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PERFORMANCE EVOLUTION OF AN IMPROVED SOLAR THERMAL HOT AIR HEATING SYSTEM FOR DRYING GROUND-NUTS

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ABSTRACT

Drying is the most seasoned safeguarding strategy of rural items and it is a vitality serious procedure. High costs and deficiencies of petroleum products have expanded the accentuation on utilizing elective sustainable power source assets. This analytical research is for the structure of an appropriate sunlight based warm sight-seeing heating framework for drying grounds nuts and to build a run of the mill level plate sun powered authority. After attentive investigation and research, a spending amicable and a do it without anyone's help sight-seeing thermal warming system for drying ground nuts was intended to permit anybody that is intrigued to put resources into its development and advantage from its utilization. A progression of examination demonstrates that the sun oriented warm air warming framework can decrease the dampness content inside the groundnuts as the analyses demonstrated that the normal last dampness inside the groundnuts were 10.575% and 8.4%. The drying proficiency for the two examinations were observed to be 39.125% and 30.9% separately.

KEYWORDS

solar drying, agriculture, solar energy, thermal storage.

1. INTRODUCTION

Practically all the sustainable power sources start completely from the sun. Photovoltaic sun-based energy change is the immediate transformation of daylight into power. This should be possible by level plate and concentrator frameworks. A fundamental segment of these frameworks is the sun-oriented cell, in which the photovoltaic impact the age of free electrons utilizing the vitality of light particles happens. These electrons are utilized to produce power. Sunlight based power is vitality from the sun and without its quality all life on earth would end. Sunlight based vitality has been viewed as a genuine wellspring of vitality for a long time due to the immense measures of vitality that are made unreservedly accessible, whenever tackled by present day innovation [1]. "Drying is characterized as a procedure of dampness evacuation because of concurrent warmth and mass exchange.

It is an established strategy for nourishment protection, which gives longer timeframe of realistic usability, lighter load for transportation and little space for capacity" [2]. Sun based energy alludes to electromagnetic radiation created and produced by the sun which are then collected by man-made hardware's to be changed over into usable warm or electrical vitality relying upon the required use. Sun based warm air warming gatherers for drying, effectively collect the sun's radiation in contact with the boards and warming the streaming air before being passed into the drying chamber to dry the items. Drying of farming items utilizing sustainable power source, for example, sun oriented vitality is earth well-disposed and has less natural effect [3]. "Sun drying is a typical cultivating and rural procedure in numerous nations, especially where the outside temperature achieves 30 °C or higher. In numerous parts of South East Asia, flavors and herbs are routinely dried and here in Botswana ground nuts and some vegetables (spinach, rape, viscos etc.) are ordinarily dried [4].

Distinctive sorts of sun based dryers have been structured, created and tried in the diverse districts of the world. The real two classes of the dryers are characteristic convection sun based dryers and constrained convection sunlight based dryers. In the regular convection sun oriented dryers, the wind current is set up by lightness while in constrained convection sun powered dryers the wind stream is given by utilizing fan worked either by power/sunlight based module or non-renewable energy source [5]. Sun oriented warm innovation is an innovation that is quickly picking up acknowledgment as a vitality sparing measure in rural application. It is liked to other elective wellsprings of vitality, for example, wind and shale gas since it is rich, unlimited, and non-contaminating [5]. "Sun oriented air radiators are basic gadgets to warm air by using sun powered energy and it is utilized in numerous applications expecting low to direct temperature underneath 80°C, for example, crop drying and space warming" [6].

2. PROBLEM STATEMENT

With the continuous interest for accessibility of ground nuts in the nation by buyers, road sellers and little scale agriculturists have volunteered benefit this item to people in general as a method for producing additional pay to fund their day by day normal costs. Because of absence of information and subsidizing for development of a reasonable sun powered warming air framework for drying grounds, both little scale ranchers and road sellers have embraced a typical strategy for drying ground nuts in particular the Open Sun drying (OSD) technique. This strategy for drying is picked because of the impact that it is modest (bounty of free energy from the sun), should be possible at any area whether at home or at the ranch. Despite the fact that it might appear to be a decent strategy according to people in general, it accompanies a great deal of impediments that end up prompting a ton of chance expenses and further decrease the measure of pay that could have been created. A portion of the issues looked because of utilizing Open Sun drying technique are:

• Spoilage of items because of rehydration amid sudden stormy days.
• Contamination of ground nuts by pets, irritations and rodents since sun drying is completed in a non-controlled condition.
• Over drying and lacking drying.
• Discoloring of the items shell because of UV radiation introduction prompting an un-engaging appearance.
• Time taken for drying ground nuts utilizing Sun drying is longer.
• Hardening of the items shells because of presentation to the sun at high temperatures.

3. LITERATURE REVIEW

"Energy is imperative for the presence and advancement of mankind and is a key issue in worldwide legislative issues, the economy, military readiness, and tact. To decrease the effect of regular vitality sources on nature, much consideration ought to be paid to the improvement of new vitality and sustainable power source assets. Sun oriented vitality, which is condition well disposed, inexhaustible and can fill in as a feasible vitality source, henceforth, it will surely turn into an imperative piece of things to come vitality structure with the inexorably evaporating of the earthly petroleum product. Sooner rather than later, the substantial scale presentation of sunlight based vitality frameworks, specifically changing over sun powered radiation into warmth, can be looked forward [4]. Harvest drying is the most vitality devouring procedure in all procedures on the homestead. The reason for drying is to expel dampness from the farming produce with the goal that it tends to be prepared securely and put away for expanded timeframes. Harvests are likewise dried before capacity or, amid capacity, by constrained flow of air, to counteract sudden ignition by restraining maturation.

It is assessed that 20% of the world's grain creation is lost after gather in view of wasteful taking care of and poor execution of post-reap innovation. Grains and seeds are ordinarily reaped at a dampness level somewhere in the range of 18% and 40% relying upon the idea of yield. These must be dried to a dimension of 7% to 11% contingent upon application and market need. When an oat crop is gathered, it might need to be put away for an extensive stretch of time before it very well may be promoted or utilized as feed. The timeframe a grain can be securely put away will rely upon the condition it was reaped, and the kind of storeroom being used. Grains put away at low temperature and low dampness substance can be kept away for longer periods previously its quality will crumble. A portion of the grains which are ordinarily put away incorporate maize, rice, beans [3]. "In any case, sun oriented vitality is discontinuous by its inclination; there is no sun around evening time.

The lower vitality thickness and occasional brilliance doing with land reliance are the real difficulties in recognizing reasonable applications utilizing sun based vitality as a warmth source. Untrustworthiness is one of the greatest hindering components for broad sun based vitality usage. Obviously, unwavering quality of sunlight based vitality can be expanded by putting away its bit when it is more than the heap and utilizing the put away vitality at whatever point required. Therefore, investigating high proficiency sun based vitality fixation innovation is fundamental and reasonable [4]. "Sunlight based drying might be ordered into immediate and aberrant sun based dryer. In direct sun based dryers, the air warmer contains the grains and sun powered vitality goes through a straightforward spread and is consumed by the grains.

Basically, the warmth required for drying is given by radiation to the upper layers and consequent conduction into the grain bed. In any case, in aberrant dryers, sun powered vitality is gathered in a different sun based authority (air radiator) and the warmed air at that point goes through the grain bed, while in the blended mode kind of dryer, the warmed air from a different sun based gatherer is gone through a grain bed, and in the meantime, the drying bureau retains sun based vitality specifically through the straightforward dividers or the rooftop" [7]. Sun powered vitality has been utilized all through the world to dry items. Thusly, the work of sunlight based dryer taps on the unreservedly accessible sun vitality while guaranteeing great item quality by means of prudent control of the radiative warmth.

Such is the assorted variety of sun based dryers that are ordinarily utilized on sunlight based dried items, for example, grains, natural products, meat, vegetables and fish. A run of the mill sun powered dryer enhances the customary outside sun framework in such vital courses as: It is quicker. Materials can be dried in a shorter period. Sunlight based dryers upgrade drying times in two different ways. Right off the bat, the translucent, or straightforward, coating over the gathering region traps heat inside the dryer, raising the temperature of the air. Besides, the adaptability of developing the sun based accumulation zone takes into consideration more noteworthy gathering of the sun's energy. It is increasingly proficient. Since materials can be dried all the more rapidly, less will be lost to waste following harvest. "This is particularly valid for items that require quick drying, for example, newly gathered grain with high dampness content [8]. Along these lines, a bigger level of item will be accessible for human utilization. Additionally, less of the reap will be lost to ravaging creatures and creepy crawlies since the items are in securely encased compartments.

It is clean. Since materials are dried in a controlled domain, they are less inclined to be polluted by vermin, and can be put away with less probability of the development of dangerous organisms. It is more advantageous. "Drying materials at ideal temperatures and in a shorter measure of time empowers them to hold a greater amount of their healthy benefit, for example, nutrient C [9]. A reward is that items will look better, which improves their attractiveness and consequently gives better monetary comes back to the agriculturists. It is shabby. Utilizing openly accessible sun powered vitality rather than customary powers to dry items, or utilizing a shoddy beneficial supply of sun based warmth, so lessening regular fuel request can result in noteworthy cost reserve funds.

3.1 Solar Drying Methods

Some common solar drying methods are as follows: **Open sun drying-** Figure 1 below shows the working principle of an open sun drying system by using solar energy. The short wavelength solar energy falls on the uneven product surface. A part of this energy is reflected, and the remaining part is absorbed by the surface. The absorbed radiation is converted into thermal energy and the temperature of the product starts increasing. This will result in long wavelength radiation loss from the surface of the product to the ambient air. In addition to long wavelength radiation loss, there is convective heat loss too due to the blowing wind through moist air over the material surface. Evaporation of moisture takes place in the form of evaporative losses and so the material is dried.

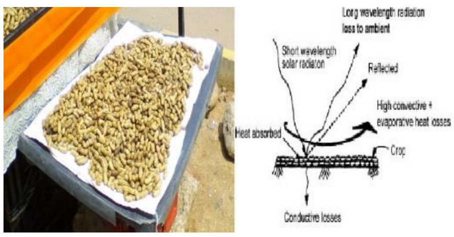

Figure 1: Sun Drying Illustration

In open sun drying, there is a considerable loss due to unexpected rain or storms further worsens the situation. Further, contamination by foreign material like dust, dirt, insects, as well as micro-organism are characteristic for open sun drying. In general, open sun drying does not fulfil the international quality standards and therefore it cannot be sold in the international market.

3.2 Direct Type Solar Drying (DSD)

“Direct solar drying is likewise called characteristic convection bureau dryer. Direct sun powered dryers utilize just the normal development of warmed air. A piece of occurrence sunlight-based radiation on the glass spread is reflected to the environment and the remaining is transmitted inside the lodge dryer. Moreover, a piece of the transmitted radiation is reflected from the outside of the item However, convective and evaporative misfortunes happen inside the chamber from the warmed material [10].

Figure 2 underneath shows precisely how dampness is removed by the air entering the chamber from beneath and getting away through another opening gave at the best. A direct sun oriented dryer is one in which the material is straightforwardly presented to the sun's beams. Sun oriented radiation goes through the straightforward spread and is changed over to second rate heat when it strikes an obscure divider. This poor quality warmth is then caught inside the container by what is known as the nursery impact [11]. Simply stated, the short wavelength solar radiation can penetrate the transparent cover. Once converted to low-grade heat, the energy radiates.

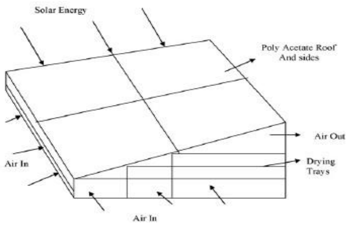

Figure 2: Direct Solar Drying (natural convection type cabinet drier)[4]

3.3 Indirect Type Solar Drying (ISD)

The items are not specifically presented to sun oriented radiation to limit staining and separating on the outside of the ground nuts. The drying load is utilized for keeping the wire work plate were the ground nuts will be put as appeared in figure 3. A descending confronting safeguard is settled beneath the drying chamber at enough separation from the base of the drying chamber [12]. A barrel shaped reflector is put under the safeguard fitted with the glass spread on its gap to limit convective warmth misfortunes from the safeguard. The inclination of the glass cover is taken as 45^0 from horizontal to receive maximum radiation.

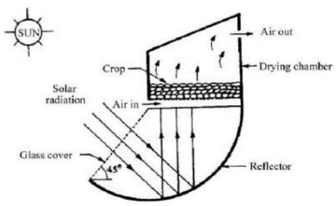

Figure 3: Reverse Absorber Cabinet Drier[9]

4. METHODOLOGY

The primary point of this examination was to move the concentrate far from the for the most part utilized Open Solar Drying strategy by little scale agriculturists as without intuitively knowing, it's removing on the benefits that they could have amplified on. This sort of a sun based warm tourist heating framework works on the guideline of aberrant sunlight based drying were by the produce are not presented to sun powered radiation by any stretch of the imagination, to avert staining brought about by direct sun based radiation [13]. The sun powered gatherer is the main segment in the framework that assimilates the suns irradiance through the straightforward zero covered coating glass. The zero-covering straightforward coating glass goes about as the way path for the suns vitality takes (irradiance) to achieve the dark painted sun based authority (aluminum wire pound).

The coating glass has no coat on it as to help in augmenting sunlight based transmittance subsequently the coating glass has a transmittance of about 90%. The suns vitality pockets consumed by the layers of the wire crush causes the wire squashes to warm up and transmit heat radiation further into the air inside the sun based authority causing an expansion in the show temperature [14]. Surrounding air enters the sun based gatherer through the delta damper were after passage the air is warmed by the produced radiation from the authority expanding the pretense temperature. The warmed air from the sun based authority segment will start to ascend into the drying chamber because of the lightness impact (the impact of warm, soggy air rising supporting ventilation) [15]. The warmed air from the sun oriented gatherer experiences the wet produce on the drying plate and expels dampness while going from the principal plate (base plate) the whole distance to the fifth plate (top plate).

The plate are made punctured to permit simple air development from one plate to the next. The drying chamber is outfitted with a smokestack at the best to go about as the clammy sodden air outlet. This empowers the old stale air to be expelled from the framework while preparing for outside air that is entering from the gulf damper, rehashing the cycle everywhere [16]. Approach incorporates the structure, recreation and last trial and result with impressive all energy misfortunes.

5. RESULT AND DISCUSSIONS

The solar thermal hot air dryer tests/experiments were finished with the dryer set outside in the open space with the sun oriented gatherer straightforwardly confronting the sun for most extreme sunlight based absorbability. The dryer was normally balanced with the development of the sun to keep up the equivalent or close enough irradiance for accumulation. Groundnuts that filled in as tests were drenched for a time of 2 hours in the sink before being taken out for gauging. The four plate of the sun powered sight-seeing dryer were gauged exclusively and after that stacked with groundnuts a short time later. From that point, the wet masses of the plate and their separate groundnuts were gauged (See figure 4 beneath) and recorded before being put in the drying load for tests to start. The little air spaces left by the entryway conclusion were totally fixed with a twofold edged tape. The underlying temperature readings were taken utilizing the information collector preceding stacking the groundnuts into the drier and there after readings were taken at 30 minutes interims for a time of 4 hours. The temperatures were taken utilizing an information collector and thermocouples. See figure 5 beneath demonstrating information collector readings before drying for various plate areas with the primary perusing being for the main plate the whole distance to the last. Testing for the two trials started at 11:30 to 15:30 hours.

Figure 4: Weighing of wet and dry groundnuts.

Figure 5: Readings prior to drying and during the process.

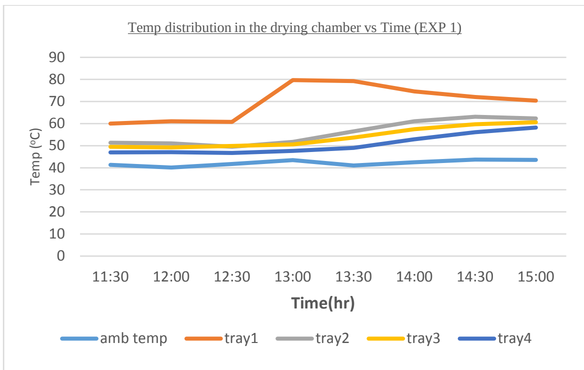

Figure 6: Distribution of temperature across the trays in the drying chamber together with the ambient temperature at the time (experiment 1)

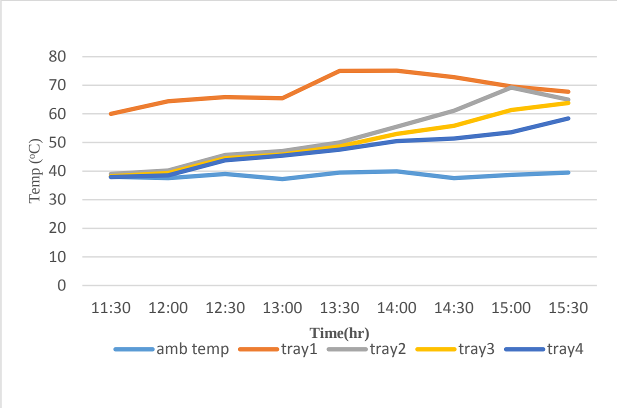

Figure 7: Distribution of temperature across the trays in the drying chamber together with the ambient temperature at the time (experiment 2)

The graphs on figures 7 and 7 show an increase in temperature from the beginning of the drying test until the end as the chamber temperatures converged to almost a single temperature reading. The ambient air temperature and solar radiation also play an important role as temperatures in the drying cabinet are dependent on the increase and decrease in ambient air temperature and solar irradiance. The highest temperatures in the dryer are associated with the highest temperatures of the ambient air and solar radiation and vice-versa. The solar air dryer during the process of drying draws ambient air, raises its temperature to a certain point hence the importance of the latter. The maximum drying chamber temperatures recorded in both tests were 79.2°C for experiment 1 and 75.1°C for experiment 2 and the maximum ambient temperature recorded were 39.5°C for experiment 2 and 43.6°C for experiment 1.

5.1 Moisture content and drying efficienct calculation

Table 1 show the tray numbers and all their corresponding weighed masses. Initially the empty tray masses were weighed and recorded m_T, tray 1 which is the one at the bottom of the drying chamber weighed 418.9g followed by the second tray with 434.3g, third tray with 439.0g and lastly the fourth tray with 264.4g. The cooked groundnuts were then loaded on the trays and wet mass weighed and recorded as ($m_T + m_{WG}$). Lastly the dry masses ($m_T + m_{DG}$) were also weighed to enable the moisture loss calculations. Figures 8 and 9 show the comparison between wet masses and dry masses on a bar graph for experiment 1 and 2 respectively. Upon acquiring the masses, the moisture content on wet basis were calculated and tabulated as shown on Table 2 and Table 4. Then lastly the dryer efficiencies were calculated using information from Table 2 and Table 4 and results are shown on Table 3 and Table 5.

Table 1: Weighed results for groundnuts of 512.1(g)

Trays number	Mass of tray $m_T(g)$	Before drying $m_T + m_{WG}$ (g)	After drying $m_T + m_{DG}$ (g)
1	418.9	600.3	534.6
2	434.3	603.3	547.2
3	439.0	649.1	587.6
4	264.4	439.7	384.9

Where: $\boldsymbol{m_T}$ = *mass of empty tray*

$\boldsymbol{m_{WG}}$= mass of wet ground nuts

$\boldsymbol{m_{DG}}$ = mass of dry ground nuts

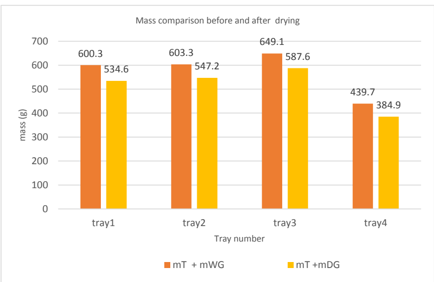

Figure 8: Comparison of masses before ($m_T + m_{WD}$) and after drying ($m_T + m_{DG}$)

Table 2: Calculated moisture content after testing. NB: (recommended percentage is 8%)

Tray number	Moisture content of grounds after drying (%)
1	11
2	9.3
3	9.5
4	12.5
Average	**10.575**

Used equations for the above calculations:

$M_{wb} = \left(\frac{m_i - m_d}{m_i}\right) \text{x } 100$

Where:

M_{wb} = moisture on wet basis

m_i= initial mass of sample ($\boldsymbol{m_T + m_{WG}}$)

m_d= final mass of sample ($\boldsymbol{m_T + m_{DG}}$)

$M_{wb} = \left(\frac{600.3 - 534.6}{600.3}\right) \text{x } 100 = \underline{11\%}$

Table 3: Drying rates and drying efficiency of all four trays

Tray number	Drying rate (kg/hr)	Drying efficiency (%)
1	0.016425	43.2
2	0.014025	36.9
3	0.015375	40.4
4	0.01370	36.0
Average	**0.01488**	**39.125**

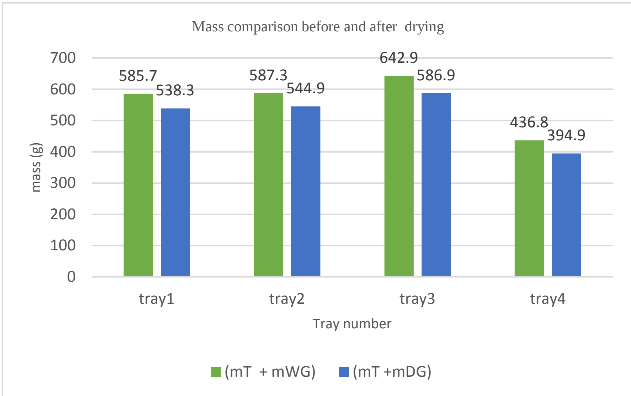

Figure 9: Comparison of masses before ($m_T + m_{WD}$) and after drying ($m_T + m_{DG}$)

Table 4: Calculated moisture content after testing. NB: (recommended percentage is 8%)

Tray Number	Moisture Content of grounds after drying (%)
1	8.1
2	7.2
3	8.7
4	9.6
Average	**8.4**

Table 5: Drying rates and drying efficiency of all four trays

Tray number	Drying rate (kg/hr)	Drying efficiency (%)
1	0.01185	31.2
2	0.01060	27.9
3	0.01400	36.8
4	0.01048	27.5
Average	**0.01173**	**30.9**

Both experiments have given conclusive evidence that when it comes to the drying efficiency, both tray 3 and 2 have higher average dryer efficiencies of 38.6% and 37.2% respectively followed by tray 2 with 32.4% and 4 with an average of 31.75%. These high average efficiencies were caused by moist air taking time around the trays due to lack of enough air circulation. Tray 4 was the lowest in terms of dryer efficiency with an average of 31.75% which looking at the available factors would have been caused by the fact that the tray was closer to chimney hence air escaped more frequently and the temperature difference between the inside of the drying chamber and the environment played a crucial role.

Another element worth looking at is the drying rates of all the four trays. Tray 3 and 1 had higher average drying rates of 0.01468 kg/hr and 0.01414 kg/hr. Tray 1 had the second highest average drying rate due to it being closer to the solar absorber meaning that the warm air coming from absorber dried it first but due to the air speed being slightly high, the air passed quickly onto other trays, thus, not availing the first tray to dry well enough. The third tray average drying rate was the highest mostly due to poor air circulation resulting in warm air taking more time than required to dry the tray. Trays 2 and 4 had lower average drying rates of 0.0123 kg/hr and 0.01209 kg/hr respectively. All these average drying rates played a role on the dryer's efficiency as the higher drying rate is proportional to the dryer's efficiency.

Looking at the tables for moisture content within the groundnuts it can be observed that on both the two experiments, trays 2 and 3 had lower moisture content which were closer to the required 8% for optimal preservation. Tray 2 and 3 had lower moisture contents of 8.25% and 9.1% respectively. Due to limiting the chimney outlet space and the dampers inlet space, warm air within the drying chamber was able to remove more moisture from the middle trays than the first tray with average moisture of 9.55% and the fourth tray with 11.05%. The warm drying air was manipulated intentionally to induce it to remove moisture from the nuts before the air was taken out.

6. CONCLUSION

Such system can build the surrounding air temperature by in excess of twenty degrees is seen in the investigations. The encompassing air went at a normal of forty degrees while temperature of air leaving the sun oriented safeguard came to as high as sixty-eight degrees. The drying framework likewise enhanced the general drying rate of the groundnuts which further thus lead to diminish in drying time. The normal drying rates were 0.01488kg/hr for investigation 1 and 0.01173 kg/hr for analysis 2, while the drying effectiveness for both the two tests were 39.125% and 30.9% individually. The investigations were directed in a time of 4 hours to dry the required measure of the groundnuts which when contrasted with the normal sun drying strategy could have taken longer because of low surrounding temperatures and extremely poor air flow. It very well may be reasoned that the sun based warm air warming framework can lessen the dampness content inside the groundnuts as the examinations demonstrated that the normal last dampness inside the groundnuts were 10.575% and 8.4% for the two tests separately which were nearer to the required 8%.

REFERENCES

[1] Agarwal, A., Vashishtha, V.K., Mishra, S.N. 2012. Solar Tilt Measurement of Array for Building Application and Error Analysis. International Journal of Renewable Energy Research, 2 (4), 782-789.

[2] Abugalia, A. 2019. Effect Of Corona On The Wave Propagation Along Overhead Transmission Lines. Acta Electronica Malaysia, 3(1), 06-09.

[3] El-sebaii, A.A., Shalaby, S.M. 2012. Solar drying of agricultural products: A review. Renewable & Sustainable Energy Reviews, 16 (1), pp. 37–43.

[4] Soy, S.M.A. 2015. Capstone Project Report.

[5] Gupta, J.K., Gupta, S.K. 2019. A Comparative Study of Crowd Counting and Profiling Through Visual and Non -Visual Sensors. Acta Informatica Malaysia, 3(1), 04-06.

[6] Akarslan, F. 2012. Solar-Energy Drying Systems," in Modeling and Optimization of Renewable Energy Systems, First., A. Ş. Şahin, Ed. Rijeka: InTech Open, p. 1.

[7] Agarwal, A., Seretse, O.M., Letsatsi, M.T., Dintwa, E. 2018. Review of Energy Status and Associated Conservational Issues in Botswana. MATEC Web Conference, 06003, pp. 1–8.

[8] Bolaji, B.O., Olalusi, A.P. 2008. Performance Evaluation of a Mixed-Mode Solar Dryer. AU Journal of Technology, 11 (4), pp. 225–231.

[9] Natrayan, L., Aravindaraj, E., Santhosh, M.S., Kumar, M.S. 2019. Analysis and Optimization of Connecting Tie Rod Assembly In Agriculture Application. Acta Mechanica Malaysia, 3(1), 06-10.

[10] Seretse, O.M., Agarwal, A., Letsatsi, M.T., Moloko, O.M., Batlhalefi, M.S. 2018. Design, Modelling and Experimental Investigation of an Economic Domestic STHW System Using T∗Sol® Simulation in Botswana. MATEC Web Conference, 172, pp. 1–9.

[11] Weiss, W. 2011. Contribution of Solar Heating and Cooling to a 100 % Renewable Energy System. Austria.

[12] Taheri, M., Ghasem, O., Farokh, S. 2012. New technologies of solar drying systems for agricultural and new technologies of solar drying systems for agricultural. The 1st Middle-East Drying Conference (MEDC2012), pp. 2–7.

[13] Scanlin, D. 2018. Best-Ever Solar Food Dehydrator Plans. Mother Earth News, Feb-2018. [Online]. Available: https://www.motherearthnews.com/diy/tools/solar-food-dehydrator-plans-zm0z14jjzmar. [Accessed: 09-Feb-2018].

[14] Sathishkumar, S., Kannan, M. 2019. Topology Optimization of Integrated Combustion Engine Piston Using F ea Method (Cae Tools). Acta Mechanica Malaysia, 2(1), 01-05.

[15] Earle, R.L. 2017. "DRYING ch. 7," An introduction to the principles of food process engineering web edition. [Online]. Available: www.nzifst.org.nz/unitoperations/documents/UnitopsCh7.pdf%0A. [Accessed: 20-Jul-2017].

[16] Abbasi, M., Rafique, U., Murtaza, G., Ashraf, M.A. 2018. Synthesis, characterisation and photocatalytic performance of ZnS coupled Ag2S nanoparticles: A remediation model for environmental pollutants. Arabian Journal of Chemistry, 11(6), 827-837.