coefficient of determination (R^2) value was between 0.967-0.994. Because of drying process enhancement in terms of drying period the value of drying rate constant appeared to be decreased with the increase in drying temperature. For any particular temperature, Grade-III gum showed comparative more *k* values than grade-II gum, which in turn was more than grade-I gum. The overall variation range of dimensionless number (*n*) was between 1.603-2.226 and its value was always more than 1 which was in agreement with the findings reported by other workers on drying behavior of food materials. Page's equation adequately described the hot air drying of gum karaya over a range of temperatures in the falling rate period.

4. CONCLUSION

The drying kinetics of gum karaya in a cabinet-type dryer at three air temperatures (50, 60 and 70ºC) was investigated. Drying of gum occurred in the falling rate period and thin-layer drying Page's model effectively described the drying behaviour of gum karaya in the present study. 70ºC temperature is suggested to be the most effective for drying. The proper drying of gum can exempt the need of processes like gamma-ray irradiation and use of preservatives to prevent microbial decontamination of this extremely important non timber forest product from India.

CONSENT

Not applicable.

ETHICAL APPROVAL

Not applicable.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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