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The influence of different solar drying systems on the vitamin content of Pawpaw (*Carica papaya*)

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Abstract

Ripe pawpaw was peeled, chipped and dried. Samples of the pawpaw were dried under four different conditions: open-air sun drying method and by using three different models of integral passive solar dryers which include Green house solar dryer, Sun-tracking solar dryer and Latitudinal box solar dryer. The fresh pawpaw samples and the dried samples were analysed for vitamins A, B_1, B_2, C and E. The results showed a significant difference in the concentrations of Vitamins A, B_1, B_2, C and E between the fresh samples and the dried samples for all drying systems. While Vitamins A, B_1, B_2, and C reduced in concentration for all dried samples, Vitamin E increased significantly for samples dried with solar dryers and reduced significantly for the open-to-air dried samples. In all cases, open-to-air dried samples recorded the least concentrations while solar dryers recorded varying concentrations with Latitudinal box dryer giving the best result in terms of vitamins retention. All year round availability of pawpaw could be enhanced by chipping and drying. Packaging and marketing of dried chips in small quantities could be a lucrative entrepreneurial endeavour for the business minded.

Keywords: Concentration; Models; Open-to-air; Passive; Ripe; Sun.
Abbreviations: a_Latitudinal box solar dryer, **b**_Green house solar dryer, **c**_Sun-tracking solar dryer, **CRD**_Completely Randomized Design, **d.f**_Degree of freedom, **f**_Fresh (undried) pawpaw samples, **F-LSD**_Fisher's least significant difference, **H_o**_null hypothesis, **o**_Open-air drying system, **r**_replications, **UV**s_ultra violet rays, **s**_standard deviations , **t**_test value, **x**_ individual vitamin value.

Introduction

Pawpaw (Carica papaya L.) is the most economically important fruit in the *Caricaceae* Family (Medina et al., 2010). It is native to the tropics of the Americas but now popularly grown in the tropics (Ashaye et al., 2005). Pawpaw fruit is 15–50 cm long, 10–20 cm in diameter, and weighing up to 9 kg (Medina et al., 2010). Pawpaw has many uses, including as food, cooking aid, and in medicine (Ray, 1994). However the present study is limited to its use as food. The ripe fruit is usually eaten raw, without its skin or seeds. According to Tietze (2002) mature green papaya fruit contains more vitamin A than carrots, more vitamin C than oranges, abundant vitamin B factors and vitamin E. It also contains a complex of enzymes that help to digest proteins, carbohydrates and fats (Ray, 1994). It possesses antiseptic qualities and helps prevent the abnormal proliferation of undesirable bacteria in the intestines (Ray, 1994). Pawpaw contains arginine which is known to be essential for male fertility and also carpain, an enzyme thought to be good for the heart (Rovira, 2009). According to Medina et al (2005), "when the fruit is green and hard it is rich in white latex. As it ripens, it becomes light or deep-yellow externally and the thick wall of succulent flesh becomes aromatic, yellow, orange or various shades of salmon or red. It is then juicy, sweetish and somewhat like a cantaloupe in flavour; in some types quite musky". Simple observation shows that like every other fruit, preservation of pawpaw is at a very low level in Nigeria (Orwa et al., 2009). Storing the fruit fresh through refrigeration or drying mechanically can hardly be attained due to epileptic power supply in the country (Ojike et al., 2010). In this respect, solar drying could be a good option in its preservation.

Sun drying is a cheap method of preserving fruits and vegetables because it uses sunlight as its source of heat. However, it is generally accepted that open-air sun drying has limitations such as dust contamination, bird and rodent attacks, fungal attacks and the risk associated with sudden rainfall on the product being dried (Ojike et al., 2010). Several works have been reported on the development and evaluation of solar dryers to mitigate the limitations of open-air sun drying (Ekechukwu and Norton, 1999; Muthuveerappan et al, 1985; Ojike et al, 2010). Solar drying combines the advantages of traditional open-air drying and industrial methods. This according to Whitefield (2000) requires low investment costs but yields high product quality. The use of solar drying systems by farmers is still unpopular in Nigeria. Several passive solar dryers have been developed by the National Centre for Energy Research and Development, University of Nigeria, Sokoto Energy Research Centre, Usmandafodio University and other tertiary institutions in Nigeria. Most of these dryers are very simple and easy to construct using local materials. Most of the dryers were designed and evaluated only in comparison with open-

Fig. 1a Latitudinal box solar dryer (a)

Fig. 1b. Green house solar dryer (b)

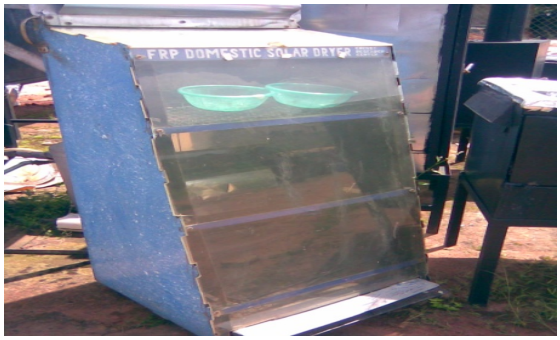

Fig. 1c Sun-tracking solar dryer (c)

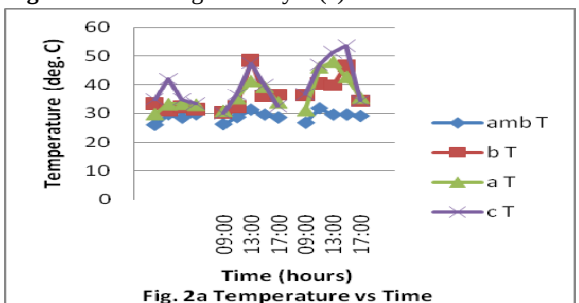

Fig. 2a Temperature vs Time

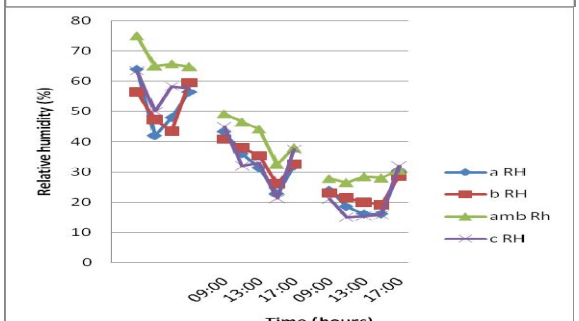

Fig. 2b Relative Humidity of the dryers vs Time. Where amb = open-air, a= Lat. box dryer, b = Gr house solar dryer and c = Sun-tr. solar dryer

air drying method (Eze and Chibuzor, 2008; Oparaku, 2008; Okonkwo and Nwoke, 2008; Okonkwo and Okoye, 2005; Eze and Ekechukwu, 1999). Comparative evaluation is seldom reported. In this paper, three different models of the passive solar dryers were selected for comparison using pawpaw as test sample to determine the effect of these dryers on its nutrient content namely vitamin A, B_1, B_2, C and E.

Materials and methods

Drying method

Three models of passive solar dryers developed at the National Centre for Energy Research and Development, University of Nigeria, Nsukka were used for this study. The solar dryers used are all of natural convection type as shown in Fig 1, which include Green house solar dryer, Sun-tracking solar dryer and Latitudinal box solar dryer. Latitudinal box solar dryer is of metal body painted black. It has a perforated opening at the top and bottom of the north and the south end respectively. The glass cover is inclined at an angle of 22°. Green house solar dryer is made of glass at all sides except at the bottom with a perforated aluminium sheet. Sun-tracking solar dryer has a manual sun tracking system. It is covered with glass on both the top and on one side with the rest covered with metal. It is perforated at the bottom and along its door.

Plant materials

Pawpaw fruit (maradol variety) bought from Nsukka main market was used for this study. It was washed, pilled and sliced uniformly. Random samples from the chips were analyzed for vitamins A, B_1, B_2, C, and E using the official methods of analysis of the Association of Official Analytical Chemists, AOAC (Greenfield and Southgate, 2003). The initial moisture contents were also analysed using MB 35 Halogen moisture meter. It was then divided into four parts, each for the three dryers and one part for open-air sun drying as control for the study. The ambient and chamber temperatures throughout the duration of the process were measured using I-BK Precision thermocouple. While relative humidities of the systems were measured with Vaisala Humidity Indicator. The weight loss during drying which was assumed to be only moisture loss was monitored periodically by weighing the samples until the weight was constant. It was used to determine moisture content periodically. The vitamin analysis of the dried samples were determined and the results compared with fresh (undried) ones.

Statistical design and method

The vitamin analysis was done using the Completely Randomized Design (CRD) statistical method. The analysis of variance table for CRD is as shown in table 1 (Obi, 2002). The decision for CRD is if F-calculated is greater than or equal to F-tabulated at a given probability level then the F test is significant. A significant F test means that at least one of the drying systems (treatments) is significantly different. Then, the multiple comparison test using equation 1 was done to find out which treatment differ from others (Obi, 2002).

$$F - LSD_{.05} = \left(t_{\frac{.05}{2}}, Error\ d.f.\right)\sqrt{\frac{2 * S^2}{r}} \qquad (1)$$

Table 1. The ANOVA Format for a Completely Randomized Design (CRD)

Sources of Variation	Degrees of Freedom (DF)	Sum of Squares (SS)	Mean Squares (MS)	F-Cal	F-Tab. (5%)
Among Treatments	t_a -1	Among Treatments SS (T_aSS)	Among Treatments MS = TMS = (T_aSS)/ (t_a - 1)	TMS/EMS	From statistical table
Within Treatments (Experimental error)	t_a (r -1)	Within Treatments SS (ESS) = TSS - T_aSS	Within Treatments MS (EMS) = ESS /(t_a(r -1))	_	_
Total	t_a r -1	Total SS (TSS)	_	_	_

(Obi, 2002) where t_a = treatment sources,

Table 2. The Vitamin Analysis of Pawpaw

Drying system	Vitamin A (µg/ml)	Vitamin B_1 (mg/100m)	Vitamin B_2 (mg/ml)	Vitamin C (mg/ml)	Vitamin E (mg/100ml)
f	5.948	0.579	4.348	36.275	1.240
o	0.015	0.022	0.034	0.065	0.045
a	0.184	0.517	1.930	0.82	31.865
b	0.162	0.357	1.93	1.108	39.275
c	0.092	0.848	2.065	0.997	27.941
F-$LSD_{.05}$	0.002086	0.001826	0.002015	0.001475	0.002975

Table 3. Quantities of dried pawpaw required for daily body requirement

Vitamins	o dryer(g)	a dryer(g)	b dryer (g)	c dryer (g)
Vitamin A	2667	217	247	435
Vitamin B_1	182	8	11	5
Vitamin B_2	1	0.02	0.02	0.02
Vitamin C	31	2.4	1.8	2.0
Vitamin E	889	1.26	1.02	1.4

If the difference between two means is greater than the F-$LSD_{.05,}$ H_o is rejected with the conclusion that the two mean are statistically different.

Results and discussion

The maximum ambient and chamber temperatures throughout the duration of the process were 31.7 ^oC (ambient), 47.9^oC (a dryer), 48.5^oC (b dryer), and 53.5 ^oC (c dryer) with ambient temperature having the least values for all readings as shown in Fig. 2a. The maximum relative humidity recorded were 75.0% (ambient), 64% (a dryer), 64% (b dryer) and 59.5% (c dryer) with ambient relative humidity having the highest values for all readings as shown in Fig. 2b. At interval of two hours each sample was weighed and moisture content calculated from the weight loss. The average initial moisture content (dry basis) of the samples was 607.71(db)% while the moisture content (dry basis) of the samples when they were dried were 6.78% (o dryer), 6.58% (b dryer), 5.31% (a dryer) and 3.99% (c dryer). The monthly average daily radiation for the month of November during which the study was done has been estimated to be 17.101 $MJm^{-2}day^{-1}$ for Nsukka (Agbo and Ezema, 2008). The result of the analysis of CRD showed varying significant difference for all vitamins. The dried samples for all drying systems showed significant different vitamin concentrations from the fresh samples and from each other except in vitamin B_2 where there was no difference between a and b dryers. This simply means that there was an acceptable change in vitamins concentrations as a result of the drying and the type of dryer used. While there are losses of vitamin concentration in vitamins A, B1, B2, and C in all the drying methods used, Vitamin E concentration in the solar dryers increased significantly (except in open-air drying system where Vitamin E showed loss in concentration). Vitamin B and C are water soluble vitamins and are rapidly destroyed by heat (Roig et al, 1995). The vitamin contents were lower in the samples dried in the open sun than the ones dried in the solar dryers. According to Kreutler and Czajka-Narins (1987), many other factors than heat can destroy vitamins, such as: solubility in water, exposure to air (oxidation), exposure to light (UVs), acid and alkaline solutions, storage losses, etc. Thus, the low levels of vitamin B and C in the open sun dried samples may be due to oxidation of vitamin after prolonged exposure to the air (Eze and Chibuzor, 2008). Another cause of vitamin C being lost was leaching, where the water-soluble vitamin leaks through the open-pores at the base of the containing vessel during drying (Eze and Chibuzor, 2008). Vitamin E was not affected by heat but susceptible to light and air (Kreutler and Czajka-Narins, 1987) as can be observed from increase in concentration of it in solar dried samples. Thus, it can be

observed from table 2 that "c" dryer recorded the lowest value of vitamin E among the solar dryers used due constant tracking of light. The result of the sensory evaluation of the samples indicates that "o" sample has less acceptability when compared to solar dried samples. This perhaps could be attributed to exposure of the samples to UVs from the sun which adversely affected its colour and darkened the samples after prolonged exposure to direct sunlight (Eze and Chibuzor, 2008). The daily recommended requirements for vitamins A, B1, B2, C and E revolve around 800 µg, 1mg, 1.1 mg, 40 mg and 8 mg respectively even though the actual requirements depend on gender, age, activity, health condition et c. (Bienz et al, 2003). Table 3 compares the quantities of the dried pawpaw under the four drying conditions required to meet the daily requirement of the vitamins stated above. In all cases it can be observed that lesser quantities of pawpaw dried using solar dryers are required to meet the vitamin requirements of the human body system compared to that of open air sun drying system. However, considering table 3 on the average, latitudinal box dryer gave the best result since only 217g of dried pawpaw from it gave the minimum daily requirement.

Conclusion

Samples of pawpaw fruit were dried in the open-air and with solar dryers. Vitamin A, B_1, B_2, C and E were analysed to determine their concentrations before and after drying. In all cases there were significant changes in the concentration of vitamins after drying. The changes were much in open-air drying than in solar dryers used. Thus, the use of solar dryers for drying of pawpaw is highly recommended. Among the solar dryers used Latitudinal box dryer gave the best result in terms of vitamin retention. Dried pawpaw fruits could be packaged in small quantities as chips and utilized in form of snacks. Packaging of pawpaw fruit chips in this form will literally improve economic status of farmers and provide job opportunities for marketers.

References

Agbo SN, Ezema FI (2008) Estimation of the monthly Averagte Daily Global Solar Radiation in Nsukka, Nigeria. Nigerian Journal of Solar Energy 19(1): 40-47

Ashaye OA, Babalola SO, Babalola AO, Aina JO, Fasoyiro SB (2005) Chemical and Organoleptic Characterization of Pawpaw and Guava Leathers. World Journal of Agricultural Sciences 1(1): 50-51

Bienz D, Cori H, Hornig D (2003) Adequate dosing of micronutrients for different age groups in the life cycle. Food and Nutrition Bulletin 24(3):S7-S15.

Ekechukwu OV, Norton B (1999) Review of Solar Energy Systems: An Overview of Solar Drying Technology. Energy Conversion and Management 40: 615-655.

Eze JI, Chibuzor EE (2008) Evaluation of Drying Efficiency of Solar Cabinet Dryer using Okro and Tomato. Nigerian Journal of Solar Energy 19(1): 25-33

Eze JI, Ekechukwu OV (1999) Improved Studies on Tomato Preservation using a Solar Dryer. Renewable Energy 7: 67-72

Greenfield H, Southgate DAT (2003) Food composition data: Production, Management and Use, 2nd Edition FAO, Rome

Kreutler PA, Czajka-Narins DM (1987) Nutrition in Perspective, 2nd edition Prentice Hall, Englewood Cliffs, New Jersey

Medina JD, Gutiérrez GV, García HS (2010) PAWPAW: Post-harvest Operation. In: Mejía D (ed) Compendium on Post-harvest Operations. Accessed online on 15th September, 2010 from <http://www.fao.org/inpho/content/compend/text/CH22_01.htm>

Muthuverrappan VR, Ambalavanan G, Kunchithapatham M, kamaraj G, Ananthanatesan T (1985) Low Cost Plastic Suction–type-greenhouse Grain Dryer. Proceedings ISES Conference, INTERSOL 85: 1077-81.

Obi IU (2002) Statistical Methods of Detecting Differences Between Treatment Means and Research Methodology Issues in Laboratory and Field Experiments. Snaap Press (Nig) LTD, Enugu

Ojike O, Nwoke OO, and Okonkwo WI (2010) Comparative Evaluation of Passive Solar Dryers using the Drying Rate Constants of Yellow Pepper and Okro as a Case Study. Nigerian Journal of Solar Energy 21:156-164

Okonkwo WI, Nwoke OO (2008) Family Size Green House Solar Energy Crop Dryer. Nigerian Journal of Solar Energy, 19(2): 6-10

Okonkwo WI, Okoye EC (2005) Performance Evaluation of a Pebble Bed Solar Crop Dryer. Nigerian Journal of Technology 24(2): 67-73

Oparaku NK (2008) Development and Performance Evaluation of Medium-Scale Solar Fish Dryer. Nigerian Journal of Solar Energy 19(1): 34-39

Orwa C, Mutua A, Kindt R, Jamnadass R, Simons A (2009) Agroforestree Database: a tree reference and selection guide version 4.0. Accessed online on18th September, 2010 from <http://www.worldagrofor estry.org/af/treedb/>

Ray JW (1994) Patient's Guide to Body Electronics. A technical article accessed online on 23rd March, 2010 from <http://www.bodymindhealing.info/papaya.php>

Roig MG, Rivera ZS, Kennedy JF (1995) A model study on rate of degradation of L- ascorbic acid during processing using home-produced juice concentrates. International Journal of Food Sciences and Nutrition 46 (2): 107–115

Rovira DD (2009) Technology and Engineering. Accessed online on 23rd March, 2010 from <http://books.google.ca/books?isbn=0813821355.>

Tietze HW (2002) Health and Fitness. Harald W. Tietze Publishing Property Limited, Bermagui

Whitefield D (2000) Solar Dryer Systems and the Internet: Important Resources to Improve Food Preparation. In: Ojike O, Nwoke OO, and Okonkwo WI (2010) Comparative Evaluation of Passive Solar Dryers using the Drying Rate Constants of Yellow Pepper and Okro as a Case Study. Nigerian Journal of Solar Energy 21:156-164