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Performance of Hybrid Solar Food Dryer

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ABSTRACT: In this Research paper we will evaluate the performance of food dryers. As we know Solar drying is a promising technique for preserving food and dairy products that utilizes the sun's energy to create a safe and regulated environment for drying. This paper discusses the theory behind solar drying, which involves hot air rising and pulling moisture from food slices, and how this process is repeated in a cycle to improve the quality and lifetime of the products.

The solar dryer does not require an external electrical supply and is built to maximize the absorption of available heat throughout the day. The position of the glass panel is adjusted based on the geographical position of the country to ensure optimal absorption of the sun's rays. This research paper highlights the benefits of solar drying as a healthy, low-cost, and long-term investment for preserving food and dairy products.

Keywords: Food Preservation,Solar drying,Quality improvement,Moisture content, Self-reliability,Energy efficiency

I. INTRODUCTION

The increasing demand for food has resulted in the need for efficient and sustainable food preservation methods. Solar drying, which uses the sun's energy to dry food, has been gaining attention as a cost-effective and eco-friendly alternative to traditional drying methods.

However, solar drying alone may not always provide consistent and optimal results due to factors such as weather conditions and varying solar radiation. This has led to the development of hybrid solar food dryers that combine solar energy with other energy sources to enhance the drying process.

Hybrid solar food dryers are designed to provide a controlled drying environment that is independent of external factors such as weather conditions. These dryers use a combination of solar energy and other energy sources such as electricity, biomass, or fossil fuels to provide a constant supply of heat for drying food. The use of these energy sources ensures that the drying process can continue even during periods of low solar radiation or at night, leading to more consistent and reliable drying results.

The design and operation of hybrid solar food dryers vary depending on the type of food being dried and the energy sources used. Indirect type solar dryers, for example, use a heat exchanger to transfer heat from the solar collector to the drying chamber, while direct type solar dryers use the sun's energy directly to heat the drying chamber. Hybrid solar dryers can also use phase change materials, which absorb and release heat during the drying process to maintain a consistent temperature and reduce energy consumption.

Recent research has focused on optimizing the design and performance of hybrid solar food dryers. Mathematical modeling and simulation techniques have been used to analyze the performance of these dryers and optimize their design parameters such as air flow rate, temperature, and humidity. The use of energy storage systems such as batteries or thermal energy storage can also enhance the efficiency and reliability of hybrid solar food dryers.

Several studies have shown that hybrid solar food dryers are effective in preserving the quality of various food products such as fruits, vegetables, and meat. In addition to their cost-effectiveness and sustainability, these dryers can also provide economic opportunities for small-scale farmers and entrepreneurs by enabling them to process and preserve their produce for longer periods.

In general terms, the development of hybrid solar food dryers has provided a promising solution to the challenges associated with traditional food drying methods. With continued research and development, these dryers have the potential to transform the food preservation industry, providing sustainable and reliable solutions for food security and economic growth.

II. METHODS AND MATERIALS

The detail design phase provides controlled documentation for the product, consisting of drawings and templates, created using Solidworks software.

Design Calculation of Parts

- ➔ The design of the hybrid dryer was carried out along the following lines:
- ➔ Based on the quantity and density of chilies , the recommended bed thickness empirical area of the collector was calculated.
- ➔ Solar radiation available for various inclinations of the glazed surface were calculated based on equations. The angle of inclination for which least fluctuations were present was selected.
- ➔ The total heat required to remove the moisture content and to dry the chilly is calculated based on the available solar energy.
- ➔ Design of combustion chamber. The quantity of heat required and the rate of heating was calculated based on the calorific value of the heating element used.

Solar Calculations for chilly

01. Area

Quantity of chilly to be dried in one batch, m = 1 kg

Wet density of chilly, ρ = 720 kg/m3 (taken from anval‟s bulk density chart)

Volume of chilly, v = m/ρ = 1/720 =1.3889 x 10-3 m 3

Assumed bed thickness for chilly, t = 10mm = 0.01 m

Area required for 1kg of chilly of bed thickness of 0.01m

A = v/t =1.3889 x 10-3 /0.01 = 0.13889 m 2

Adding 25% of clearance, the tray walls and walls of the dryer we get the area as

0.13889 x 1.25 = 0.1736 m2

For ease of operations a rectangular dryer is preferred. Assuming a length of 0.6m and the width as 0.3m we get an area of 0.18m 2 , as seen from the top, which is satisfactory.

Length of dryer = 0.6 m

Width of dryer = 0.3 m

In case if the square shaped dryer is preferred,then,

Length of dryer = 0.42 m

Width of dryer = 0.42 m

Quantity of chilly	Volume	Area for t =10 mm	Area x25% clearance	Shape of Dryer			
				Rectangular		Square	
				Length	Width	Length	Width
1	1.3889 x10^{-3}	0.18	0.1736	0.6	0.3	0.42	0.42
2	2.778 x 10^{-3}	0.2778	0.3472	0.7	0.5	0.59	0.59
3	4.167 x 10^{-3}	0.4167	0.5208	1.0	0.52	0.73	0.73
4	5.556 x 10^{-3}	0.5556	0.6944	1.2	0.7	0.84	0.84
5	6.944 x 10^{-3}	0.6944	0.8681	1.35	0.7	0.94	0.94
10	0.01389	1.389	1.736	1.74	1.0	1.32	1.32

Final Dimension Fixed = 0.6m x 0.3

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The table above shows the calculated values of volume, area and shape of the dryer based on the quantity of chilly to be dried.

02. Inclination

The inclination of the glazed surface has to be selected so that maximum solar radiation is incident on it. Recommended inclination is below 250 . It is known that by giving an inclination equal to the latitude of the location, the effect of variation in zenith angle can be minimized.

By increasing the inclination the area of the glazed surface is increased and hence radiation collected can be increased.

Latitude at Ghansoli = Φ = 19.120N (standard value)

The monthly average daily irradiation for each inclination for each month was calculated for cloudless skies using the below relationship.

Global radiation on a horizontal surface at Ghansoli for 20th April 2023

On April 20 n=110nd day of the year.

"All the formulas in this section are taken from the journal, Solar calculations, K.E. Holbert."

Declination,

δ = 23.45sin[360/365 (284 + n)] (1)

δ = 8.250

Latitude of Ghansoli , Ψ = 12.280

Total angle between sunrise and sunset

$\omega s = \cos{-1}\ (-\tan\Phi\tan\delta)$

$\omega s = \cos{-1}\ (-\tan 12.280\ \tan\ 8.250\ )$

$\omega s = \cos{-1}\ (-0.03108)$

ωs = 88.210 (2)

The average daily extra terrestrial radiation,

$$H^{-} o = 24x3600/\pi * ISC(1 + 0.033COS\ 360n/365\ ) * [cos\Psi cos\delta sin\omega s + (2\pi\omega s\ /360\ )sin\Psi sin\delta]$$

Isc = solar constant = 429.5Btu/hrf t2 (1353 W/m2)

H¯ o = 501965956 x 0.9651 x 0.060 (3)

H¯ o = 11.08 x 106J/m2 = 29MJ/m2

Maximum number of light hours,

N = 2 15 cos−1 (−tanΨtanδ)

N =2/15 cos−1 (−tan19.12.tan 8.25)

N = 12.38 Hours

n¯ = 5 Hours(Bright Sunlight Hours)

a = −0.110 + 0.235cosΦ+0.323 n/N

a = -0.110+0.235cos12.8+0.323*(5/12.38)

a = 0.242

b = 1.449-0.553cosΨ-0.694 n/N

b = 1.449-0.553cos12.28-0.694*(5/12.38)

b = 0.6462

Total Average Irradiation H/Ho = a+b n/N

H/Ho = 0.242+0.6462 (5/12.38)

H/Ho = 0.50899

H = Ho*0.50899

H = 11.080.5029

H = 5.57MJ/m2

H = 5500kJ/m

03. Capacity

The heat available to the dryer is used to dry the chilly. Actually the heat is used for two purposes.

i. To raise the temperature of the chilly.

ii. To remove the moisture.

All the formulas in this section are taken from the paper "Design Development of Indirect Type Solar Dryer with Energy Storing Material",C.V.Papade, M.A.Boda

1) <u>To raise the temperature of the chilly</u>

Q1 = W CP∆T

CP for chilly = 3.81 kJ/kg (value taken from Table 1 of Performance evaluation of a PV powered solar dryer Md. SayeedUr Rahman Mahadi Mahadi)

The chilies are raised from ambient temperature to 550C.

Hence Heat Required For 1kg Of chilly

(Ambient Temperature of thedryeristakenfromTable2 of P performance evaluation of a P V powered

Q1 = 1x3.81x103x(55 − 30)

Q1 = 61.25x103J = 61.25kJ

2) <u>To remove the moisture</u>

Q2 = M′xL

W here,

L = latent heat of vaporization = 2.26x106J/kg

M′ = Amount Of Moisture To Be Removed.

M´ = IMC − FMC/(100−FMC) x W

Where, ISC = Initial Moisture Content = 85%

FM C = Final moisture content = 10%

Hence,

M´ = (85 − 10)/(100 − 10)x1

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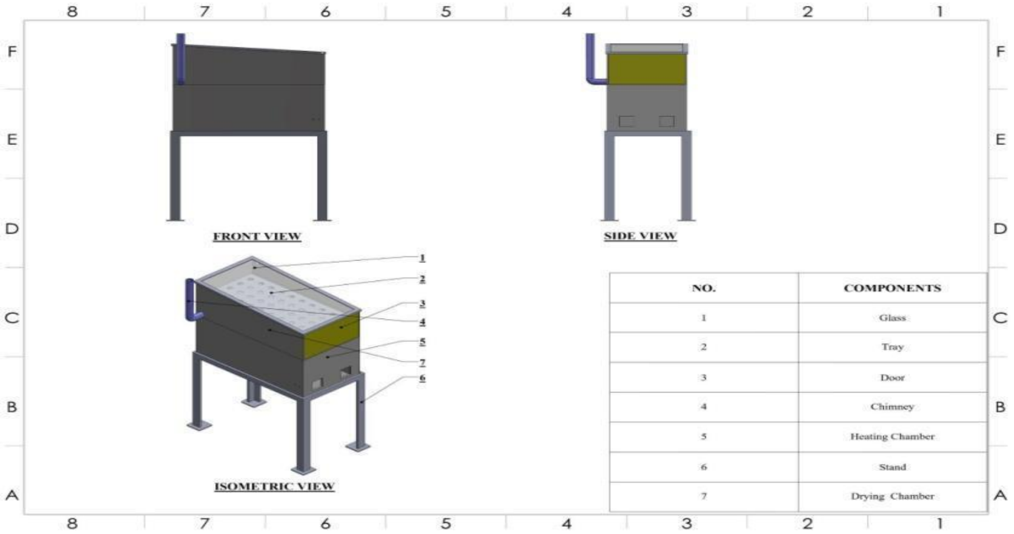
M′ = 0.833kg
Q2 = 0.833x2.26 x 10^6J

Q2 = 1882.58kJ

Weight W in kg	Heat required to raise the temperature,Q1in kJ	Heat required to remove moisture,Q2 in kJ	Total heat required to dry chilly =Q1+ Q2 in kJ
1	61.25	1882.58	1943.83
2	122.5	3766.52	3889.02
3	183.7	5649.77	5833.52
4	245	7533.03	7778.03
5	306.2	9416.29	9722.54
10	612.5	18832.58	19445.08

Availableenergy = HxA = 15000x0.1842 = 2700kJ/day
RequiredEnergy = 1943.83kJ/kg
As the dryer avoids heat losses,(leakproof),
Assuming efficiency of solar dryer, ηdryer = 70%,
Actualenergyavailable = ηdryerxAvailableenergy = 0.7x 1013 = 709kJ/day
Number Of days required dry chilly in solar dryer
= Energy required/ActualEnergy = 1943.83/709
= 2.74day/kg = 3 day/kg

Experiment conducted on open sun drying:
Number of days required to dry chilly = 6 days
Total energy required to dry chilly
= Number of days x Available energy
= 6 x 1013 = 6078kJ
Efficiency of Open Sun Drying
= ηsun
= Required Energy/Total Energy x 100
= 1943.83/6078 *100
= 32%



3d model of dryer

III. EXPERIMENTATION

This is the simplest traditional method of drying; it involves simply laying the product on the platform such as mats, roofs or drying floors directly exposed to sun. A major disadvantage of this method is contamination of the products by dust, birds and insects – Some percentage will usually be lost or damaged, nutrients loss occurs, it is labor intensive, and the method totally depends on good weather conditions. Because the energy requirements - sun and wind - are readily available in the ambient environment, little capital is required. This type of drying is frequently the only commercially used and viable method in which to dry agricultural products in developing countries.

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CHILLY

A green chilly sample of 200 gm was taken, washed and spread on a thin sheet open to the sun.The experimentation was carried out for about two days and the temperature & sample weights were recorded after every hour and tabulated. Mass of chilly before drying = 200gm. Mass of chilly after drying = 20gm. Type of weather = Clear

Day1

Time	Mass	Moisture Reduction
9:00	200	0
10:00	181.2	9.4
11:00	175.6	12.2
12:00	163.2	18.4
1:00	151.0	24.5
2:00	145.5	27.2
3:00	132.3	33.8
4:00	120.8	39.6
5:00	111.2	44.4

Day 2

Time	Mass	Moisture Reduction
9:00	111.2	44.4
10:00	100.2	49.9
11:00	91.3	54.3
12:00	82.3	58.8
1:00	70.3	64.8
2:00	63.6	68.2
3:00	51.9	74
4:00	40	80
5:00	35.6	82.2

Day 3

Time	Mass	Moisture Reduction
9:00	35.6	82.2
10:00	30.9	84.5
11:00	20	90

Total no.of hours = 21 hours

Moisture Reduction % = u = (mw-md)/mw Where, mw = Mass of wet sample = 200gm. md = Mass of dry sample = 20gm.

u = [(mw-md)/mw] x 100 = [(200-20)/200] x 100 ,

u = 90%

POTATO

A potato sample of 200 gm was taken, cut into thin slices and spread on a thin sheet open to the sun.The experimentation was carried out for about a day and the temperature & sample weights were recorded after every hour and tabulated.Mass of potato before drying = 200 gm. Mass of potato after drying = 19.5 gm. Type of weather = Clear

Day 1

Time	Mass (gm)	Moisture Reduction (%)
9:00	200	0
10:00	152.4	23.8
11:00	120.8	39.6
12:00	91.8	54.1
1:00	73.5	63.2
2:00	50.9	74.5
3:00	35.6	82.2
4:00	19.5	90.2

Total no.of hours = 8 hours
Moisture Reduction % = u = (mw-md)/mw Where,
mw = Mass of wet sample = 200gm.
md = Mass of dry sample = 19.5 gm.
u = [(mw-md)/mw] x 100
= [(200-20)/200] x 100
u = 90.2%

PORTABLE HYBRID DRYING

Procedure :

At the initial stage of the experiment 200 gm of chilly was placed on the Aluminum tray. The tray is then placed inside the solar dryer chamber. The stainless-steel sheet used as a reflector/mirror for solar radiation is tilted in such a way that the reflected solar radiation falls on the food product kept drying inside the chamber. After this setup the drying chamber door is closed, the inlet air entering the chamber by a vent hole provided inside the chamber is first heated and the temperature of air inside the chamber gradually increases. This in turn is passed through the chilly kept on tray and the drying process is carried out. After every hour the mirror is tilted and the position of the portable dryer is changed with respect to the direction of solar radiation normal to the inclined surface of the solar chamber. Mass of chilly is tabulated.

CHILLY

- Mass of chilly before drying = 200 gm.
- Mass of chilly after drying = 18 gm.
- Type of weather = Clear

Day 1

Time	Mass (gm)	Moisture Reduction (%)
9:00	200	0
10:00	170.4	14.8
11:00	151.2	24.4
12:00	132.8	33.6
1:00	100	50
2:00	81.3	59.3
3:00	50	75
4:00	30.2	84.9
5:00	18	91

Total no.of hours = 9 hours
Moisture Reduction % = u = (mw-md)/mw Where,
mw = Mass of wet sample = 200gm. md = Mass of dry sample = 18 gm.
u = [(mw-md)/mw] x 100
= [(200-20)/200] x 100 ,
u = 91%

POTATO

- Mass of potato before drying = 200 gm.
- Mass of potato after drying = 19.5 gm.
- Type of weather = Clear

Day 1

Time	Mass (gm)	Moisture Reduction (%)
9:00	200	0

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10:00	150.2	24.9
11:00	101.7	49.15
12:00	51.3	74.35
1:00	20	90

Total no.of hours = 5 hours
Moisture Reduction % = u = (mw-md)/mw Where, mw = Mass of wet sample = 200gm. md = Mass of dry sample = 20 gm.
u = [(mw-md)/mw] x 100
= [(200-20)/200] x 100 ,
u = 90%

IV. RESULTS

EVALUATION
In order to test the fabricated prototype, different tests are carried out on the new portable hybrid dryer by the following methods:

- Using Solar Energy.
- Using Heater energy .
- Using both Solar and Heater Energy.

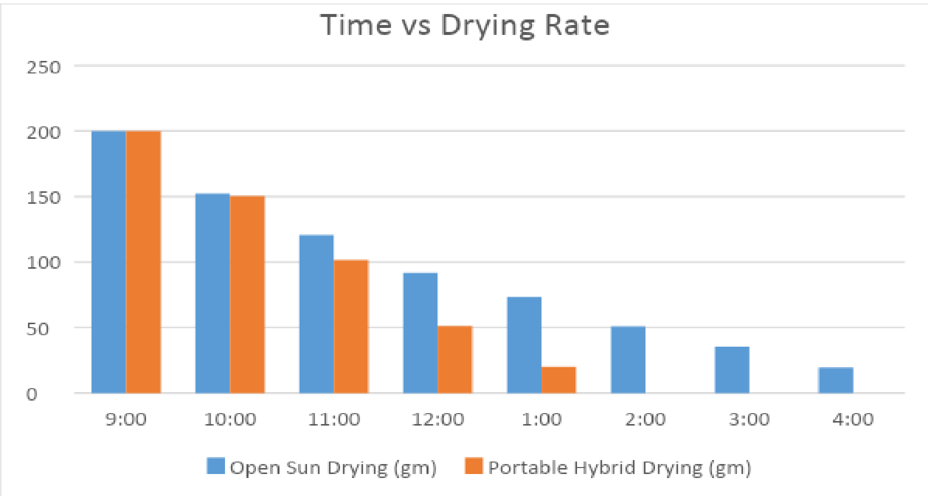
Testing Criteria

- Ease of operation
- Accessibility of components
- Portability
- Comfort in use
- Ease of maintenance

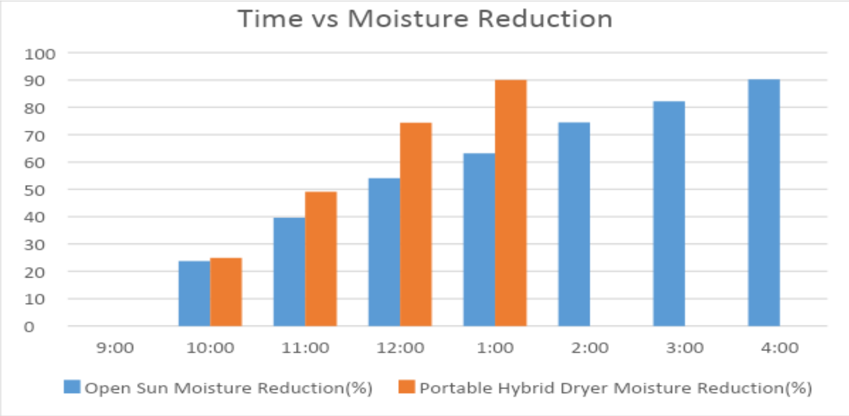
Comparison of drying with open sun drying

Sr.No	System	Time
1	Open sun drying	21
2	Portable hybrid dryer using only heating energy	12
3	Portable hybrid dryer using both solar and biomass energy	06

GRAPHICAL REPRESENTATION
Graphical representation between Drying rate and time for comparing sun drying and hybrid drying
1. POTATO
Time vs Drying Rate

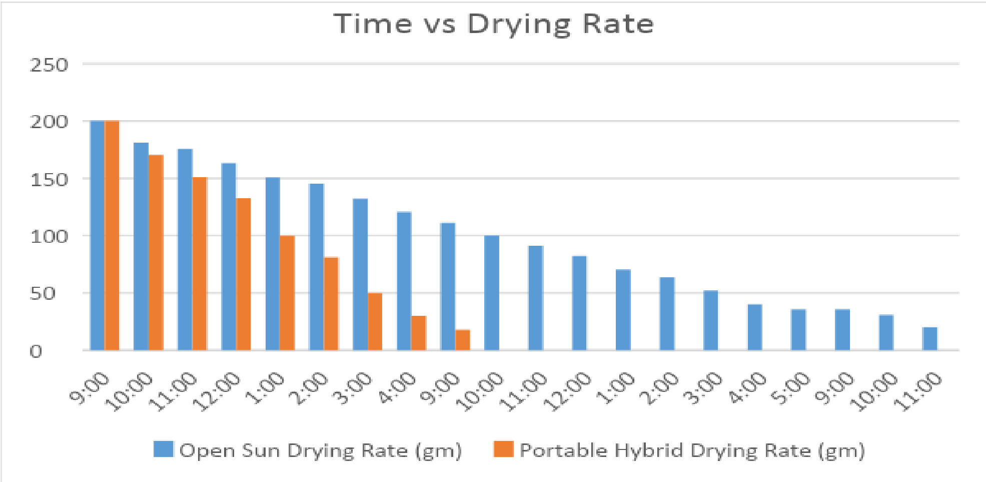


Time vs Moisture Reduction

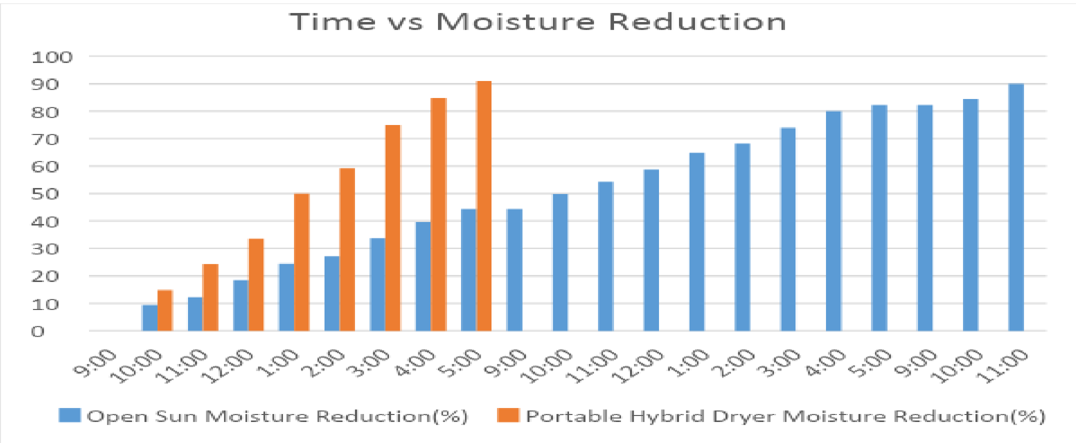


2. CHILLY

Time vs Drying Rate



Time vs Moisture Reduction



V. CONCLUSION

The portable hybrid dryer has several advantages over traditional sun drying and mechanical drying methods. It has the ability to raise air temperature to a high value, resulting in faster drying rates for agricultural crops. It also requires less frequent attention than crops drying in the open sun, and the monitoring process is easier and more efficient. The capital cost involved in the construction of a portable hybrid dryer is lower than that of a mechanical dryer, making it an efficient and cost-effective method for drying agricultural crops.

Some Benefit of of this project

The portable hybrid dryer has significant potential for future development and implementation in the agricultural industry.

One area of future scope is in the improvement of the hybrid dryer's design and technology, such as the integration of smart sensors and controls to optimize the drying process. This can include temperature and humidity sensors, automated airflow controls, and data analysis to optimize the drying process for different types of crops.

Overall, the portable hybrid dryer has promising future scope in terms of improving the efficiency and effectiveness of crop drying processes, and it can have a positive impact on the agricultural industry as a whole.

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