Volume : 2 | Issue : 8 | Aug 2013 • ISSN No 2277 - 8160

Research Paper | Agriculture

Development and Performance Evaluation of a Solar Assisted Hybrid Dryer for Cassava Chips

Onipede E. A	Department of Agricultural Engineering, Kwara State Polytechnic, Ilorin, Kwara State, Nigeria.
Agbetoye L. A. S	Department of Agricultural Engineering, Federal University of Technology, Akure, Ondo State

ABSTRACT

A solar assisted hybrid dryer was designed, fabricated and evaluated for performance. The major components of the dryer include the drying unit, the solar collector, the ducting unit, the auxiliary heating unit, solar panel unit and the frame. The performance evaluation of the dryer was carried out to investigate the effect of drying temperatures (500C, 550C, 600C, 650C & 700C), airflow rates (0.033 m3/s, 0.038 m3/s & 0.044 m3/s) and shapes (rectangular and square) of fresh cassava chips at 62% moisture content (w.b) on drying rate. Data from the test were subjected to statistical analysis of variance (ANOVA). Duncan Multiple Range Test (DMRT) was used to compare the values. Results show that drying temperature, airflow rate and shape of cassava chip had significant effect on drying rate of chips at 1% level of significance. Drying rate increases as drying temperature and airflow rate increases but decreases as drying time increases.

KEYWORDS: Cassava, Chips, Hybrid Dryer, Drying Rate, Evaluation

1. INTRODUCTION

Cassava (*Manihot esculenta,* Crantz*)* is a major staple crop in Nigeria as cassava and its products are found in the daily meals of Nigerians. According to Kajuna *et al.* (2001), cassava is the third most important staple food in the tropics after rice and maize. It provides 37% of the calorie requirement in Africa, 12% in Latin America and 7% in Asia. Tunde-Akintunde and Afon (2009) reported that cassava roots contain about 32% starch, 65% moisture, 0.8%-1% protein on wet weight basis.

Cassava crop is grown in large quantities in plantation due to the discovery of cassava as a food security, famine reserve and for its versatility. Nigeria is the world's largest producer of cassava tuber with annual production of 49 million metric tonnes (Kolawole, 2012). Cassava crop is a viable source of raw materials for a number of industrial products like starch, flour and ethanol. The production of cassava is relatively easy as it's tolerant to the biotic and edaphic encumbrances that hamper the production of other crops. It tolerates marginal soil fertility status where other crop will fail completely. The different parts of the plant can be used as animal feed, the leaf as silage, dried for feed supplementation and as leaf meal for feed concentrate. The stems can be mixed with leaves and used as ruminant feed or dried for feed concentrate. The root tubers can be chipped or pelletized and used as feed, while the root peel, broken root, fibre and baggase from starch extraction and gari processing can be dried and used directly as animal feed or a substrate for single cell protein production.

Cassava tubers are bulky and perish relatively quickly and cannot be stored in raw form for too long, hence the need for its immediate processing to avoid post-harvest losses. The processes involved in cassava processing include washing, peeling, grating/chipping dewatering, drying, cooling and packaging which are stressful, time consuming, laborious and expensive. Drying of agricultural product has always been of great importance for the preservation of food by human being. The major objective in drying agricultural products is the reduction of the moisture content to a level which allows safe storage over an extended period. Also, it brings substantial reduction in weight and volume, minimizing packaging, product diversity, storage and transportation cost (Bukola and Ayoola, 2008). Drying is a unit operation for making virtually all cassava products and it is the most challenging because it makes the commodity to have a good or bad market value. Therefore this research work focussed on the drying process of cassava.

The use of traditional method of drying (sun drying) offers a cheap and easy method of drying but the drying rate is very low and it often results in inferior product quality due to dependence of weather conditions and vulnerability to be attacked and contaminated with insects, pests, micro organism, dust and dirt. Mechanical drying is fast, has higher rate of performance but sources of heat energy like fossil fuel, electricity are expensive, totally absent or are not readily available. These have led to the search for alternative method that can be easily available to the local farmers and processors.

Sequel to the above reasons, a solar assisted hybrid dryer was designed and fabricated from locally available materials for drying cassava chips to reduce post harvest spoilage especially in adverse weather. Solar hybrid dryer allows drying to continue in off-sunshine hours by backup heat energy or storage heat energy. Therefore drying is continued and product is saved from possible deterioration by microbial infestation during off-sunshine hours and adverse weather (Hossain *et al.,* 2008). Some hybrid dryers have been developed to control drying air conditions throughout the drying time independent of sunshine especially at night when it is not possible to use the solar energy using alternative sawdust burner (Bassey, 1985) or by using the biomass stove (Mastekbayeua *et al.,* 1999: Prasad and Vijay, 2005: Taringan and Tekazakul, 2005) or by electric heater (Hossain and Haguel, 2009) or by fuel wood burner (Fuller and Bena, 2002).

2. MATERIALS AND METHODS

2.1 Machine Description

The solar-assisted hybrid dryer basically consisted of a drying unit, solar collector, ducting unit, auxiliary unit, solar panel unit and a frame. The isometric, exploded and pictorial views of the solar assisted hybrid dryer are shown in Figures 1 to 3. A brief description of each unit is given bellow:

2.1.1 The drying unit: This is where food is placed for drying. It protects the products from insects, dust and rain. It is made up of a double walled cabinet. The outer cabinet was made with 1mm mild steel sheet of 0.61 m × 0.61 m × 1.15 m while the inner cabinet was made with 1mm galvanized steel sheet of 0.5 m × 0.5 m × 0.76 m and a fibre glass (k=0.04 W/mK) of 50 mm thickness was used as lagging between the cabinets.

The drying unit consists of four tray mesh of 0.45 m × 0.45 m × 0.03 m made with galvanized steel and arranged to create a zigzag parallel and perpendicular drying air flow channel under and over the tray mesh. The chimney is located at the topmost part of the drying unit for exit of evaporated moisture from the products. The door of the cabinet is 0.61m × 0.87m in dimension.

2.1.2 The solar collector unit: This is a double pass type, which absorb solar energy and convert it to thermal energy for drying or other application. The overall dimensions of the v-shaped corrugated and finned solar collector were 2 m long, 1m wide and 0.15 m high. The transparent cover of the collector was 5 mm thick clear glass. About 80 mm below the glass was 2 mm black painted v-shaped corrugated mild steel and below the v-shaped corrugated steel were fins made of mild steel to conduct and direct the heat transfer fluid from inlet and pass through the absorber surface which further increases the temperature of the fluid into the dryer.

The solar collector was insulated by 1 mm plywood at the sides and blanket at the bottom. The v-shaped corrugated and finned collector was oriented facing south and tilted at 18° to the horizontal. This is approximately 10° more than the local geometrical latitude (Ilorin location in Nigeria, latitude 8° 29' N and longitude 0.04° 35' E) which according to (Kalogirou ,2004) is the best recommended orientation for stationary absorber. This inclination is also to allow easy run off of water and enhance air circulation.

2.1.3 The ducting unit:

This is a unit that convey heated air from the solar collector to the drying cabinet. It is made with mild steel and stainless steel of 118 mm in diameter and of 940 mm in length. The heated stainless portion is 200 mm (0.2 m) long. The mild steel portion of the ducting unit was lagged with 50 mm fibre glass. The ducting unit consist of an axial-flow fan situated behind the heated stainless portion. The axial fan is to draw the atmospheric air in the collector and to push out the heated air with a desired air velocity through a diffuser which assists in gradual release of heated air into the drying chamber at low speed and low pressure.

2.1.4 The auxiliary heating unit:

This is provided to complement heating of the air during the off sunshine hours and poor weather conditions so as to allow drying process both in the day time and at night which will enhance maximum production of good quality product.

Auxiliary heating unit is made of kerosene stove installed along the ducting unit and heat the stainless portion of the ducting unit when the desired temperature is not attained in the drying unit. The auxiliary heating unit is electronically controlled through a motorized wick flame adjuster to the right level as desired. .

2.1.5 The solar panel unit:

This consists of solar panel and solar charger, and a dc battery. The dimension of solar panel is 1020 mm × 680 mm × 35 mm, the weight is 8.2 kg and of model number HS 80-36P. The solar panel is installed at a convenient place where it will have maximum exposure to the solar energy. The solar panel assist in charging the DC battery that serves as source of power for axial fan, the wick flame adjuster and the temperature controller for the efficient working of the system.

The solar panel has rated maximum power of 80 W, output tolerance ± 3% current at P_{max} 4.65A, voltage at P_{max} 17.2V, short circuit current 5.25A, open circuit voltage 22V, normal operating cell temperature 48±2°C, maximum system voltage 715V, maximum system rating current 10A cell technology is POLY-SI.

2.1.6 The frame:

This is the unit on which the dryer and solar collector is supported to withstand the load. The cabinet frame was fabricated from mild steel angle of 50mm x 50mm x 5mm while collector frame was made of 38mm x 38mm mild steel square pipe.

2.2 Design Considerations

A number of factors were considered in the design of the solar assisted hybrid dryer. These include, the physical and mechanical properties of materials for construction, harvesting time of cassava tubers, initial and final moisture content of cassava chips, lagging of necessary area to prevent heat loss, sunshine hours, incident solar radiation and crop characteristics.

2.3 Experimental Test

2.3.1 Sourcing and preparation of test sample

Fresh cassava tubers for tests were purchased at a local market in Ilorin, Kwara State, Nigeria. The tubers were washed, peeled and cut into rectangular shapes of 10 mm x 5 mm x 5 mm and square shapes of 10 mm x 10 mm x 5 mm using mechanical cutter. The average moisture content of the sample was 62% (wb).

2.3.2 `Test variables and experimental design

Many factors which affect the performance of dryer include: shape, size, temperature, humidity, air flow rate, thickness of the layer, bulk density, turning interval, initial and final moisture content etc. In these research, three factors were investigated; the temperature, air flow rate and the shape of the crop. Tests were conducted at five temperatures i.e 50°C, 55°C, 60°C, 65°C and 70°C and three air-flow rates i.e 0.033 m^3/s, 0.038 m^3/s and 0.044 m^3/s and two different shapes of cassava chips i.e rectangle and square making a total of 30 runs and each treatment replicated five times.

2.3.3 Experimental procedure

Drying experiments were conducted during the period of November 2012 in Ilorin, Kwara State in the hybrid solar assisted dryer that was described above. The dryer was pre-heated for 1h before the drying experiments to achieve steady state conditions before each drying run. Each sample weighing 6000 g was used per batch by spreading the chips on four trays in a thin layer. The ambient temperature ranged from 27°C-40°C, the relative humidity of ambient air range from 50%-60% The drying experiment were carried out at different air flow rates measured by flow meter (Type 5 manometer, Airflow Development Limited, High Wycombe U.K) and air temperature was measured by thermo-hygrometer in/out temperature display(model JB913). Initial and final masses of the sample were noted. During drying process, the tray was taken out at 30 min interval and was weighed using electronic balance having an accuracy of 0.01g, the drying process was continued until the products reached their final moisture content of 10% wet basis. The relative humidity of drying air ranges from 30% to 35% while the drying temperature has error margin of5°C.

3. RESULT AND DISCUSSION

The data generated from the calculated values of the average drying rate were subjected to statistical analysis to investigate the level of significance of the factors as well as the interaction effect. The analysis shows that the factors (temperature, air flow rate and time) and the interactions between these factors had significant effect on drying rate of cassava chips at 1% level of significance for both shapes (rectangular and square). This shows that all the factors affect the drying rate of cassava chips thus any change in one factor will affect the drying rate. Since the factors are significant, a New Duncan Multiple Range Test was carried out to compare the mean drying rate of the cassava chips.

Tables 1 and 2 show the Analysis of Variance and New Duncan Multiple Range Test.

3.1 Effect of Drying Time on Drying Rate

Drying rates at different levels of drying duration are significantly different from one another. The drying rate and moisture content decreased continuously with drying time. Higher rate of moisture removal was observed at initial stage of drying than in the later stages. This characteristic behaviour is due to various forms in which water is present in food products. Figures 4 to 6 show the effect of drying time on drying rate for rectangular shaped chips. The observe pattern was that as drying time increases the drying rate decreases. At airflow rate of 0.033 m^3/s and at temperatures ranging from 50°C to 70°C, the drying rate increases as drying time decreases. The drying rate at 50°C and at 30 min was 24.05 g/min while at 240 min was 2.85 g/min. The same pattern was obtained at airflow rates of 0.038 m^3/s and airflow rate of 0.044m^3/s at various temperatures. Figures 7 to 9 also show the pattern of the effect of drying time on drying rates for square shaped chips. The drying rate increases as drying time decreases at various temperatures and airflow rates considered. From the curves shown, there was no constant rate drying period in the entire process. All drying processes occurred in falling rate drying process and during the falling rate period, the drying process of cassava chips was mainly controlled by diffusion mechanisms. This is in agreement with earlier research workers (Lopez *et al*., 2000; Piga *et al*., 2004; Kingsly *et al*., 2007; Doymaz, 2004; 2005, 2006 ; Akanbi *et al*., 2006; Ertekin and Yaldiz, 2004; Sacilik *et al*., 2006; Tunde-Akintunde and Afon, 2009) .

3.2 Effect of Drying Temperature on Drying Rate

The result of comparison among the five levels of temperature revealed that at any particular drying temperature the observed means of drying rate are significantly different from each other for both shapes of chips studied. This implies that chips dried at 50°C are statistically different from chips dried at 55°C, 60°C, 65°C and 70°C or vice versa. The graph further revealed that higher drying rate was observed at higher temperature (70°C) irrespective of the shapes of chips considered for the experiment. Figure 10 shows the observed pattern of temperature on drying rate for rectangular shaped chips. It was observed that as temperature increases the drying rate also increases at various levels of air flow rates considered. For air flow rate of 0.033 m^3/s the drying rate increases from 14.43 g/min to 28.89 g/min as temperature increases from 50^0C to 70^0C. The same pattern was observed at 0.038 m^3/s and 0.044 m^3/s. The drying rate increases from 16.54 g/min to 38.60 g/min and 14.43 g/min to 27.98 g/min at 50^0C to 70^0C respectively. Figure 11 shows the effect of temperature on drying rate for square shaped chips. As temperature increases from 50^0C to 70^0C the drying rate also increases at various level of air flow rates. At 0.033 m^3/s drying rate increases with temperature from 12.83 g/min to 23.21 g/min, at air flow rate of 0.038 m^3/s the drying rate increases from 14.55 g/min to 28.87 g/min and at airflow rate of 0.044 m^3/s the drying rate also increases from 14.48 g/min to 23.27 g/min. This is because as temperature of air increases the drying air is warm (hot), dry and able to heat up the product, move over the product and provide latent heat for moisture evaporation thereby increasing the driving force for drying. Several authors reported considerable increases in drying rates when higher temperatures were used for drying various fruits, vegetables and crops. These include, (Madamba *et al*., 1996 for garlic, Lee *et al.*, 2004 for chicoryroot slices, Akpinar, 2006 for aromatic plants, Erenturk *et al.,* 2004 for rosehip, Doymaz, 2009 for spinach leaves, Tunde-Akintunde and Afon, 2009 for cassava chips, Omodara and Olaniyan, 2012 for drying cat fish).

3.3 Effect of Air Flow Rate on Drying Rate

Air flow rate was also seen to have similar effect on drying rate as temperature. Each level of air flow rate record significantly different drying rate. Figure 12 shows the drying rate for rectangular shaped chips; at air flow rate of 0.033 m^3/s the least drying rate of 14.43 g/min was recorded at 50^0C while the highest drying rate of 28.89 g/min was recorded at 70^0C. For air flow rate of 0.038 m^3/s, the least drying rate of 16.54 g/min and the highest drying rate was 38.60 g/min at 50^0C and 70^0C respectively. For air flow rate of 0.044 m^3/s, the least drying rate was 14.43 g/min at 50^0C and the highest drying rate of 27.98 g/min was observed at 70^0C. The highest drying rate was observed at air flow rate of 0.038 m^3/s. Figure 13 shows the drying rate for square shaped chips. At airflow rate of 0.033 m^3/s, the least drying rate of 12.84 g/min was recorded at 50^oC and 23.11g/min was recorded at 70^oC. For air flow rate of 0.038 m^3/s the least drying rate was 14.44 g/min at 50^oC and the highest drying rate of 28.88 g/min was recorded at 70^oC while at air flow rate of 0.044 m^3/s the least drying rate was 12.84 g/min at 50^oC and the highest drying rate of 23.11 g/min was recorded at 70^oC.The highest drying rate was also observed at airflow rate 0.038 m^3/s This is due to the fact that increase in air flow rate without changing the amount of energy given over for heating the air leads to a decrease in temperature and consequently the drying rate moreover increase in temperature and decrease of airflow rate leads to decrease in drying rate. This is in agreement with the work of (Rozis, 1997).

3.4 Effect of Sample Shapes on Drying Rate

The new Duncan Multiple Range Test revealed that the chips of rectangular shape had higher drying rate than the chips of square shape for all processing conditions. At air flow rate of 0.033 m^3/s, the highest drying rate for rectangular shaped chips was 28.89 g/min and for square shaped chips 23.11 g/min. At air flow rate of 0.038 m^3/s, the highest drying rate were 38.52 g/min and for square shaped chips 28.88 g/min and at air flow rate of 0.044 m^3/s the highest drying rate were 28.88 g/min and for square shaped chips 23.11 g/min. At temperature of 70^0C where the highest drying rate was observed for the two shapes of chips also reveals that the rectangular shaped chips had the highest drying rate. At 70^0C and air flow rate of 0.033 m^3/s the highest drying rate for rectangular shaped chips was 28.89 g/min as against 23.21g/min for square, at 0.038 m^3/s the highest drying rate for rectangular shaped chips was 38.60 g/min as against 28.87 g/min and at 0.044 m^3/s the highest drying rate for rectangular shaped chips was 38.60 g/min as against 23.27 g/min for square shaped chips. This is due to the surface area available for moisture removal and the part of travel of moisture is shorter in rectangular shaped chips than in the squared shaped chips. This is in agreement with the work of (Rozis, 1997) that when the air/product exchange surface is increase then the air can reach the surface easily and as such more moisture will be evaporated.

4. CONCLUSIONS

A hybrid solar assisted dryer for the purpose of drying cassava chips both in the day time and at night was designed and fabricated. Test result with the hybrid dryer shown satisfactory performance. The test analysis shows the interactions between the processing conditions (temperature, airflow rate, drying time and shape) had significant effect on drying rate of chips at 1% level of significance for both shapes (rectangular and square) and consequently on drying time. Increase in airflow rate and drying temperature at different level resulted in increase in drying rate but drying rates decreases as drying time increases. The dryer uses solar energy and kerosene stove as a source of heat energy. It reduced drudgery, saved labour, save time, eliminate micro-organism and insect infestation, increase production output and drying can be done both in the day time and at night.

Table 1: Analysis of variance for final Drying Rate of chips

Shape	Source	Sums of square	df	Mean Square	F	Sig.	PES
1	Time (A)	1319.658	5	263.932	2.005E4	0.001*	0.999
	Air Flow Rate (B)	63.570	1	63.570	10.133	0.002*	0.985
	Temperature (C)	2250.835	4	562.709	89.698	0.001*	0.986
	AXB	45.527	7	6.504	494.141	0.001*	0.960
	AXC	57.833	7	8.262	627.710	0.001*	0.968
	BXC	40.763	4	10.191	11.430	0.001*	0.960
	AXBXC	48.599	8	6.075	461.547	0.001*	0.962
	Error	407.768	65	6.273			
	Total	38738.154	75				
2	Time (A)	1118.386	6	186.398	8.185E4	0.001*	1.000
	Air Flow Rate (B)	56.771	1	56.771	11.561	0.001*	0.989
	Temperature (C)	1075.246	4	268.811	54.742	0.001*	0.988
	AXB	23.271	9	2.586	1.135E3	0.001*	0.983
	AXC	14.121	9	1.569	688.982	0.001*	0.972
	BXC	32.44	4	2.356	14.56	0.001*	0.948
	AXBXC	10.685	12	0.890	390.977	0.001*	0.963
	Error	319.182	65	4.910			
	Total	27229.730	75				

Source: Author's Analysis, *significant at 1*, 1=rectangular, 2=square

Table 2: Time Comparison Using New Duncan Multiple Range Test

Shape	Factors	Process parameter	Drying Rate
1	Time	90	38.60a
		120	28.65b
		150	21.92c
		180	19.16d
		210	16.55e
		240	14.43f
2		120	28.87a
		150	23.19b
		180	20.61c
		210	15.84d
		240	14.49e
		270	12.84f
1	Air Flow Rate	0.033	20.45a
		0.038	24.48b
		0.044	20.32a
2		0.033	17.23a
		0.038	21.25b
		0.044	16.91c

1	Temperature	50	15.13a
		55	17.33b
		60	19.30c
		65	25.18d
		70	31.82e
2		50	13.41a
		55	15.14b
		60	18.05c
		65	20.61d
		70	25.10e

Means with the same alphabet are not significantly different from each other.

Source: Author's Analysis, 1=rectangular, 2=square

Figure 1: Isomerric veiw of a solar assisted hybrid dryer

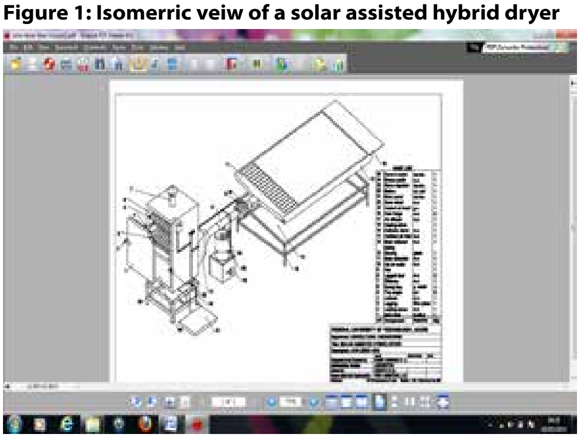

Figure 2: An exploded view of a solar assisted hybrid dryer.

Figure 3: Pictorial View of Hybrid Dryer

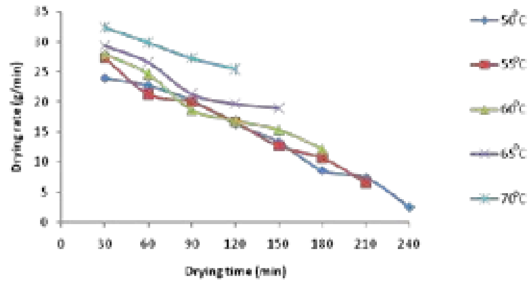

Fig. 4: Effect of drying time on the drying rate at different temperatures at 0.033m³/s for rectangular shaped chips.

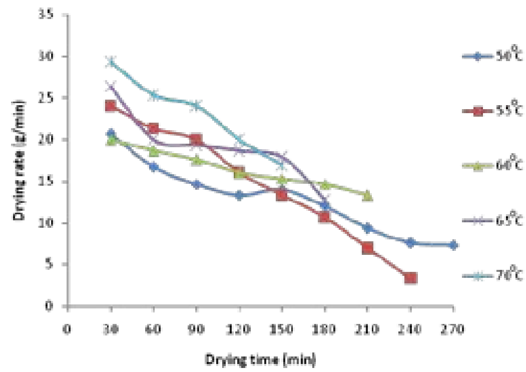

Fig 5: Effect of drying time on the drying rate at different temperatures at 0.033m³/s for square shaped chips.

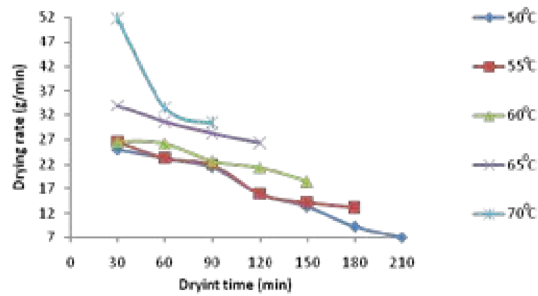

Fig 6: Effect of drying time on the drying rate at different temperatures at 0.038m³/s for rectangular shaped chips.

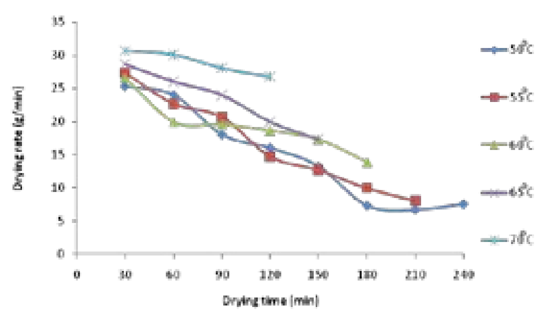

Fig 7: Effect of drying time on the drying rate at different temperatures at 0.038m³/s for square shaped chips.

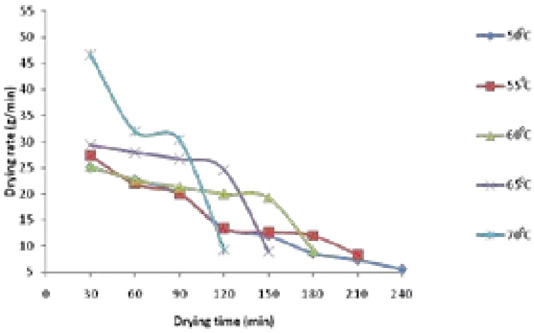

Fig 8: Effect of drying time on the drying rate at different temperatures at 0.044m³/s for rectangular shaped chips.

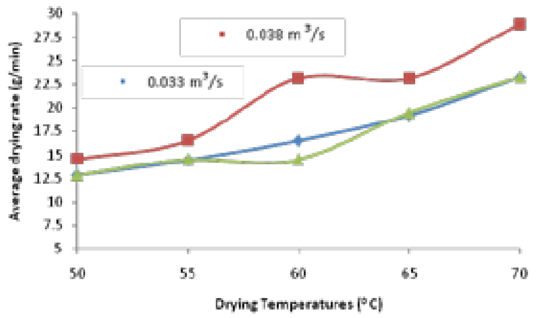

Fig 11: Effect of drying temperatures on the drying rate at different air flow rates of square shaped chips

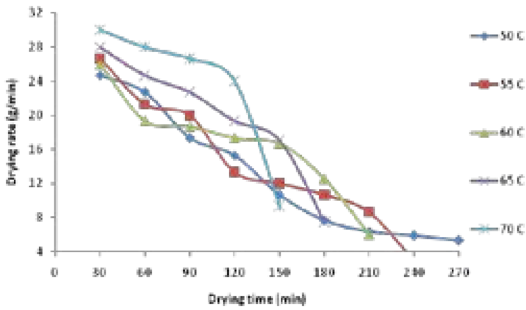

Fig 9: Effect of drying time on the drying rate at different temperatures at 0.044m³/s for square shaped chips.

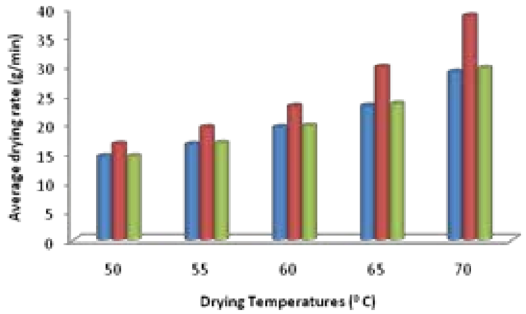

Fig 12: Effect of air flow rates on the drying rate at different temperatures of rectangular shaped chips

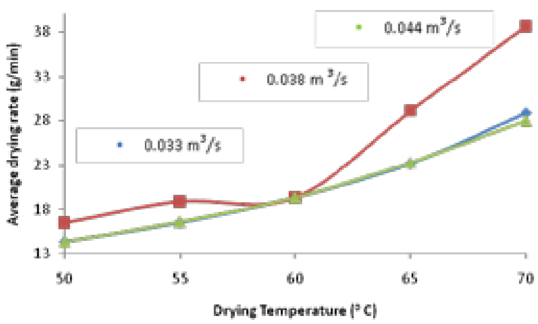

Fig 10: Effect of drying temperatures on the drying rate at different air flow rates of rectangular shaped chips

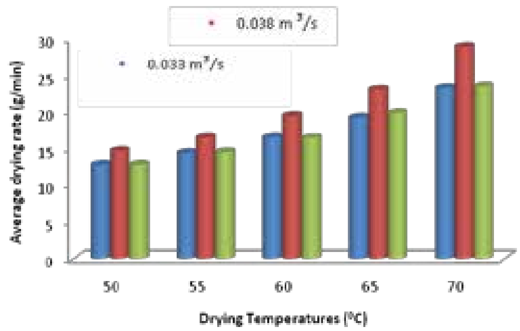

Fig 13: Effect of air flow rates on the drying rate at different temperatures of square shaped chips

REFERENCES

Akanbi, C.T.; Adeyemi, R.S. and Ojo, A. (2006): Drying Characteristics and Sorption Isotherm of Tomato Slices. Journal of Food Engineering, 73:141-146 | Akpinar, E.K. (2006): Mathematical Modelling of Thin Layer Drying Process under Open Sun of Some Aromatic Plant. Journal of Food Engineering, 77: 864-870 | Bassey M.W. (1985): Design and Performance of Hybrid Crop Dryer using Solar Energy and Sawdust. Proceedings ISES Congress INTERSOL 85. Monreal, Canada, Pergamon Press, Oxford. 1038-1045. | Bukola O.P, and Ayoola P.O (2008): Performance Evaluation of a Mixed Mode Solar Dryer A.U.J.T, 11 (4): 225-231. | Doymaz, I. (2009): Thin Layer Drying of Spinach Leaves in a Convective Dryer. Journal of Food Engineering, 32: 112-125. | Doymaz, I. (2004): Pre-treatment Effect on Sun Drying of Mulberry Fruits (Morus alba L). Journal of Food Engineering, 65: 205-209. | Doymaz, I. (2006): Air Drying Characteristics of Tomatoes. Journal of Food Engineering, 78, 1291 – 1297. E.I.E, General Directorate of Electrical Power Resources Survey and Development Administration, http://www.eie.gov.tr | Erenturk, S.; Gulaboglu, M.S. and Gultekin, S. (2004): The Thin Layer Drying Characteristics of Roeship. Journal of Biosystems Engineering, 89: 159-166. | Ertekin, C. and Yaldiz, O. (2004): Drying of Egg Plants and Selection of a Suitable Thin Layer Drying Model. Journal of Food Engineering, 63: 349-359. | Fuller R.J., Bena, B. (2002): Natural Convection Solar Dryer with Biomass Back-up Heater. Solar Energy, 75: 75 – 83. | Hossain, M.A.; Amer, B.M.A and Gottschalk, K. (2008): Hybrid Solar Dryer for Quality Dried Tomato. Drying Technology, 26: 1591-1601 | Hossain, M.A. and Haque, A. (2009): Development and Evaluation of a Solar Assisted Hybrid Dryer; Proceeding of the 5th CIGR Section VI International Symposium on Food Processing, Monitoring Technology in Bio-processes and Food Quality Management. Potsdam, Germany. | Kajuna, S.T.; Silayo, V.C.K.; Mkenda, A. and Makungu, P.J.J. (2001): Thin Layer Drying of Diced Cassava Roots. African Journal of Science and Technology (AJST). Science and Engineering Series, 2(2): 94-100 | Kalogirou, S.A. (2004): Solar Thermal Collectors and Application. Progress in Energy and Combustion Science, 30: 231-295. | Kingsley R.P.; Goyal, R.K.; Malikantan, M.R. and Llyas, S.M. (2007): Effects of Pre-treatment and Drying Temperature on Drying Behaviour of Peach Slice. International Journal of Food Science and Technology, 4: 65-69. | Kolawole, O.P. (2012): Development and Performance Evaluation of Cassava Mash Processing Handling Machine. Unpublished Ph. D. Thesis, Department of Agricultural Engineering, Federal University of Technology, Akure. | Lopez, A., Iguaz, A., Exnoz, A. and Virsed P. (2004): Thin Layer Drying Behaviour of Vegetable Waste from Wholesale Market. Journal of Drying Technology, 18: 995-1006. | Madamba, P.S.; Griscoll, R.H. and Buckle, K.A. (1996): The Thin Layer Drying Characteristics of Galic Slices. Journal of Food Engineering, 29: 75-97. | Omodara, M.A and Olaniyan A.M. (2012): Effects of Pre-Treatments and Drying Temperature on Drying Rate and Quality of African Catfish (Clarias garicpinus). Journal of Biology, Agriculture and Health Care, 2 (4): 1-10. | Piga, A., Pinna, I.; Ozer, K.B.; Agobbio, M. and Aksoy, U. (2004): Hot Air Dehydration of Figs (Ficus carica L): Dying Kinetic and Loss. International Journal of Food Science and Technology, 39: 793-799. | Rozis, J.F. (1997): Drying Food Stuffs; Technical Guide Book. Backhuys Publishers | Sacilik, K.; Keskin, R. and Elicin, A.K. (2005): Mathematical Modelling of Solar Tunnel Drying of Thin Layer Organic Tomato. Journal of Food Engineering, 73: 231-238. | Tarigan, E. and Tekasakul, P (2005): A Mixed-mode Natural Convection Solar Dryer with Biomass Burner and Heat Storage Back-up Heater. ANZSES (2005) | Tunde-Akintunde, T.Y. and Afon, A.A. (2009): Modelling of Hot Air Drying of Pre-treated Cassava Chips. Agricultural Engineering International: The CIGR Ejournal, Manuscript: 1493 Vol. |