Asian Journal of Advances in Agricultural Research

4(4): 1-13, 2017; Article no.AJAAR.39157
ISSN: 2456-8864

Energetics of Drying Animal's Hide and Skin via Different Dryer Designs

Joseph Amechi Ujam[1], Christian Emeka Okafor[1*] and Johnpaul Nkemjika Onovoh[1]

[1]*Department of Mechanical Engineering, Nnamdi Azikiwe University, Awka, Nigeria.*

Authors' contributions

This work was carried out in collaboration between all authors. Author JNO designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors JAU and CEO managed the analyses of the study. Authors CEO and JNO managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJAAR/2017/39157
Editor(s):
(1) Rajesh Kumar, Department of Veterinary and Animal Husbandry Extension, College of Veterinary Science & A.H., Junagadh Agricultural University, Junagadh, India.
Reviewers:
(1) Jelili Babatunde Hussein, Modibbo Adama University of Technology, Nigeria.
(2) Alok Kumar Pandey, Roorkee Institute of Technology, India.
(3) Obiekea Kenneth Nnamdi, Ahmadu Bello University, Nigeria.
Complete Peer review History: http://prh.sdiarticle3.com/review-history/22903

Original Research Article

Received 1st November 2017
Accepted 22nd January 2018
Published 29th January 2018

ABSTRACT

Aims of the Study: The aim of this study was to evaluate the total energy requirement, specific energy consumption, activation energy and system efficiency for drying of hide and skin using various drying methods including solar drying, oven drying, hot air conventional drying and direct sun drying.

Materials and Methods: Cattle hide, Donkey hide and Sheepskin with initial moisture content of 64%, 70%, and 60% respectively (all wet basis) was dried to a final moisture content of 5.26% (after 660 min), 6.25% (after 720 min) and 4.76% (after 540 min) in an oven dryer. Energy and specific energy consumption under the different drying conditions of the hides and skins were compared.

Results and Discussion: The activation energy ranged from 20.961 kJ/mol to 27.363 kJ/mol for cattle hide, 23.246 kJ/mol to 26.039 kJ/mol for sheep skin and 26.414 kJ/mol to 31.344 kJ/mol for donkey hide. The maximum total energy consumption and specific energy consumption for the hides and skin studied were 1355.2 kWh and 3880.6 kWh/kg respectively. The overall system drying efficiency was 78%, 81% and 83% for cattle hide, sheep skin and donkey hide respectively.

**Corresponding author: Email: ce.okafor@unizik.edu.ng;*

Conclusion of the Findings: The activation energy of cattle hide was higher than the activation energy of donkey hide followed by sheep skin. The specific energy consumption and total energy consumption increased with increase in the air speed and decreased with increase in temperature. The values obtained in this work are consistent with the values reported by other authors and will form the basis for optimal dryer designs. The system efficiency decreased with drying time and was faster with sheep skin than cattle hide and donkey hide while the thermal efficiency of the dryers is highest in the solar cabinet dryer and least in the oven dryer.
Recommendation: Some other types of dryers should be compared with the solar cabinet dryer to determine the best economical dryer design that will give the best quality product.

Keywords: Solar drying; oven drying; hot air conventional drying; activation energy; total energy consumption; specific energy consumption and system efficiency.

ABBREVIATIONS

CDCH : Conventional Dried Cattle Hide
CDSS : Conventional Dried Sheep Skin
CDDH : Conventional Dried Donkey Hide
SDCH : Solar Dried Cattle Hide
SDSS : Solar Dried Sheep Skin
SDDH : Solar Dried Donkey Hide
ODCH : Oven Dried Cattle Hide
ODSS : Oven Dried Sheep Skin
ODDH : Oven Dried Donkey Hide

1. INTRODUCTION

Hides and skins are co-products of livestock farming, primarily known for providing meat, milk, wool or animal draught power. Hide and skin is the external integuments of animals involving materials derived from birds, fish, amphibians, reptiles, and mammals. Generally, hide refers to larger animals like cattle and camel while skin refers to smaller animals like goat, sheep, and dog. The size, weight, and degree of uniformity of the hides or skins produced in any particular region depend on farming technologies, quality of pasture, range of breeds, transport and marketing systems as well as methods of slaughter, flaying and curing [1]. The recurrent and usual problems encountered with the processing of agricultural produce (hide and skin) have prompted design and agricultural engineers around the world to constantly study energy requirements in product refinement and preservation. This is because many agricultural products have short supply period and must be preserved and stored for future use. Artificial drying is commonly used to remove moisture and thus improve the storability and quality of agro-food materials [2]. The agricultural product conservation through drying is based on the fact that the micro-organisms require moisture or water for their metabolic activities.

Drying is a moisture removal process due to simultaneous heat and mass transfer [3]. It is also a mass and heat transfer process resulting in the removal of water or moisture by evaporation from a solid, semi-solid or liquid [4]. In terms of animal produce preservation, drying is the process of removal of excess moisture from the product in order to reduce the moisture content to the desired limit that hinders the growth, attacks, and activities of micro-organisms. It also decreases the weight and bulk of the product for cheaper transport, storage and packaging [5,6,7]. In the Eastern part of Nigeria, it serves as part of the food and is used as a thickener in some meal preparations. Similarly, most of the meat consumers prefer the hide intact meat. Public awareness along these lines is still lack conformity, and the cash value of hide/skin is ignored in many of the places. The tannery operation involves converting the raw hide or skin, a highly putrescible material, into leather, a stable material, which can be used in the manufacturing of a wide range of products like clothes, shoes, bags, upholstery, haberdashery etc. The major drawback is that the shelf life of hide or skin is not long hence the need for its preservation through drying.

Selection of an efficient drying system is necessary in order to reduce the energy consumption of a dryer during dehydration process and also minimize the quality degradation of dried products [2]. Bahu [8] reported that industrial dryers consume about 12% of the total energy used in manufacturing processes and the drying cost may rise to 60-70% of the total cost. Discussions on the performance, energy consumptions, energy savings and design of various agricultural drying systems are well documented in the literature [9,10]. Prvulović, et al. [11] conducted an experimental research on energetic characteristics of starch dryer, Hany and Gikuru [12] calculated the specific energy consumption of onion slices, Nwakuba, et al. [2] studied the energy consumption of different agricultural dryers, Ohijeagbon, et al. [13] carried out energetic performance of drying agricultural products, Brunetti, et al. [10] evaluated energy consumption of industrial drying plants, Tolmač, et al. [14] experimentally studied the drying kinetic and energetic characteristics of convection pneumatic dryer, Prvulovic, et al. [15] researched extensively on energetic characteristics of convection drying and Mirzaee, et al. [16] determined the activation energy in drying of apricots.

Energy analysis aids in designing of the very efficient thermal system by removing the existing inefficiencies. However, there is a dearth of information on energetic characteristics of animal's hide or skin for specific dryer design to the best of our knowledge. The objectives of this study focus on the activation energy, total energy consumption, specific energy consumption, system and thermal efficiencies of samples and dryers.

2. MATERIALS AND METHODS

The experimental design was used in the study. The study was conducted in the faculty of Engineering workshop, Nnamdi Azikiwe University, Awka, Nigeria. Fresh cattle hides, donkey hides, and sheep skins were used in this study. Donkey hides were obtained from Nkwo market 135 Ezzamgbo in ohaukwu L. G. A Ebonyi State, Nigeria while cattle hides and sheep skins were obtained from Gariki Amansea cattle market, Awka, Anambra State, Nigeria. They were stored in a refrigerator that was maintained at 4℃ and 60% relative humidity for tissue stabilization. The hides and skins were washed after purchase to ward off blood and dirt, needed mass and size was cut out. The hides and skins were approximately 0.45 ± 0.05 cm in thickness. Three measurements were made on each sample for its thickness, using a vernier caliper and the corresponding average values were considered and the ones that did not meet the requirements were removed.

Readings of temperature during the drying process were taken with LCD Multi-Thermometer (Mextech) with a mean deviation of ± 1℃, + 2℉. All the mass measurements were obtained using Lab Tech BL7501 Electronic Compact Scale with a mean deviation of ± 0.1 g and a stopwatch. Measurements involving length were carried out using Raider Digital Caliper with mean deviation +0.1 mm. Relative humidity reading was taken using Hygrometer and Humidity calculator of capacity -10℃ to 120℃, considering dry and wet bulb temperatures. The Oven drying experiment was carried out using Lab-Tech Oven 14 by 14 with Serial Number 03108 and rating 500 Watts. The Natural convection solar cabinet dryer was used which has solar collector plate, glass cover, air blower of maximum speed 6m/s, etc whereas the laboratory hot air conventional dryer with a temperature controller of maximum temperature reading of 0℃ to 500℃ and drying speed between 1.5 m/s to 4.5 m/s. The direct sun drying had the hide or skin hung on a crossbar with metallic peg and the drying took place under the climatic weather condition. Each sample was dried until there was no more change in mass for about 3 hours. Reading of time and mass were properly taken and error due to parallax avoided.

Activation energy and rate of a reaction are related to the following Arrhenius type equation:

$$k = A \exp\left(\frac{-Ea}{RT}\right) \tag{1}$$

Where k = rate constant, A = temperature independent constant (frequency factor), E_a = activation energy, R = universal gas constant, and T = temperature.

Due to the relationship of reaction rate with activation energy and the temperature is exponential, a small change in temperature or activation energy causes a large change in the rate of the reaction during the drying process. Activation energies are also determined experimentally by measuring the reaction rate k at different temperature T, plotting the logarithm of k against 1/T on a graph, and determining the slope of the straight line that best fits the points. In drying mechanism, the effective moisture diffusivity (D_{eff}) is analogous to the rate constant (k). Roberts et al. [17] showed that temperature dependence of the effective moisture diffusivity can be presented by an Arrhenius relationship.

$$D_{eff} = D_o \exp\left(-\frac{E_a}{RT}\right) \tag{2}$$

Putting the equation in linear form by taking the natural logarithm gives

$$\ln D_{eff} = \ln D_o - \frac{E_a}{R}.\frac{1}{T} \quad (3)$$

Where D_o = pre-excremental factor of the Arrhenius equation in m^2/s; E_a = activation energy in kJ/mol; R = universal gas constant (8.314 x 10^{-3} kJ/mol k); T = absolute air temperature (K).

The pre-exponential factor of the Arrhenius equation and the corresponding activation energy were evaluated by using the data of effective moisture diffusivities and absolute air temperature to plot In (D_{eff}) against I/T. Activation energy E_a was determined from the slope of the line in equation 4.

$$E_a = -(\text{slope} \times R) \quad (4)$$

The correlation coefficient was used to determine the validity of the activation energy equation. In this study, the effective moisture diffusivity D_{eff} was evaluated by plotting the experimental data in terms of In(MR) against drying time (t) and then using the slope in equation given as

$$D_{eff} = \frac{-\text{slope}}{\left[\frac{2.4674}{H^2}\right]} \quad (5)$$

Where H = half thickness of sample

The value of MR is mostly expressed as moisture content at a time (M_t) over initial moisture content (M_0) especially for agricultural materials [18,19,20]. Therefore, equilibrium moisture content (M_e) can be considered as zero, hence the MR is simplified as equation 6.

$$MR = \frac{M_t}{M_o} \quad (6)$$

System drying efficiency (η_p) explains how effectively the input energy to the drying system is used for drying processes of a product [21]. Considering solar dryers, the heat supplied to the dryer is the solar radiation incident on the plane of the solar collector. The system drying efficiency is determined using equation 7.

$$\eta_p = \frac{M_e.L}{A_c.I_c.t} \quad (7)$$

In solar drying, the transmittance of the solar collector enhances the efficiency and effectiveness of the solar dryer [21].

$$\eta_p = \frac{M_e.L}{A_c.I_c.t.\tau} \quad (8)$$

Where M_e = moisture content, L = latent heat of vaporization; A_c = drying area, I_c = solar radiation, t = time interval; τ = transmittance of the solar collector.

Furthermore, the thermal efficiency of the dryer is the ratio of temperature input to the temperature utilized in drying [21]. It can be expressed mathematically as in equation 9:

$$E_{eff} = \frac{T_p - T_{out}}{T_p - T_a} \quad (9)$$

Where T_p = plenum air temperature (hot air entering into the drying chamber), ℃; T_{out} = outlet air temperature (air leaving through the chimney), ℃, T_a = Ambient temperature, ℃.

Specific energy consumption is the energy required to eliminate 1kg of water (moisture) from a wet material during heated-air drying [22,23]. The total energy consumption $E_{t,}$ in a system, is expressed by equation 10.

$$E_t = (A.V.\rho_a.C_a.\Delta T).t \quad (10)$$

Where A = area of drying sample, V = drying air speed, ρ_a = air density, C_a = specific heat capacity of air, ΔT = temperature difference and t = time of drying.

However, Specific Energy Consumption (SEC) can be calculated using equation 11.

$$SEC = \frac{E_t}{M} \quad (11)$$

Where M = mass of water removed.

3. RESULTS AND DISCUSSION

3.1 Activation Energy in Relation to Oven Drying Method

Generally, in the drying of agricultural products, the activation energy is a measure of the temperature sensitivity of the effective moisture diffusivity and it is equally the minimum amount of energy required to initiate moisture diffusion within the surface of the product [16]. Therefore, a straight line plot of ln D_{eff} against 1/T in Fig. 1 gave a slope from which the activation energy was determined. The coefficients of determination for the three processes were 0.926, 0.985 and 0.929 indicating good correlation.

The activation energy was calculated as 10.99 kJ/mol, 6.21 kJ/mol and 7.6 kJ/mol for ODCH, ODSS, and ODDH respectively. The difference in the activation energy of the materials was less than 5 KJ/mol. Some activated energy reported by many authors was that of drying of beef and storage, Daniela et al. [24] reported activation energy value of 38.6 kJ/mol mol while Akhtar et al. [25] in the drying of treated chicken meat reported an activation energy between 37.53 KJ/mol to 44.54 KJ/mol while for raw chicken meat samples it was varied from 37.630 KJ/mol to 44.68 KJ/mol, Athinoula et al. [26] reported activation energy values of fish and meat as 27 KJ/mol and 33 KJ/mol respectively. The larger values they had was due to other forms of dryer aside oven dryer were used. The magnitude of the activation energy for agricultural products has been generally reported to be up to 110 kJ/mol [16,27].

3.2 Activation Energy in the Hot-Air Conventional Drying Technique

Changes of the different air speed on the activation energy in the hot-air conventional dryer were obtained by plotting the graph of In D_{eff} against I/T as shown in Figs. 2 to 4.

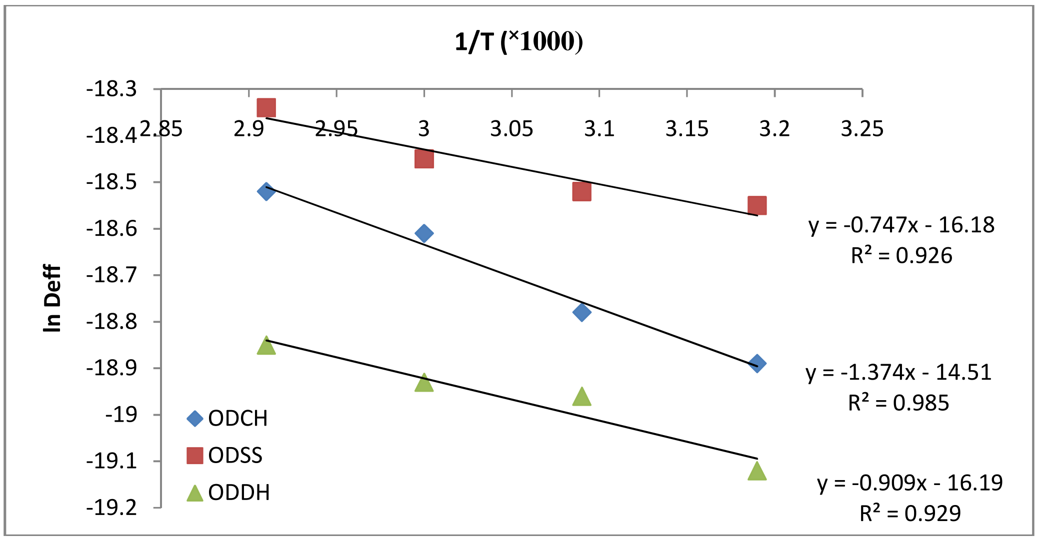

Fig. 1. Plot of In D_{eff} against 1/T for oven dried cattle hide, sheep skin and donkey hide

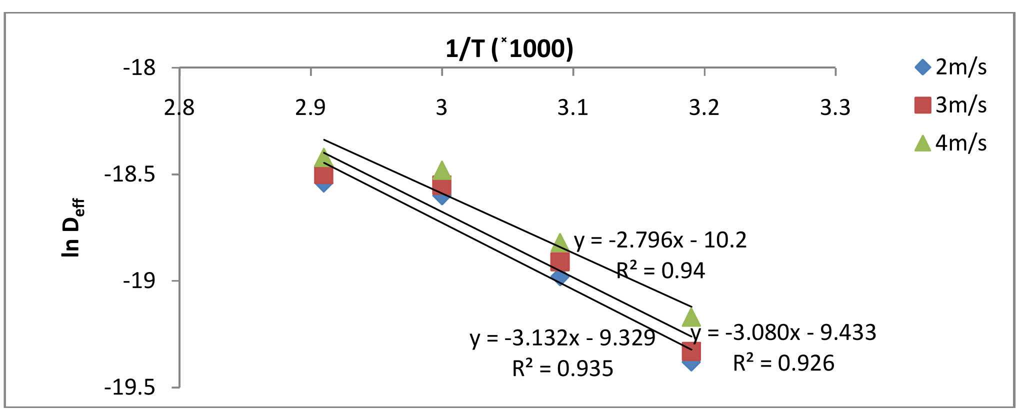

Fig. 2. Plot of In D_{eff} against 1/T at different air speeds for conventional dried cattle hide

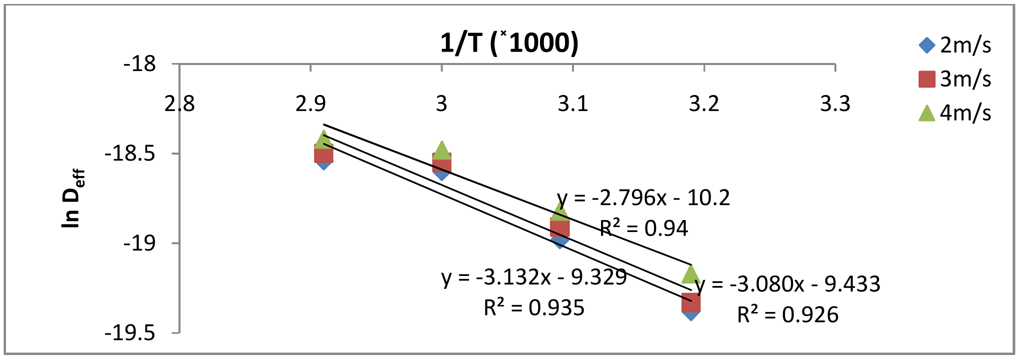

Fig. 3. Plot of ln D_{eff} against 1/T at different air speeds for conventional dried sheep skin

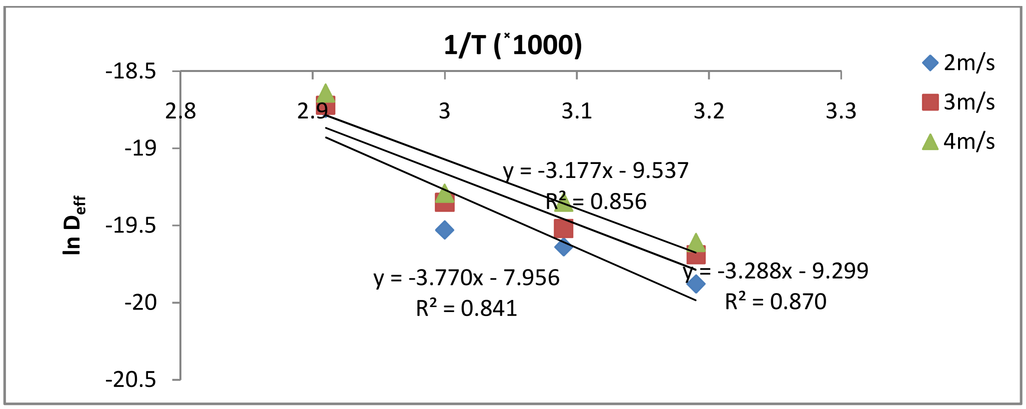

Fig. 4. Plot of ln D_{eff} against 1/T at different air speeds for conventional dried donkey hide

The coefficients of determination of the fitted lines with experimental data as seen from the plots were mostly on the high side indicating a good correlation. The activation energy of CDCH, CDSS and CDDH were calculated and presented in Table 2. It was observed that the magnitude of the activation energy is affected by the drying air speed. The minimum activation energy for CDCH was 20.961 kJ/mol while the maximum was 27.363 kJ/mol. For CDSS, the minimum and maximum activation energy was 23.246 kJ/mol and 26.039 kJ/mol respectively and thus, 26.414 KJ/mol and 31.344 kJ/mol for CDDH. The magnitudes or values of the activation energy were in agreement with the general range of activation energy of 12.7 KJ/mol to 110 KJ/mol reported for most food materials using hot air conventional dryer [28].

The researches on the activation energy revealed that as the air speed increased, the activation energy progressively decreased. Nwajinka et al. [29] and Mirzaee et al. [16] reported similar trends in activation energy in their research on drying of agricultural products. In the thin-layer drying of Russian olive, the activation energy decreased from 63.83 kJ/mol to 48.18 kJ/mol as the drying air speed was increased from 0.5 m/s to 1.5 m/s [30]. The activation energy was higher in CDDH, followed by CDCH and then CDSS. This is probably because donkey hide has more moisture content than cattle hide and sheep skin and its composition reduces the transfer of moisture. A linear regression of the relationship between drying air speed (V) and Activation Energy (E_a) is presented in Table 1.

Table 1. The relationship between drying air speed (V) and activation energy (E_a) in the conventional dryer

Designation	Drying media	Activation Energy (E_a)	R^2
CDCH	Conventional Dried Cattle Hide	E_a = -4.694V + 36.75	0.958
CDSS	Conventional Dried Sheep Skin	E_a = -4.365V + 34.77	0.960
CDDH	Conventional Dried Donkey Hide	E_a = -4.465V + 40.27	0.960

Table 2. Activation energy in hot air conventional dryer

Velocity (m/s)	R^2	Activation Energy (KJ/mol)	$D_0 \times 10^{-5}$ (m^2/s)
Cattle hide			
2.0	0.94	27.363	7.588
3.0	0.926	24.703	8.133
4.0	0.935	20.961	8.379
Sheep skin			
2.0	0.935	26.039	8.881
3.0	0.926	25.607	8.003
4.0	0.924	23.246	3.710
Donkey hide			
2.0	0.886	31.344	9.999
3.0	0.870	27.340	9.152
4.0	0.856	26.414	7.213

3.3 Relationships between Air Speed, Total Energy Consumption and Specific Energy Consumption

The variations of air speed on the total energy consumption and specific energy consumption were valuated using the solar dryer and given in Figs. 5 and 6. The total energy consumption ranged from 724.4 kWh to 1358.2 kWh for the products. This was due to a longer period of time it takes in drying hide or skin, unlike the result reported by Sebastian, et al. [23] in drying and smoking meat. A total energy consumption ranging from 13.89 kWh to 23.94 kWh was gotten while Abbaszadeh et al. [30] in thin layer drying of Russian Olive reported total energy consumption between 16.34 kWh and 75.04 kWh because of the little time involved in drying Russian Olive. The specific energy consumption increased from 2263.8 kWh/kg to 3880.6 kWh/kg as the air speed increased 2.0 m/s to 4.0 m/s. The trend is in agreement with the results reported for thin-layer drying of Jujube [22] and Russian Olive [30]. This is because vapour pressure decreases with increasing air speed, thereby the product moisture faces less resistance to evaporation [22].

3.4 Variation of Temperature with Total Energy Consumption and Specific Energy Consumption

The total energy consumption (TEC) and the specific energy consumption (SEC) were also seen to vary with different drying temperature as shown in Figs. 7 and 8. The total energy consumption of CDCH, CDSS and CDDH were seen to be only slightly different. However, it is seen that energy consumption of the drying process decreases with increasing air temperature.

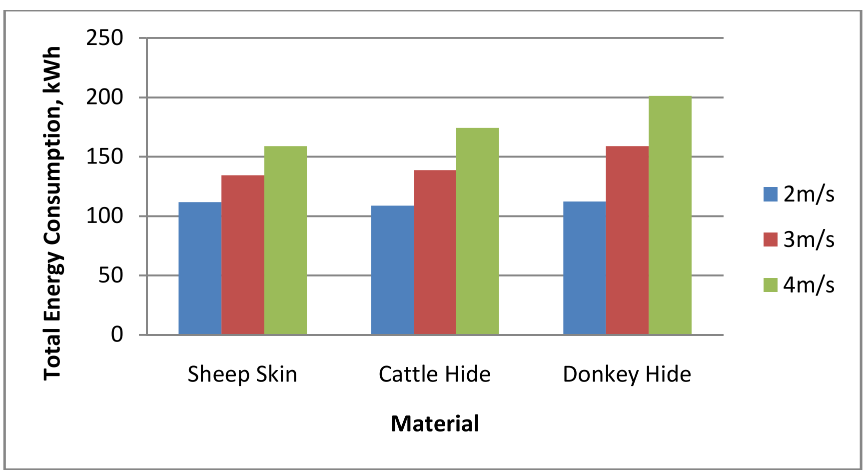

Fig. 5. Effect of air speed on the total energy consumption of solar dried sheep skin, cattle hide and donkey hide

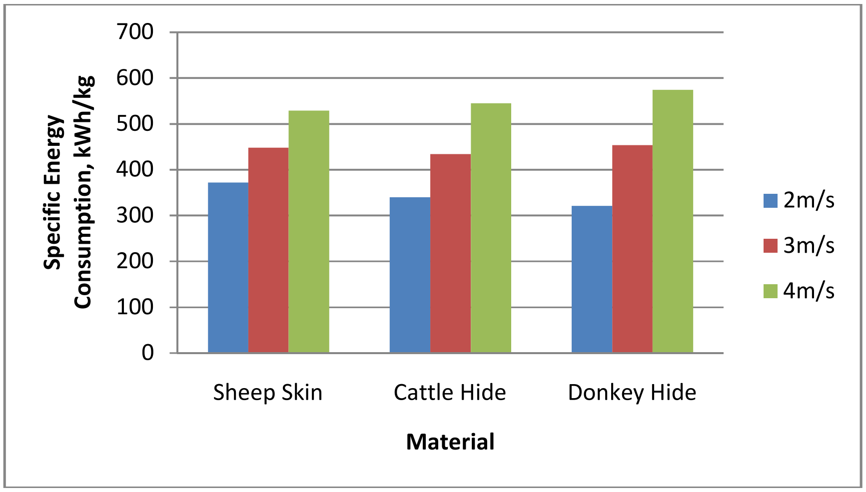

Fig. 6. Effect of air speed on specific energy consumption of solar dried sheep skin, cattle hide and donkey hide

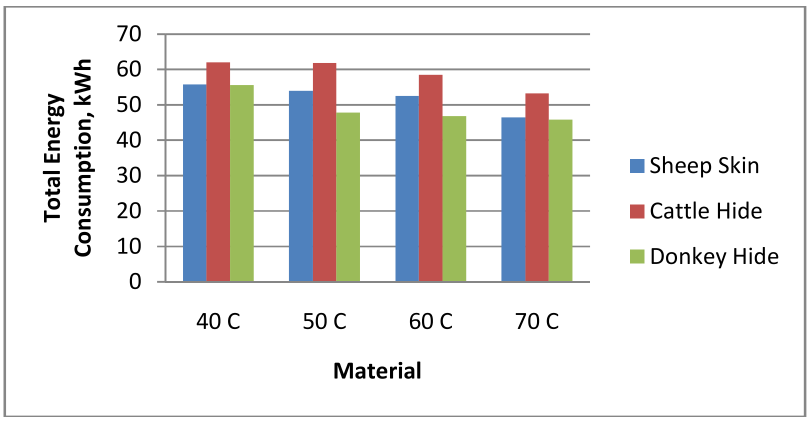

Fig. 7. Effect of temperature on the total energy consumption of conventional dried sheep skin, cattle hide and donkey hide

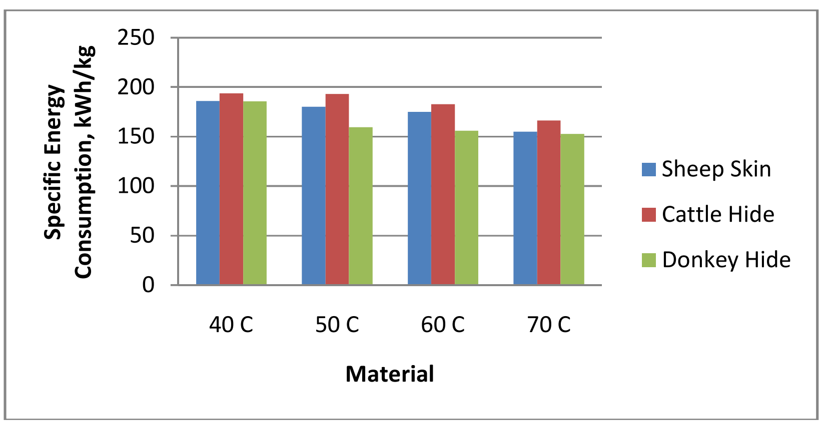

Fig. 8. Effect of temperature on the specific energy consumption of conventional dried sheep skin, cattle hide, and donkey hide

The total energy consumption and specific energy consumption increased from a minimum of 814.9 kWh and 2716.3 kWh/kg to a maximum of 2065.7 kWh and 8902 kWh/kg respectively as the temperature decreased from 70℃ to 40℃. This is because, with increasing temperature, the drying time reduces due to increased thermal gradients inside the material dried [22]. This phenomenon can also be linked to the fact that greater heat transfer and water vapour pressure deficit which occurs during drying is done at a higher temperature. This according to Tinuade, et al. [31] may result to a greater uptake of air and evaporation is achieved in a shorter time thus reducing the amount of energy needed.

3.5 System Drying Efficiency

The effects of the system drying efficiency in different dryers for the samples are given in Figs. 9 to 11. The system drying efficiency reduces with time probably because as the time of drying increases, the moisture content reduced. This observation/outcome is in agreement with the trend reported by Navale, et al. [32] in the study of open sun and solar drying for fenugreek leaves. At first, the donkey hide gave the highest efficiency but as the drying nears its completion, the efficiency dropped. This is due to the fact that the small distance that the moisture has to travel before getting to the surface is quickly removed and as the drying time continues, there was just a little moisture to be removed. For the drying of cattle hide, the average system drying efficiency was 78% for solar drying. Generally, the efficiency obtained in the solar dryer was higher than that obtained in the other dryers and this leads to a reduction in its drying period. This according to Navale, et al. [32] is because there is better energy utilization in the solar dryer.

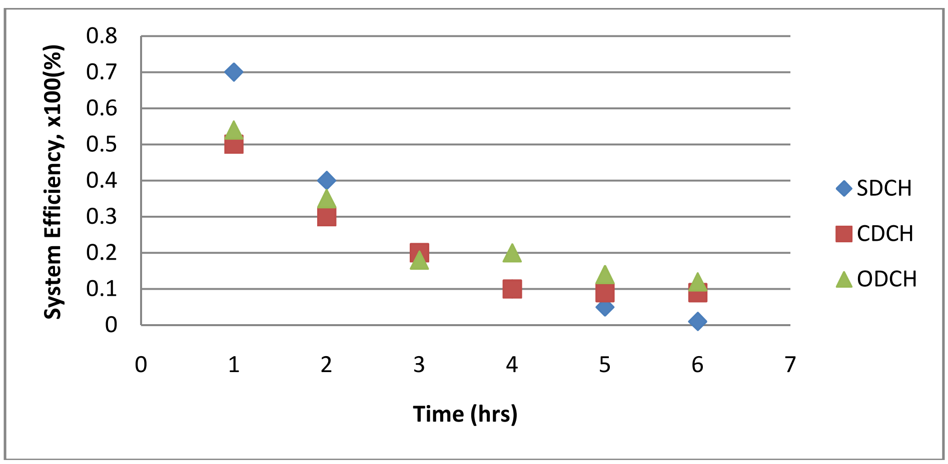

Fig. 9. Effect of dryers on system efficiency for cattle hide

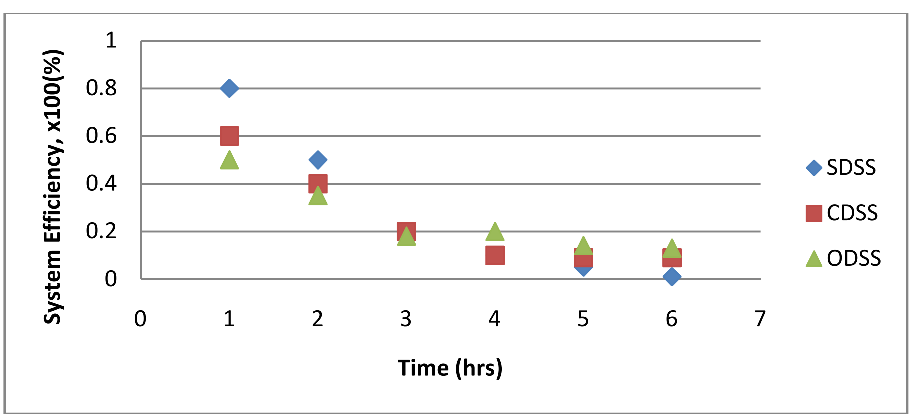

Fig. 10. Effect of dryers on system efficiency for sheep skin

3.6 Thermal Efficiency

The average thermal efficiency in a solar dryer, hot-air conventional dryer and the oven dryer are presented in Figs. 12 to 14.

The thermal efficiency can be defined as the ratio of heat input to the heat utilized in the drying. The result indicates that the thermal efficiency is higher in the solar dryer with a value as high as 90%. This is solely due to the transmittance of the glass which greatly increased the temperature in the solar collector far above the ambient temperature.

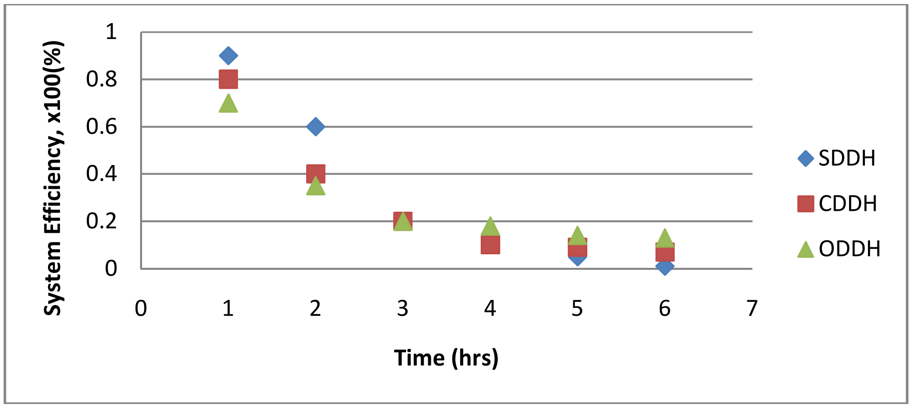

Fig. 11. Effect of dryers on system efficiency for donkey hide

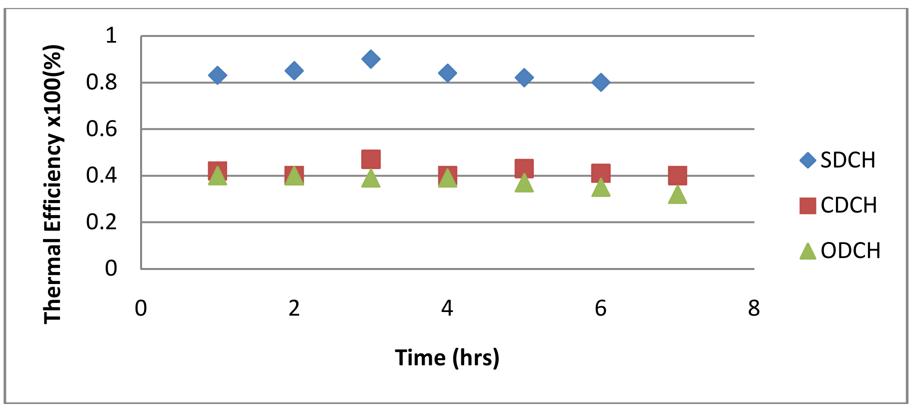

Fig. 12. Average thermal efficiency for the different dryers for cattle hide

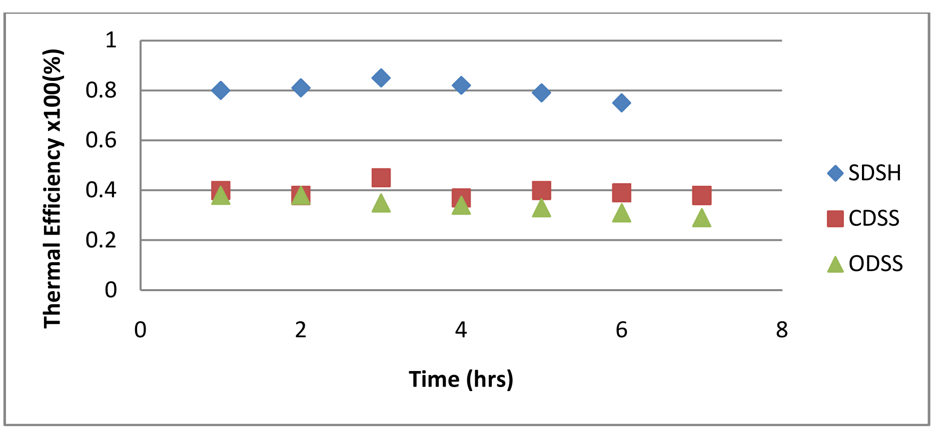

Fig. 13. Average thermal efficiency for the different dryers for sheep skin

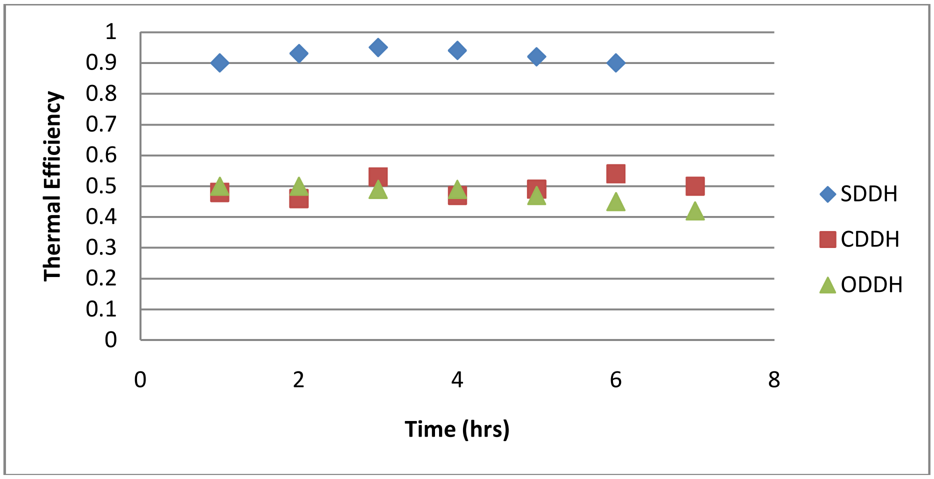

Fig. 14. Average thermal efficiency for the different dryers for donkey hide

4. CONCLUSION AND RECOMMENDATION

This study focused on drying of Animal's hide/skin which includes Cattle hide, Sheep skin and Donkey hide. From the study, it was seen that the activation energy of cattle hide was higher than the activation energy of donkey hide followed by sheep skin. The specific energy consumption and total energy consumption increased with increase in the air speed and decreased with increase in temperature. The values obtained in this work are consistent with the values reported by other authors. The system efficiency decreased with drying time having the sheep skin decreasing faster while the thermal efficiency of the dryers is highest in the solar cabinet dryer and least in the oven dryer.

In the recommendation, some other types of dryers should be compared with the solar cabinet dryer in other to determine the best drying system economically that will also give the best quality to dried products.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Mwinyihija M. Morphological characteristics of hides and skins as affected by various environmental parameters during pre and post slaugther treatment. Paper Presented to the Kenya Revenue Authority Officer's Seminar Held at Pan Africa Hotel on 29th to 31st May; 2006.
2. Nwakuba NR, Asoegwu SN, Nwaigwe KN. Energy consumption of agricultural dryers: An overview. Agricultural Engineering International: CIGR Journal. 2016;18(4): 119-132.
3. Ravinder KS. Open sun and greenhouse drying of agricultural food products: A review. International Journal of Engineering Research and Technology. 2014;3(3):1053-1065.
4. Wankhade PK, Sapkal RS, Sapkal VS. Drying characteristics of okra slices using different drying methods by comparative evaluation. Proceedings of the World Congress on Engineering and Computer Science San Francisco, US., 24-26; 2012.
5. Chenchaiah M, Muthukumarappan K. Processing aids for improving coefficient during onion flakes drying. American J. of Food Tech. 2013;1(1):1-18.
6. Khaled MY, Sayed MM. Effect of drying methods on the antioxidant capacity, colour and phytochemicals of *Portulaca oleraceal* leaves. J. of Nutrition and Food Science. 2014;4(6):1-6.
7. Kaptso KG, Njintang YN, Nguemtechouin, MMG, Scher J, Hounhouinyan J, Mbofuny CM. Drying kinetics of two varieties of Bambara groundnuts (*Vigna subterranca*) seeds. J. of Food Technology. 2013;11(2): 30-37.
8. Bahu RE. Energy consumption in dryer design. In: A. S. Mujumdar, I. Filkova (eds.), Drying '91. Elsevier, Amsterdam, the Netherlands. 1991;553-557.

9. Sheehan ME. Britton PE, Schneider PA. A model for solid transport in flighted rotary dryers based on physical considerations. Chem. Engine. Sci. 2005;60:4171-82.
10. Brunetti Lucio, Ferruccio Giametta, Pasquale Catalano, Francesco Villani, Jonathan Fioralba, Flavio Fucci, Giovanna La Fianza. Energy consumption and analysis of industrial drying plants for fresh pasta process. J. of Agric. Eng. 2015;46(4):167-171.
11. Prvulović S, Tolmač D, Blagojević Z, Tolmač J. Experimental research on energetics characteristics of starch dryer. FME Transactions. 2009;37(1):47-52.
12. Ohijeagbon IO, Ogunforowa LI, Omale JI, Ameh P. Energetic performance analysis of drying agricultural products integrated with solar tracking. Nig. J. of Tech. 2016;35(4):825-830.
13. Tolmač D, Blagojević Z, Toplifikacija JP, Prvulović S, Tolmač J, Radovanović L. Experimental study on drying kinetic and energetic characteristics of convection pneumatic dryer. FACTA UNIVERSITATIS Series: Mech. Eng. 2010;8(1):89–96.
14. Prvulovic S, Tolmac D, Radovanovic L. Results research of energetic characteristics of convection drying. Strojniški Vestnik. 2008;54(9):639-644.
15. Mirzaee E, Rafiee S, Keyhani A, Emam-Djomeh Z. Determining of moisture diffusivity and activation energy in drying of apricots. Research in Agric. Eng. 2009;55(3):114-120.
16. Collier JR, Gebremedhin GK. Thermal biology of domestic animals. Annu. Rev. Anim. Biosci. 2015;3(10):1–10.
17. Berhe A. Assessment of hides and skins marketing in Tigrai Region: The case of Atsbi Wemberta Wereda, Eastern Tigrai. MA Thesis. Addis Ababa (Ethiopia): Addis Ababa University. 2009;34-65.
18. Junling S, Zhongli P, Tara HM, Delilah W, Edward H, Don O. Elsevier - Food Sc. and Tech. 2008;41:1962-1972.
19. Agarry SE, Aworanti OA. Modelling the drying characteristics of osmosised coconut strips at constant air temperature. J. of Food Processing and Tech. 2012;3(4):1-6.
20. Mohammad Z, Seyed HS, Barat G. Kinetic drying and mathematical modeling of apple slices in dehydration process. J. of Food Process and Technology. 2013;4(7):1-4.
21. Anna H, Iva K, Rithy C, Petra C, Jan B. Development of solar drying model for selected Cambodian fish species. The Scientific World Journal. 2014;10. Article ID: 439431.
22. Motevali A, Abbaszadeh A, Minaei S, Khoshtaghaza M, Ghobadian B. Effective moisture diffusivity, activation energy and energy consumption in thin-layer drying of jujube. J. of Agric Sc. and Tech. 2012;14: 523-532.
23. Sebastian P, Bruneau D, Collignan A, Rivier M. Drying and smoking of meat: Heat and mass transfer modeling and experimental analysis. Journal of Food Engineering. 2005;70:227–243.
24. Daniela F. Olivera, Ruth Bambicha, Gladys Laporte, Fernanda Coll Cárdenas, Nora Mestorino. Kinetics of colour and texture changes of beef during storage. J Food Sci Technol. 2013;50(4):821–825.
25. Akhtar J, Omre P, Tanwar V. Moisture diffusivity and activation energy for high velocity hot air drying of chicken meat. International Journal of Livestock Research. 2017;7(6):25-36. Available:http://dx.doi.org/10.5455/ijlr.20170414111113
26. Athinoula L. Petrou, Maria Roulia, Konstantinos Tampouris. The use of the arrhenius equation in the study of deterioration and of cooking of foods-Some scientific and pedagogic aspects. Chemistry Education: Research and Practice in Europe. 2002;3(1):87-97.
27. Reza AC, Kamran S, Qasem A, Ali AS. Modeling moisture diffusivity, activation and specific energy consumption of squash seeds in a semi fluidized and fluidized bed drying. J. of Food Sc. and Tech. 2013;50(4):667-667.
28. Aghbashlo M, Kianmehr MH, Samimi-Akhijahani H. Influence of drying conditions on the effective moisture diffusivity, energy of activation and energy consumption during the thin-layer drying of beriberi fruit (Beriberidaceae). Energy Conversion and Mangt. 2008;49(10):2865-2871.
29. Nwajinka CO, Nwuba EIU, Udoye BO. Moisture diffusivity and activation energy of drying of melon seeds. Intl J. of Applied Sc. and Eng. 2014;2(2):37-43.
30. Abbaszadeh A, Motevali A, Ghobadian B, Khoshtaghaza MH, Minaei S. Effect of air velocity and temperature on energy and effective moisture diffusivity for Russian olive (*Elaeugnusan gastifolial*) in thin-layer drying. Iran J. of Chemistry and Chemical Eng. 2012;31(1):75-79.

31. Tinuade JA, Toyosi YT, Oluseyun JO. Influence of drying conditions on the effective moisture diffusivity and energy requirements of ginger slices. J. of Food Research. 2014;3(5):103-112.

32. Navale SR, Harpale VM, Mohite KC. Comparative study of open sun and cabinet solar drying for fenugreek leaves. Intl J. of Renewable Energy Tech. Research. 2015;4(2):1-9.

Peer-review history:
The peer review history for this paper can be accessed here:
http://prh.sdiarticle3.com/review-history/22903