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Drying of Chhana using Solar Energy: Physical and Thermal Properties of Dried Chhana

(Chhana Drying by Solar Energy)

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Abstract- ***Chhana*****, India's traditional soft cottage cheese, is used as an intermediate base for a wide variety of milk based Bengali sweets. It has limited shelf life at room temperature. Drying helps in enhancing the shelf life of any food product. This study deals with the drying characteristics of *Chhana* using specially developed indirect solar cabinet dryer. The thermal parameters like specific heat, thermal conductivity and thermal diffusivity were calculated from equations given by previous investigators. The analysis of the drying characteristics showed that the rate of moisture removal was high at the beginning and it declined later. The drying process of *Chhana* recorded one falling rate curve. The drying process was evaluated for per cent moisture reduction, drying rate, drying ratio. The dried *Chhana* powder was evaluated for determination of physical and thermal properties. After rehydration, the *Chhana* powder was not able to regain its original characteristics.**

Keywords: Solar dryer, moisture reduction, drying rate, drying ratio, Chhana powder,

I. INTRODUCTION

India, the largest milk producer in the world, accounts for 14.2% of world milk production. It is estimated that the total production of *Chhana* based sweets is 1 million tonnes. Its production involves precipitation of casein along with entrapped fat and water soluble components of milk by addition of an acidulant to milk at near boiling temperatures. This is followed by removal of whey from the curd. The coagulum is collected in a cloth and hung on a peg to drain off the whey. The moisture content of *Chhana* is very high hence it has comparatively less shelf life. The problem of perishability of *Chhana* has an important guiding influence on the technology involved in their processing and handling. The limited shelf life of *Chhana* can be ascribed to its high moisture content and unhygienic handling practices. Drying of a product helps in increasing the shelf life of the product. The dried product can be used for preparation of different kind of desirable foods. Solar energy can be effectively used for drying of dairy products by developing efficient solar dryers. The present study was conducted to determine the drying characteristics, to assess the performance of specially developed indirect solar cabinet dryers for drying of *Chhana* and to study the rehydration characteristics of solar dried *Chhana* powder.

II. MATERIALS AND METHODS

A. *Preparation of Chhana*

Each sample of *Chhana* was prepared using standardized milk (4.5% fat, 8.5% SNF). The milk was hated to boiling temperature, after boiling, milk was cooled to 70^{o}C. Citric acid solution (1%) at a temperature of 70^{o}C is added to coagulate the milk. The light greenish tinge of whey indicates complete coagulation. The coagulum was then separated from the whey using a muslin cloth. *Chhana* was spread on stainless steel trays to cool for around 30 min after which it was grated manually using a shredder. The shreds of *Chhana* are then uniformly spread in a stainless steel tray.

B. *Development of Indirect Solar Cabinet Dryer (ISCD)*

The ISCD is actually a cabinet type natural convection solar dryer. The material used for fabrication was mild steel sheet of 20 gauge (1 mm). The frame for ISCD was fabricated using angle iron. Gas welding of the MS sheet with the frame was done in such a way so as to ensure that it forms an air tight welded dryer model. A reflector glass is attached to the ISCD to collect the maximum possible solar energy reflected from the surface of the earth. This reflector is adjustable and can be rotated through nearly 120^{o} at three different positions to receive the maximum possible radiations. The cabinet used for tray drying has a chimney; attached to it at the top of drying chamber, to provide an outlet for the outgoing air from the product. A float glass (thickness: 3 mm) is used as a solar collector for the ISCD. The approximate angle of tilt of the float glass from the horizontal was 30^{o}. The cabinet of the dryer has a slot for the product tray to slide in and out so that the product can be placed on the fine mesh tray. The slot is covered by a sliding door to prevent any leakages and to also keep the product free from air born contamination. The flow of air through the ISCD is laminar. The heated air passes through the cabinet where the tray with product is placed. The experiment is carried out for 5 hours.

C. *Determination of physical and thermal properties*

(i) *Bulk density:* It was determined using a measuring cylinder to measure the volume of the known weight of dried *Chhana* powder.

(ii) *Specific heat:* The specific heat is the amount of heat needed to change one weight unit by one degree temperature. The equation is given as follow [1]

$$c_p = 2.093\ X_f + 1.256\ X_s + 4.187\ X_w \quad (1)$$

(iii) *Thermal conductivity:* The thermal conductivity is the measure of the amount of heat which passes through a material of unit area per unit thickness. For food products having higher moisture content the following equation [2]

$$k = 0.148 + 0.493\ X_w \quad (2)$$

(iv) *Thermal diffusivity:* It was calculated from following equation

$$\alpha = k/\ \rho\ c_p \quad (3)$$

(v) *Drying ratio:* It is defined as the ratio of the weight of a define sample amount of the product before drying to the weight of the product immediately after drying.

$$D_r = W_1/W_2 \quad (4)$$

(vi) *Drying rate:* It is calculated as the difference in moisture content (db) per unit time (h) for successive durations for entire drying period.

(vii) *Fineness modulus and average particle size:* The fineness modulus indicates the uniformity of grind in resultant product. It can be determined by calculating the weight of material retained in each sieve thereafter calculating the per cent of material retained adding the weight fractions retained above each sieve and dividing the sum by 100 [3]. The average particle size of *Chhana* powder was calculated by following equation

$$D_p = 0.135\ (1.366)^{FM} \quad (5)$$

III. RESULTS AND DISCUSSION

The variation in inlet and outlet temperatures and relative humidity of ambient air during drying was also observed. It was found that a significant difference of temperature constantly existed between the inlet and outlet air. Both inlet and outlet temperatures showed a constant increase from 11:00 to 15:00 Hrs after which a dip was observed up to end of the experiment. The relative humidity of ambient air was found to decrease with subsequent increase in ambient air temperature.

(i) *Temperature during drying:* The most suitable temperature during drying should be around 70°C. With the developed ISCD, the maximum temperature achieved during drying was as high as 78°C and the minimum temperature achieved is 58°C.

(ii) *Variation of moisture content of Chhana with respect to drying time:* Initial moisture content of *Chhana* was never recorded to be a fixed value during experimentation. Although *Chhana* was prepared by same methods, but there were constant variation in the moisture content each time. Therefore, the analysis regarding their variation in moisture content and time is essential to be studied differently. The drying behavior of *Chhana* is shown in Fig 1.

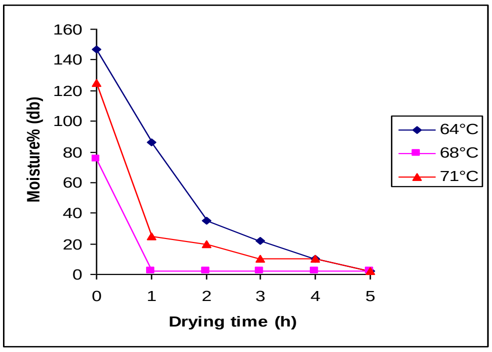

Fig 1 Variation in moisture content with respect to time during drying of *Chhana* in Internal Solar Cabinet Dryer (ISCD) at different air temperatures

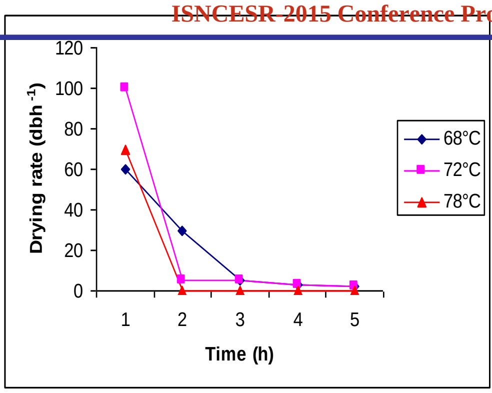

Fig 2 Variation in drying rate with respect to time during drying of *Chhana* in Internal Solar Cabinet Dryer (ISCD) at different air temperatures

The ISCD at all the three different temperatures shows an initial very high removal of moisture content up to second hour of drying, followed by slow removal of moisture for the remaining three hours with the removal of moisture nearly negligible during last hour of drying. The fall in moisture content for the first hour is recorded to be the highest when drying air temperature was 71°C. This is probably because during the initial stages of drying, free moisture available on the surface evaporates rapidly. During the later stages of drying, diffusion of moisture from the inner surface to the outer surface takes a comparatively longer time.

(iii) *Variation of drying rate of Chhana with respect to drying time:* The changes in drying rate with drying time for all the three temperatures is shown in Fig.2.

It is quite obvious that the maximum drying rate was observed during the initial stage of drying. As the drying time increased, the drying rate decreased showing an inverse proportion between drying rate and drying time.

(iv) Chemical properties: The chemical analysis of *Chhana* powder was carried out for the analysis of fat by dilution method, acidity by titration method and moisture content by gravimetric method. The *Chhana* powder was found to have 40-42% fat, 0.52-0.58% L.A. acidity and 3.05-3.18 % moisture content on dry basis.

(v) Physical and thermal properties

a). Bulk density: The value of bulk density signifies the amount of moisture retained in the product. In *Chhana* powder obtained by drying in ISCD by 78°C hot air, bulk density was recorded to be the highest at 520 kg/m^3 drying in ISCD.

b). Specific heat: As per eqn. (1), X_f = 0.4, X_s = 0.565 and X_w = 0.039, the specific heat of *Chhana* powder was recorded to be 1.71 kJ/kg K.

c). Thermal conductivity: From eqn. (2), the thermal conductivity of *Chhana* powder was found to be 0.167 kJ/m K having X_w = 0.039.

d). Thermal diffusivity: From eqn. (3), the thermal diffusivity is found to be 0.0002 m^2/s for k = 0.167 kJ/m K, ρ = 520 kg/m3 and c_p = 1.71 kJ/kg K.

e). Fineness Modulus: After drying, the dried *Chhana* was ground in a mixer grinder for 5 min. Following Table 1 shows the method of calculation of fineness modulus using the sieves of B.S.S. No. 16, 60, 120, 240 having 1 mm, 250, 125, 63 micron mesh size respectively.

TABLE I. CALCULATION OF FINENESS MODULUS OF DRIED *CHHANA*

B.S.S. 410/1969	Size	Weight of material retained (g)	Percent material retained	Fineness Modulus
16	1 mm	0.0	4 x 0 = 0.0	0 + 222.11 + 31.17 + 7.28 = 260.56 F.M. = 260.56/100 =**2.61**
60	250 µm	88.46	3 x 74. 03 = 222.11	
120	125 µm	18.62	2 x 15.84 = 31. 17	
240	63 µm	6.4	1 x 7.28 = 7.28	
Pan		6.0	0 x 5.02= 0	

From the sieve analysis carried out, the average size was found to be 0.3 mm. In eqn. (5), by keeping F.M. = 2.61, the average particle diameter, D_p of *Chhana* powder was found to be 0.003 m.

A. *Moisture Reduction*

For *Chhana*, when it is dried using ISCD, during the drying period of total 5 hours when the average air temperature was 72ºC, the total moisture reduction was reduced from 127. 2 to 2.04% (db) giving the 97.2 per cent moisture reduction. The average drying rate was 13.96 % db/h and drying ratio was 2.29.

B. *Rehydration of Chhana powder*

Rehydration of *Chhana* powder was done to match its property with freshly prepared one. The rehydrated *Chhana* can be used for preparation of end products. Therefore, *Chhana* powder prepared by ISCD was hydrated with equal amount of water. It is found that dried *Chhana* powder upon rehydration did acquire neither appearance nor properties of freshly prepared *Chhana*. This indicates the limitation of solar drying of *Chhana*. It emphasizes some modifications is needed either during its preparation or drying.

Abbreviations

c_p = specific heat of dried *Chhana* (kJ/kg K)

k = thermal conductivity of dried *Chhana* (J/s.m.ºC)

b = dry basis

D_p = average particle diameter of *Chhana* (m)

D_r = drying ratio

FM = Fineness modulus (dimensionless)

ISCD = Indirect solar cabinet dryer

wb = wet basis

W_1 = initial amount of product (*Chhana*) before drying (kg)

W_2 = final amount of product (dried *Chhana*) after drying (kg)

X_f = mass fraction of fat in *Chhana*

X_s = mass fraction of ‘solids not fat’ in *Chhana*

X_w = mass fraction of water in *Chhana*

α = thermal diffusivity of dried *Chhana* (m^2/s)

ρ = density of dried *Chhana* (kg/m^3)

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