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An Indigenously Designed Solar Drier For A Novel Ready-To-Eat Cheese Variant Processing

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ABSTRACT

The increasing population and high cost of fuels have created opportunities for using alternate energies for the processing of foods. Solar processing is an emerging sustainable energy technology that provides good quality foods at low or no additional fuel costs. The present investigation is an attempt to design and explore solar driers for traditional and ethnic food i.e Bandel cheese. It is found in Eastern- India, Bandel, and West Bengal. The objective was to modify the traditional cheese and produced a nutritive, value-added, ready-to-eat cheese by applying a solar drying process. Drying was accomplished in an indigenously designed solar dryer maintained at around 70^0C, to reduce the moisture content. Solar drying technology was used, as it is cost-effective and minimizes micro and macronutrient losses during the drying process. The physical properties and proximate composition of ready-to-eat cheese were analyzed. The sensory panel of this cheese rated more acceptable.

Keywords**:** Ready-to-eat Cheese, Solar Drying, Bandel Cheese.

INTRODUCTION

Bandel cheese is the traditional cheese that originated in an erstwhile Portuguese colony, Bandel located in eastern India (West Bengal). The two varieties of Bandel cheese available in West Bengal include smoked and non-smoked [13]. The variety is highly aromatic and fresh as it is sold in circular flats straight away after production [13]. Bandel cheese can be well salted to be stored. But these techniques, however, were not beneficial in terms of product shelf life, and taste. To increase the shelf life, the removal of moisture from the foods is important. Hence drying/dehydration of cheese to a Churpi, the prototype may be a promising option that needs to be investigated, standardized, and adopted for enhancing its shelf life and thereby improving the economic prospects and global availability of this traditional, local cheese variety. Churpi as referred to in Tibetan and Nepali languages and as slag in Mongolia is a delicious dried cheese variant having a consistency ranging from soft to slightly hard, the colour white to orange, taste, and odour, sour to pungent, pH 5.97 to 7.0. It is largely consumed in the Himalayan highland region through its industrial production is not yet standardized [1]. Churpi has two varieties soft Churpi [2] and hard churpi [3]. Soft churpi is an excellent source of protein,[4].

Drying agricultural products under direct sunlight is the traditional way of preservation of food. The process of dehydration alone contributes up to 30 % of the total cost of processing most fresh produce. Thus, the cost of dehydration and energy consumption and the quality of dried products play a very important role in choosing an appropriate drying process. Traditional sun drying takes place by putting the products under direct and indirect sunlight by covering the products with transparent or non-transparent covers [5]. Hence a solar drier could be a preferred option Advantages of solar drying include no fuel dependence, negligible operating cost, reduced environmental impact, sustainable form of energy, and allows longer storage reduced drying duration, and less chance of food spoilage.

The process of drying in the solar dryer is facilitated by the circulation of hot air, the spreading density of the product, the nature of pre-treatment as well as the nature of the product to be dried itself. The time taken for drying is also determined by the factors such as the initial moisture content and the desired final percentage of moisture of the product.

The objective of this study was the Invention of a ready-to-eat churpi cheese-like variant by applying an eco-friendly technology (solar drying) without affecting the nutritional characteristics of Bandel cheese. Major design parameters considered during the designing of the drying chamber include the quantity of product, the capacity of dryer effective circulation, vent, loading, and unloading of materials, thermodynamic aspects, etc. The effect of parameters on drying was studied and the kinetics of the drying phenomena was modelled. Resultant ready-to-eat Bandel cheese, a churpi prototype is likely to possess an increased shelf life and reduced storage and transportation cost increasing the scope of marketability in the national and international markets. Overall adoption of this process may have a positive impact on the employability of the local population and thereby promote their socio-economic upliftment.

MATERIALS METHOD

Sample collection:

Nonsmoked Bandel cheese was collected from the Newmarket in Kolkata. All the necessary items of the solar dryer like wood box, solar tray, solar collector, and glass cover were carefully designed and assembled by a trained mechanic.

Solar drier *Design Calculations:*

The angle of Tilt (β) of Solar Collector/Air Heater: It was calculated using: β=100+latφ, where latφ is the latitude of the collector location, and the latitude of Kolkata is 23 0N. Hence, β = 100 + 230 ≈350

Insulation on the Collector Surface Area was obtained Using:

$I_c = H_T = HR = 4120 \times 1.1139 = 4589.27$ Whr/m^2/day, Where average daily radiation on the horizontal surface is; H = 4120 Whr/m^2/day and the average effective ratio of solar energy on a tilted surface to that on the horizontal surface R is 1.1139.

Calculations of determination of Collector Area and Dimension [14], shown in equation n (1).

$$v = 4.48\sqrt{\frac{h(T_1 - T_a)}{(T_a + 273)}} \qquad (1)$$

v = velocity m/s
h = height of collector = 43.11cm = 0.4311 m
l = collector length m = 60.96 cm = 0.6096 m
$\varnothing$ = collector tilt angle = 35^0
T_1 = collector outlet temperature °C = 70^0C

T_a= ambient temperature °C = 30^0C.

The mass flow rate of air M_a was determined by taking the average air speed V_a = 1.263 m/s. The air gap height was taken as 5cm = 0.05m and the width of the collection was assumed to be 60cm = 0.6m. Thus,
Volumetric flow rate of air V'_a= V_a× 0.05 × 0.6, V'_a = 1.263 × 0.05 × 0.6 = 3.768 × 10^{-2} m^3/s
Thus **mass flow rate of air**: Ma = $v_a\rho_a$
The density of air ρ_a is taken as 6.38 kg/m^3, **M_a**= 3.768 × 10-2 × 6.38 =24.04× 10^{-2}kg/s,
Therefore, A**rea of the collector** A_c =4.211 m^2

The length of the solar collector (L) was taken as
L = A_c/B = 4.211/0.6 = 7 m, the length of the drier is taken as 8.77 m.
Hot air was passed from the solar collector to the bottom of the dryer. This hot air is diverted by placing a barrier at the bottom of the dryer to get proper heat distribution.

Preparation of ready to eat cheese:
Bandel cheese was cut into small pieces and immersed in water for 8 hours for desalination. After every 4hours interval, water was removed and refilled with fresh water to improve the desalination process. After desalination, it was macerated and kneaded into a smooth paste. The resultant slurry paste was then placed in a perforated cheese cutter and manually pressed. The cheese strands obtained thereafter were placed in the indigenously designed solar dryer.

Solar drying kinetics:
Cheese strands were spread on the racks of solar driers (Locally Made). Solar energy was set at 70^0C temperature. The drying was continued for 5 hours. At every 15, 30, 45, 60, 90, 120, 150, 180, 240, 300 minutes interval moisture loss was measured. Moisture ratio (MR) was calculated by following equation (2) mentioned below.

$$MR = \frac{M_t - M_e}{M_0 - M_e} \qquad (2)$$

Where, MR= Moisture Ratio, M_t = moisture content at any time, M_0 = Initial moisture constant, and M_e= Equilibrium moisture content.
The initial moisture content of the cheese slurry was found to be 70%. The experiment was conducted at 70^0C until the equilibrium moisture was achieved. Taking natural logarithm on both sides establishes a straight-line relationship between the logarithm of moisture ratio (lnMR) and time (t) was plotted in an equation (3), [6].

$$\ln MR = \ln\frac{8}{\pi^2} - \frac{\pi^2 2D_e t}{4L^2} \qquad (3)$$

The diffusion coefficient is calculated from the slope of lnMR versus time at different temperatures.

According to, **Newton's kinetic model**, [8] Shown in Equation (4)

$$\mathbf{MR = exp\ (-kt)} \quad \mathbf{(4)}$$

Henderson pubis drying kinetic models, [7] Shown in Equation (5)

$$\mathbf{MR = A_0 exp\ (-kt)} \quad \mathbf{(5)}$$

Page drying kinetic models, [12] Shown in Equation (6)

$$\mathbf{MR = exp\ (-kt^n)} \quad \mathbf{(6)}$$

Following Newton and Henderson Pubis model, we got, k = -slope. Following the page model, we got, $k = e^x$. A_0 is the dying coefficient of Henderson pubis, and n is the Page model dying coefficient.

Evaluation of physical properties of the processed cheese:

Water absorption capacity [9] and Bulk density [10] were measured. The pH of the sample was estimated using a pH meter.

Evaluation of proximate composition:

Analysis of samples for protein, moisture, total solid, fat, and ash content was carried out in triplicate using standard AOAC methods [10]. Fats were determined by Soxhlet method [11]. Protein was determined by the Lowry method [11].

Sensory evaluation:

Taste panel evaluation of dried cheese from all the samples were conducted using a panel of 15 judges who were regular cheese eaters using a 9-point hedonic scale, where 1 and 9 represent dislike extremely and like extremely respectively.

RESULTS

The designed solar dryer can be captured about 134kw solar energy per day in Kolkata (West Bengal). Solar-dried cheese has a low bulk density. The pH of products is an important factor that affects their shelf– life. The pH of solar-dried cheese was 5.19±0.17 which indicates the product is not easily spoiled by neutrophilic bacteria. (Table.1)

Table 1 Physical characteristics of ready-to-eat cheese

Property	Dried Cheese
Bulk-density (gm/ml)	0.1±0.006
Water absorption Capacity (gm/ml)	1.5±0.36
P_H	6.09±0.4

Table 2 Model constant with the R^2 value

Model	Temp (^{0}C)	Constant	References
Newton	70	K=-0.007	[8]
Page	70	K=0.12 n=1.22	[12]
Handerson-pubis	70	K=-0.006 a=1.53	[7]

Table.2. shows that the R^2 value is highest for the page model, which indicates the Page model is best fitted for drying modified Bandel cheese

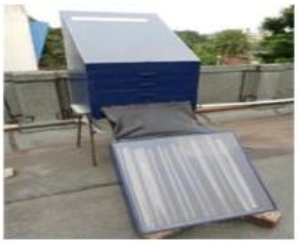

Figure 1 **Figure 2** **Figure 3**

Figure 1. The designed solar dryer, **Figure 2.** Cheese before drying, **Figure 3.** Ready–to-eat cheese after solar dying

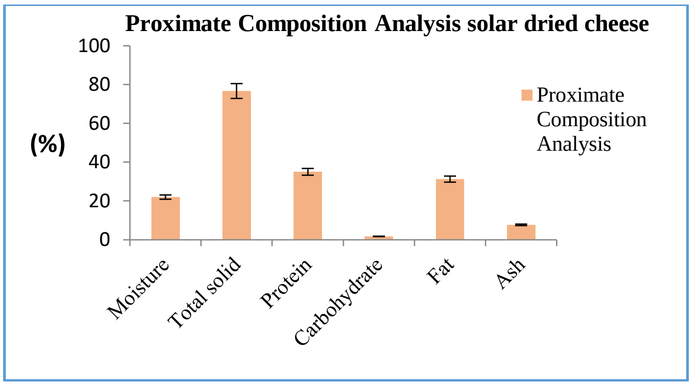

Figure.4. revealed that the moisture content of wet cheese was higher, on drying moisture content comes down to 22% and total solid was 77%. The contents of other components, namely fat 31.2%, protein 35.1%, carbohydrate 1.7%, ash 8.5%

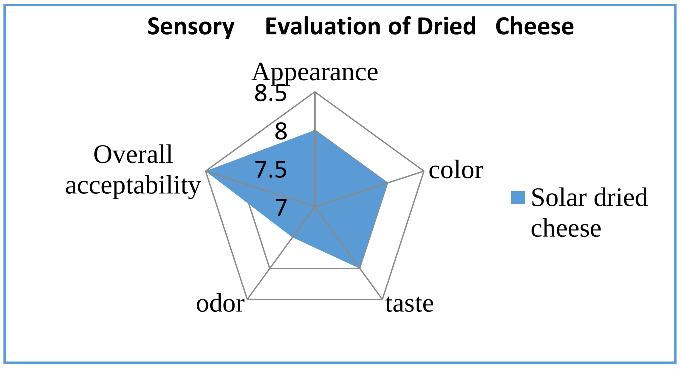

Figure 5. Shows sensory evaluation scores for ready-to-eat cheese or solar-dried cheese in terms of color, taste, odor, and overall acceptability of the dried cheese acceptable by the panellist

DISCUSSION

The designed solar drier is following a working principle of a passive solar drier. In this technique, hot air is circulated naturally or as a result of wind pressure, or in a mixture of both. A solar drier converts the light to heat then trap heat and circulates the warm heat to food. In this solar dryer wooden box and collector trays are black painted from the inside which increases heat absorption. Transparent glass is used to cover the solar drier which helps to capture solar radiation. The temperature inside the solar chamber was maintained at 70^0C. The designed solar drier can reduce moisture up to 20 to 22% which is almost similar to the literature.

The Drying kinetics data indicated that the experimental drying was fitted to Henderson, Newton's, and page's models, and the page model is the best-fitted model for drying the cheese which is confirmed by the high value of R^2 mentioned in Table 2. It is also indicated that the drying constant of the page model increases as time increases compared to other models.
The physical characteristic of dried cheese indicated that the bulk density of dried cheese is low which indicated it is porous in nature mentioned in Table 1. The proximate compositional analysis indicated that dried cheese is rich in high protein and fat mentioned in Figure 4. The presence of fat enhances the aroma of the dried product. The sensory evaluation of dried cheese also indicated that dried cheese is acceptable to the panellist except for the odor or the aroma. Therefore further optimization of the production process is required.

CONCLUSION

The study indicated that the conventional solar system had an important effect on the preservation of cheese. In the solar dryer, trays gained heat, then transferred the heat by conduction to the product, increased their temperature, then lost moisture. Since the installation cost of solar driers was less, therefore this will be beneficial for the small-scale industry. Though solar drying takes several hours to dry but compared to another conventional drying this method was eco-friendly, safe, and produces no greenhouse gases. Apart from this solar dryers prevent the destruction of micro and macronutrients. On the other hand, the composition of dried cheese turned out to be nutritionally significant because it contained a higher percentage of calories, fat, and protein. The presence of high protein and calories increased the health benefit. The study also included that it will be an instant source of energy as it served as a ready-to-eat form. The reduction of moisture improved the shelf life and reduced the storage and transportation cost. As Bandel cheese is available in the Indian market at a low price, therefore the production of dried cheese will also be less expensive. This study was a small initiation towards sustainable technology development for the preparation of ready-to-eat food at an economic cost by applying solar drying technology.

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