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Design and Experimentation on Mixed Mode Natural Convection Solar Dehydrator for Ocimum Sanctum

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***Abstract* - Tulsi (Ocimum Sanctum) is also known as "the elixir of life" since it promotes longevity. Different parts of plant are used in Ayurveda and Siddha Systems of Medicine for prevention and cure of many illnesses and everyday ailments like common cold, headache, cough, flu, earache, fever, colic pain, sore throat, bronchitis, asthma, hepatic diseases, malaria fever, as an antidote for snake bite and scorpion sting, flatulence, migraine headaches, fatigue, skin diseases, wound, insomnia, arthritis, digestive disorders, night blindness, diarrhea and influenza. We can use Tulsi in Powder form, Oil extract, etc. Drying of such kind of Ayurvedic leaves is essential for their further use. Drying is the technique in which moisture of that product removed under standard condition. Conventionally drying is done in open area but there are so many disadvantages of it viz, infection by dust and durt, the product may be contacted with bird's excreta, dead insects, etc. In order to prevent such product, solar drying is the best technique. In solar drying method we are not only dry the product but also we can reduce the drying time and produce the hygienic product. Solar dryer have shown a very good result in the preservation of the ginger from wastage, poisoning and other contaminants. The solar dryer is solely depending on the renewable energy of the sun. It does not use any fossil fuel for burning.**
Keywords: **Ocimum sanctum, Ayurveda, Solar Drying**

I. INTRODUCTION

Tulsi is cultivated for religious and supposed traditional medicine purposes, and for its essential oil. It is widely used as a herbal tea, commonly used in Ayurveda, and has a place within the Vaishnava tradition of Hinduism, in which devotees perform worship involving holy basil plants or leaves. Tulasi (Sanskrit: Surasa) has been used in Ayurveda for its supposed uses to treat diseases**.** Traditionally, tulasi is taken as herbal tea, dried powder, and fresh leaf or mixed with ghee. Essential oil extracted from tulasi is mostly used for supposed medicinal purposes and herbal cosmetics. Tulsi or Sacred basil (Ocimum sanctum L.) is a biennial shrub belonging to the family Lamiaceae. The plant has been revered by the people of India for its multi various uses since vedic times. Even now, it is worshipped by many. The essential oil of sacred basil has about 71 % eugenol and is comparable to that of clove oil. Eugenol is widely used in perfumery, cosmetics, pharmaceuticals and confectionary industries. The juice of the leaves possesses antiseptic, diaphoretic, anti-periodic, stimulating, expectorant, anti-pyretic and memory improving properties. It is one among the few plants which purifies the atmosphere. Ocimum sanctum is native to India, where it enjoys a religious attachment and liked to be grown in shrines and homes as an aromatic perennial shrub. Tulsi is part of routine worship and has scientific background as the plants possess antimicrobial and antiviral properties and purifies the air. It is also grown as temperate climates; the natural habitat of tulsi varies from sea level to an altitude of 2000 m. It grows naturally in moist soil all over the globe.

Tulsi is an aromatic medicinal plant is often taken in combination with other herbs. The fragrant leaves and flowers, in the form of tincture, tea or decoction are considered to be stomachic and expectorant, used in treating coughs, bronchitis, skin diseases, and diarrhea. These preparations are considered to be prophylactic against epidemics including cholera, influenza and malaria. The tulsi seeds, taken mixed in water, juice or cow's milk, are antioxidant, nourishing, mucilaginous and demulcent.

They are used in treating low energy, ulcers, vomiting and diarrhea or as an overall tonic. The powder of the dried root, taken in milk, ghee or as a decoction, is recommended to treat malarial fever as an analgesic application to the bites and string of insects and also to increase sexual stamina and prevent premature ejaculation. The herb improves resistance to stress and has a normalizing influence on blood pressure and blood sugar imbalances. Tulsi is likely to prove prophylactic against the negative effects of environmental toxins, including cancer. The plant is also richly endowed with bioavailable antioxidants, vitamins A and C and calcium. It has marked insecticidal activity against mosquitoes.

Solar drying has been used since time immemorial to dry plants, seeds, fruits, meat, fish, wood, and other agricultural, forest products. In order to benefit from the free in recent years to develop solar drying mainly for preserving agricultural and forest products. However, for large-scale production the limitations of open-air drying are well known. Among these are high labour costs, large area requirement, and lack of ability to control the drying process, possible degradation due to biochemical or microbiological reactions, insect infestation, and so on. The drying time required for a given commodity can be quite long and result in post-harvest losses (more than 30%). Solar drying of agricultural products in enclosed structures by forced convection is an attractive way of reducing post-harvest losses and low quality of dried products associated with traditional open sun-drying methods [1]. In many rural locations in most developing countries, grid-connected electricity and supplies of other non-renewable sources of energy are unavailable, unreliable or, too expensive. In such conditions, solar dryers appear increasingly to be attractive as commercial propositions [2-3]. During the last decades, several developing countries have started to change their energy policies toward further reduction of petroleum import and to alter their energy use toward the utilization of renewable energies.

A. Benefits of Solar Dryer

1. Product dried in solar dryer is free from dust, bird's excreta, dead insects, etc.
2. Lesser area required as compared to open sun drying.
3. Faster and efficient drying due to drying at higher temperature and in semi-continuous mode.
4. There is vast scope for setting of units for high quality of product.
5. The optimization of the properties will be relatively importance since its usage in product development has been found out various other product developments may be done.

B. Traditional Uses: Tulsi is also known as "the elixir of life" since it promotes longevity. Different parts of plant are used in Ayurveda and Siddha Systems of Medicine for prevention and cure of many illnesses and everyday ailments like common cold, headache, cough, flu, earache, fever, colic pain, sore throat, bronchitis, asthma, hepatic diseases, malaria fever, as an antidote for snake bite and scorpion sting, flatulence, migraine headaches, fatigue, skin diseases, wound, insomnia, arthritis, digestive disorders, night blindness, diarrhea and influenza. The leaves are good for nerves and to sharpen memory. Chewing of Tulsi leaves also cures ulcers and infections of mouth [2].

C. Phytoconstituents: The leaves of OS contain 0.7% volatile oil comprising about 71% eugenol and 20% methyl eugenol. The oil also contains carvacrol and sesquiterpine hydrocarbon caryophyllene[4]. Fresh leaves and stem of OS extract yielded some phenolic compounds (antioxidants) such as cirsilineol, circimaritin, isothymusin, apigenin and rosameric acid, and appreciable quantities of eugenol [4].

D. Experimental & Clinical Studies: All over the world scientific research is getting momentum to evaluate the pharmacological activities, side effects and medicinal uses of OS against different diseases. On the basis of various experimental and clinical researches, the following pharmacological activities or medicinal properties of OS have been reported.

E. Anticancer Activity: The anticancer activity of OS has been proved and cited by several investigators [5-6]. The alcoholic extract (AlE) of leaves of OS has a modulatory influence on carcinogen metabolizing enzymes such as cytochrome P 450, cytochrome b5, aryl hydrocarbon hydroxylase and glutathione S-transferase (GST), which is important in detoxification of carcinogens and mutagens [7]. The DNA was found to be fragmented on observation in agarose gel electrophoresis [8]. A similar activity was observed for eugenol, a flavonoid present in many plants, including Tulsi [9]. Oral treatment of fresh leaves paste of Tulsi may have the ability to prevent the early events of DMBA induced buccal pouch carcinogenesis [10]. Leaf extract of OS blocks or suppresses the events associated with chemical carcinogenesis by inhibiting metabolic activation of the carcinogen [11]. The anticancer activity of OS was observed in Swiss albino mice bearing Ehrlich ascites carcinoma (EAC) and S 180 tumours [12].

F. Antistress Activity: The immunostimulant capacity of OS may be responsible for the adaptogenic action of plant [13]. The AlE of OS whole plant increased the physical endurance (survival time) of swimming mice, prevented stress induced ulcers and milk induced leucocytosis, respectively in rats and mice, indicating induction of non-specifically increased resistance against a variety of stress induced biological changes by OS in animals [14].

II. LITERATURE REVIEW

A lot of research work has been done by solar scientists on design, development and testing of solar driers for different agricultural/non-agricultural products in different regions of the world. Successful applications of solar driers have been reported for the following food industrial products

1. *Grains:* Wheat, Rice, Maize, etc.
2. *Fruit and Vegetables:* Grape, Fig, Tomato, Banana, Coconut, Chilli, etc.
3. *Herbal/Medicine Crop:* Ocimum Sanctum, Turmeric, Leafy aurvedic vegetables, etc.

Sai Krishna G, Bhavani Ramesh T [15] Tulsi is a popular home remedy for many ailments such as wound, bronchitis, liver diseases, catarrhal fever, otalgia, lumbago, hiccough, ophthalmia, gastric disorders, genitourinary disorders, skin diseases, various forms of poisoning and psychosomatic stress disorders. It has also aromatic, stomachic, carminative, demulcent, diaphoretic, diuretic, expectorant, alexiteric, vermifuge and febrifuge properties. Tulsi is also known as "the elixir of life" since it promotes longevity. Different parts of plant are used in Ayurveda and Siddha Systems of Medicine for prevention and cure of many illnesses and everyday ailments like common cold, headache, cough, flu, earache, fever, colic pain, sore throat, bronchitis, asthma, hepatic diseases, malaria fever, as an antidote for snake bite and scorpion sting, flatulence, migraine headaches, fatigue, skin diseases, wound, insomnia, arthritis, digestive disorders, night blindness, diarrhea and influenza. This review will definitely help for the researchers as well as clinicians dealing with O. sanctum to know its proper usage as this herb is seemed to be highly valuable, possessing many pharmacological/medicinal properties.

Marc Maurice Cohen [16] Modern day scientific research into tulsi demonstrates the many psychological and physiological benefits from consuming tulsi and provides a testament to the wisdom inherent in Hinduism and Ayurveda, which celebrates tulsi as a plant that can be worshipped, ingested, made into tea and used for medicinal and spiritual purposes within daily life. In providing a focus for ethical, sustainable and ecological farming practices that provides a livelihood for thousands of farmers, the cultivation of tulsi goes beyond providing benefits for individuals and households and begins to address broader social, economic and environmental issues.

Bano N, Ahmed A, Tanveer M [17] Several research offers evidence that Tulsi is useful against stress; it enhances stamina and increases efficient use of oxygen by body; strengthens immune system; reduces inflammation; protects from radiation; reduces aging; supports the lungs, liver and heart; it exhibits antibiotic, antiviral and antifungal, antioxidant properties. Different parts of plant have been used in Ayurvedic ancient Medicine to cure an array of ailments including common cold, cough, headache, flu, asthma, fever, colic pain, sore throat, bronchitis, hepatic diseases, malaria fever, as an antidote for snake bite, flatulence headaches, fatigue, skin diseases, wound, insomnia, arthritis, influenza, digestive disorders, night blindness, diarrhea. Tulsi acts as an adaptogen that helps the body and mind to encounter different physical, chemical emotional and infectious stresses, and restore physiological and psychological functions. Such significant and health promising potential, in addition to its highly specific therapeutic actions, paved way for the broad range of Tulsa's traditional medical uses, and also contributes for its mythological importance and religious sanctity.

Govind Pandey and Madhuri S [18] In the present review, an attempt has been made to congregate the botanical, phytochemical, ethnomedicinal, pharmacological and toxicological information on Ocimum sanctum Linn. (OS, Tulsi), a medicinal herb used in the indigenous system of medicine. OS has been adored in almost all ancient ayurvedic texts for its extraordinary medicinal properties. It is pungent and bitter in taste and hot, light and dry in effect. Its seeds are considered to be cold in effect. The roots, leaves and seeds of Tulsi possess several medicinal properties. Ayurvedic texts categorise OS as stimulant, aromatic and antipyretic. While alleviating kapha and vata, it aggravates pitta. It has a wide range of action on the human body mainly as a cough alleviator, a sweat-inducer and a mitigator of indigestion and anorexia. OS has a variety of biological / pharmacological activities such as antibacterial, antiviral, antifungal, antiprotozoal, antimalarial, anthelmentic, antidiarrhoeal, analgesic, antipyretic, antiinflammatory, antiallergic, antihypertensive, cardioprotective, central nervous system (CNS) depressant, memory enhancer, antihypercholesterolaemic, hepatoprotective, antidiabetic, antiasthmatic, antithyroidic, antioxidant, anticancer, chemopreventive, radioprotective, immunomodulatory, antifertility, antiulcer, antiarthritic, adaptogenic / antistress, anticataract, antileucodermal and anticoagulant activities. This review will definitely help for the researchers as well as clinicians dealing with O. sanctum to know its proper usage as this herb is seemed to be highly valuable, possessing many pharmacological / medicinal properties.

N. C. Shahil, Anupama Singh, A. E. Kate [19] Drying of basil leaves study was carried to determine the effect of drying methods (Solar and Vacuum dryers) and drying air temperature on activation energy. The results show that the increase in drying air temperature decreased the drying time in both the drying methods. About 420, 300 and 236 min are required to dry the basil at air temperature of 45, 55 and 65°C, respectively, in tray dryer. Logarithmic thin layer drying equation represented the thin layer drying behavior of basil leaves. Effective moisture diffusivity of basil leaves ranged from 4.54 × 10-10 to 1.08 × 10-9 m^2/s. Effective moisture diffusivity of basil leaves was higher in solar dryer as compared to that of vacuum dryer irrespective.

Avesahemad Sayyadnaimutulla Husainy, Prof. P. R. Kulkarni [20] In this work mixed mode forced convection solar grape dryer with thermal energy storage has been developed and tested experimentally. The grapes with pretreatment have been dried with developed solar dryer. The designed dryer was integrated with a Phase Change Material to extend the use of dryer in the evening/night hours. The effect of air mass flow rate on moisture content, moisture ratio, drying rate, drying time and dryer efficiency has been evaluated for grapes. At the same time effect of thermal energy storage on drying time on grapes also evaluated with and without incorporation of thermal energy storage with variation in mass flow rate of air. The following conclusions have been arrived at, from the experimental investigation carried out in the present work on solar grape dryer.

Subhash Chandra, Pradeep Dwivedi [21] Current scientific review offers substantial evidence that tulsi protects against diseases and reduces stress; enhances stamina and endurance; increases the body's efficient use of oxygen; immune system; reduces inflammation; protects against radiation damage; lessens aging factors; supports the heart, lungs and liver; has antibiotic, antiviral and antifungal properties; enhances the efficacy of many other therapeutic treatments; and provides a rich supply of antioxidants and other nutrients. Overall, tulsi is a premier adaptogen, helping the body and mind to adapt and cope with a wide range of physical, emotional, chemical and infectious stresses, and restore disturbed physiological and psychological functions to a normal healthy state. This general vitality enhances and health promoting properties, in addition to it has many more specific therapeutic actions, likely account for much of the exceptionally broad range of Tulsi's traditional medical uses, and benefiting to the cultivators to enhance their income by commercializing tulsi.

Hina Popat Mulani, Snehal Pradipkumar Bajare [22] Agricultural products like Tomato, coriander, tobacco etc. require drying through consistent application of low heat. Generally farmers are drying such products by direct sun radiation. But by direct drying method the quality and test of product may loss and also these method of drying traditionally requires more time are expensive and requires large areas. Sometimes drying process is obtained by burning wood and fossils in oven and because of this pollution increases. So Solar drying is the convenient method for drying different Agricultural product. In this paper the study of solar dryer and the more attention is given to increase the efficiency of drying process by adjusting the position of beds (that is plate on which the drying of products is done) with the angles 0 to 5 degrees with respect to horizontal. So the purpose of this paper is to minimize the drying period and to get best quality finished product. The analysis of the Ocimum tenuiflorum (Tulasi) is done in Solar Dryer and it is found that by changing the angle of bed is deviated.

Mr. Avesahemad S. N. Husainy, Mr. Manoj P. Undure [23] In this system we have utilized the maximum amount of solar radiation. The maximum temperature obtained by this system is 48°C in the cabinet. As we provided the air vents in the setup, it makes the drying more effective. As air passes through it, it flows out the evaporated moisture content with it. We require 2 days (16 hrs considering sunshine hr) for drying the ginger and also we obtain good quality of dried gingers, where the conventional method takes 6-7 days for the same. With our system 43°C temperature can be obtained easily at any location where the ambient temperature is about 30°C. As our experimental procedure is located in Miraj (India), the maximum temperature available for drying is 48°C. This system is best suited for the farmers with smaller production rates of ginger. This system can be utilized for other product like chilies, tomato and other food stuff with some small modification.

III. DESIGN OF TULSI DRYER

The design of the drying chamber is carried out on basis of quantity of product to be dried, drying area required for the mentioned quantity of product. In accordance with the above conditions the design and calculation procedure was carried as below

A. Design of Drying Chamber

The following points were considered in the design of the natural convection solar dryer system.

TABLE I ASSUMPTIONS

S. No.	Items	Condition and Assumption
1	Location	Yadrav (Ichalkaranji) , India, 16.8165° N, 74.6425° E
2	Crop	Ocimum Sanctum
3	Drying period	JAN to DEC (Maharashtra, India)
4	Loading rate, mp [kg]	12Kg
5	Initial moisture content, M_i [%] w.b	85.45%
6	Final moisture content, M_f [%] w.b	14.55%
7	Ambient air temperature, t_{am} [degree]	31^0C (Jan 2018)
8	Ambient relative humidity, RH_{am} [%]	60.10%
9	Maximum allowable temperature, t_{max}	45^0 C
10	Drying time (sunshine hours) td [hrs]	8hr (considering sunshine hr)
11	Incident solar radiation, I_r (W/m^2)	900-1210 W/m^2
12	Wind speed [km/hr]	5km/hr

Area of tray = Length × Width =1360 cm^2

1. Assume Length=80cm
2. Width= 1360/80 = 17cm
3. Dimensions of the tray= L×W= 80cm× 17cm

Now, the overall dimensions of the chamber are calculated from the number of trays implemented, spacing between the trays in horizontal as well as vertical direction and chimney duct.

1. Width of the drying chamber = Length of the tray =0.8m =80cm

Now, for the length of the drying chamber,

2. Length of chamber = (Number of trays × Width of tray) + (4 ×Horizontal spacing two trays) + (Air duct passage or chimney passage)

(Here, width of tray = Original width of tray + Outer wooden frame width)

3. Length of chamber = (6 × 17) + (4 × 10) + (12) =154cm.

Now, for height consideration of the chamber,

4. Height = (Ground clearance + required height for chamber at 30^0 inclination + Chimney height)
   Height = 75 + (tan (30^0) ×77) + 12
   =75+44.45597+12
   =131.45597≈132cm

Overall dimensions of the drying chamber are:

5. Length×Width× Height =154cm ×80cm ×132cm

B. Capacity of Solar Dryer: 12kg

Considering amount of moisture content: 85.45% for wet tulsi 14.55 % for dried Ocimum Sanctum.

Amount of moisture to be removed from given quantity of Ocimum Sanctum to be dried

Amount of moisture (m_w) $= \frac{mp\,(mi - mf)}{(100 - mf)}$

Here, M_p = mass of product

M_i= Initial moisture

M_f= Final moisture

M_p=12kg

M_i=85.45%

M_f=14.55%

$M_w = \frac{mp\,(mi - mf)}{(100 - mf)}$

=12 × (85.45-14.55)/100-14.55

M_w=9.95 kg

Hence 9.95 kg moisture to be removed from 12 kg Tulsi

Amount of heat required to evaporate water = Q = m_w× h_{fg}

h_{fg}=latent heat of evaporation in kJ/kg of water

$h_{fg\ w}$ = 4186 × (597-0.56 ×T_p) = 2.47MJ/kg

T_p-initial temperature of the product (12^0C)

Amount of heat required to evaporate water = Q = m_w× h_{fg}

= 23.7945MJ

Assume 10 % loss of heat in drying chamber

Amount of heat required to be supply = 24.5765 MJ× 1.1

= 26.03 ≈27MJ

Amount of heat required to be supply = 27MJ

Total energy to be supplied for drying of Tulsi = 27MJ.

Final relative humidity/equilibrium relative humidity, ERH (%) was calculated.

a_w = 1-exp(-exp (0.914+0.5639InM)

Where,

M =M_f/100-M_f

=14.55/100-14.55

= 0.1702 kg

a_w = 1-exp(-exp (0.914+0.5639InM)

= 1-exp (-exp (0.914+0.5639In0.1702)

= 0.6010

ERH= a_w×100

= 0.6010×100

= 60.10%

IV. EXPERIMENTAL PROCEDURE

Only good quality of tulsi is used in this experiment. A batch of 3 kg of fresh tulsi was taken from the farm with water washing treatment. This includes the only the removal of mud particles from the crop. After this the initial moisture content and nutritional values of tulsi were determined in a laboratory testing. The information was used for various purposes. Then the experimental procedure was started. Firstly the trays of dryer cabinet were loaded with tulsi and then the setup is closed. This setup is then kept in the sunshine area. As the setup is having the air vents, the air passes through it and also the sun radiations incidents on it. The incident sun radiation evaporates the moisture content and the flowing air drives it out from the cabinet. The temperatures at various sections of dryer were taken from digital thermometer at regular interval of time. At the same time the sun radiations were measured with digital pyranometer. This procedure was carried until we obtained the good quality of dried tulsi. The dried tulsi were again tested in laboratory.

Fig. 1 Experimental Set Up

TABLE II READING

Time	T_{outlet}	T_{tray}	Weight (gm)	Solar Intensity (W/m^2)	T_{glass}	T_{amb}
10am	31	30	500	990	39	37
11am	34	32	310	1182	35	43
12pm	33	28	200	1236	31	43
1pm	32	24	120	1320	41	45

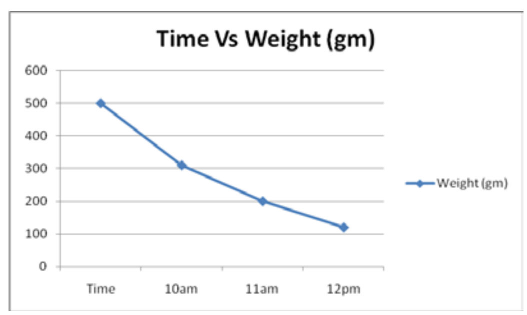


Fig. 2 Drying Time Vs. Moisture Content

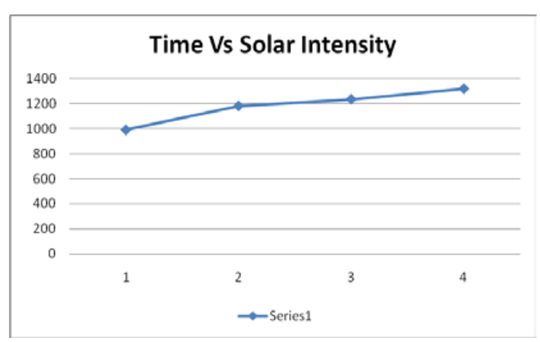


Fig. 3 Drying Time Vs. Moisture Content

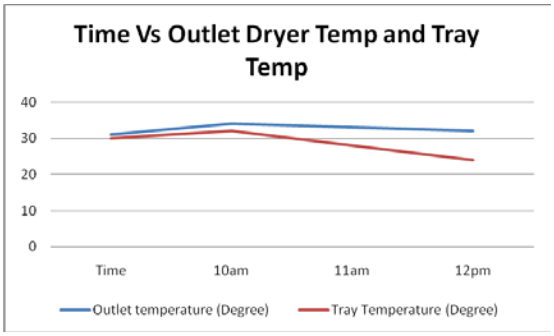


Fig. 4 Drying Time Vs. Moisture Content

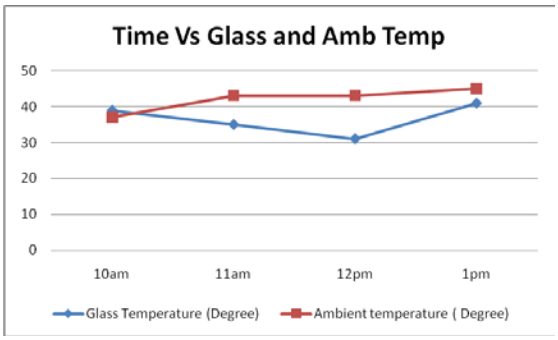
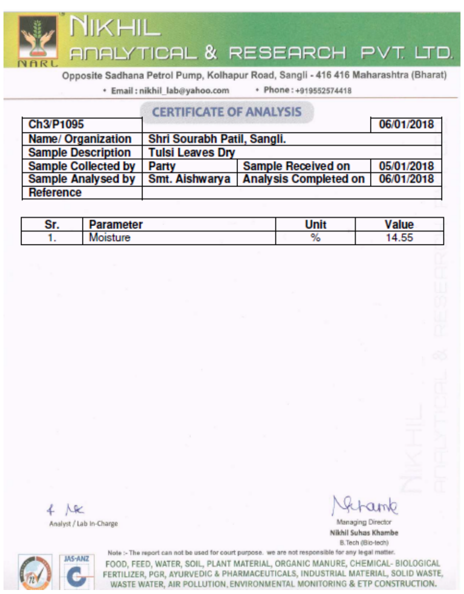


Fig. 5 Drying Time Vs. Moisture Content

Fig. 6 Dried Ocimum Sanctum



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CERTIFICATE OF ANALYSIS

Ch3/P1095			06/01/2018
Name/ Organization	Shri Sourabh Patil, Sangli.		
Sample Description	Tulsi Leaves Dry		
Sample Collected by	Party	Sample Received on	05/01/2018
Sample Analysed by	Smt. Aishwarya	Analysis Completed on	06/01/2018
Reference			

Sr.	Parameter	Unit	Value
1.	Moisture	%	14.55

Analyst / Lab In-Charge

Managing Director
Nikhil Suhas Khambe
B.Tech (Bio-tech)

Note :- The report can not be used for court purpose. we are not responsible for any legal matter.

JAS-ANZ

FOOD, FEED, WATER, SOIL, PLANT MATERIAL, ORGANIC MANURE, CHEMICAL- BIOLOGICAL FERTILIZER, PGR, AYURVEDIC & PHARMACEUTICALS, INDUSTRIAL MATERIAL, SOLID WASTE, WASTE WATER, AIR POLLUTION, ENVIRONMENTAL MONITORING & ETP CONSTRUCTION.

Fig. 7 Analysis Certificate

VI. CONCLUSION

Solar drying has been used since time immemorial to dry plants, seeds, fruits, meat, fish, wood, and other agricultural, forest products. In order to benefit from the free in recent years to develop solar drying mainly for preserving agricultural and forest products. Solar energy a form of sustainable energy has a great potential for wide variety of applications because it is abundant and accessible, especially for countries located in the tropical region. Solar drying of fruits and vegetables overcomes the drawbacks of traditional open sun drying such as, contamination from dust, insects, birds and animals, lack of control over drying conditions, possibility of chemical, enzymic, and microbial spoilage due to long drying times. It saves energy, time, occupies less area, improves product quality, makes the process more efficient and protects the environment. The solar drier was designed, fabricated and investigated for multi crop product like chili, potato, leafy vegetables, garlic, etc. We are conducting experiment on ocimum santum (tulsi). The tulsi was dried from initial moisture content 85.45% to the final moisture content about 14.55% (wet basis) in the bottom and top trays respectively. It could be concluded that, natural convection solar drier is more suitable for producing high quality dried tulsi for small holders. Although solar dryers involve an initial expense, they produce better looking, better tasting, and more nutritious foods, enhancing both their food value -and their marketability. They also are faster, safer, and more efficient than traditional sun drying techniques. Drying time required for experiment is 12hrs by considering 8 hrs sunshine hr per day. Experimentally it is proved that solar dryer is economically viable and we can dry the product at faster rate.

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