RUFORUM Working Document Series (ISSN 1607-9345) No. 14 (3): 287-294.
Available from http://repository.ruforum.org

Research Application Summary

The potential of commercial preservation of tomatoes using a mixed-mode solar drying technology in rural Botswana

Ebangu, O.B. [1,2], Dintwa, E.[1] & Motsamai, O.[1]
[1] Mechanical Department, University of Botswana, P.O Box 0061, Gaborone, Botswana
[2]Department of Biosystems Engineering, Gulu University, Uganda
Corresponding author: benebangu@yahoo.com

Abstract

Globally, the agricultural value chain is adversely affected by high postharvest losses estimated to be 30-50%. Efficient and affordable preservation technologies to mitigate the enormous postharvest losses are scarce in sub-Saharan Africa. Botswana is endowed with abundant sunshine but has little evidence of utilization of solar drying technology to preserve products as a method of reducing postharvest losses. This paper presents the findings of a study on the potential for commercial preservation of tomatoes using a mixed-mode solar drying technology in a Botswana rural setting. The study (i) assessed the needs and practices around preservation of agro-produce with particular reference to the type of agricultural products that are in need of preservation; (ii) assessed the enabling factors for solar drying that included environmental and solar thermal conditions in Botswana; (iii) assessed the available technologies to determine the different types of solar dryers, and (iv) evaluated the potential of using an enhanced mixed-mode forced air convection technology, taking into consideration possible thermal energy storage options in view of the intermittency of the solar energy source. From the survey, tomato emerged as the produce with the highest potential for preservation by use of solar drying technology. The assessment of the solar energy levels indicated sufficiency for solar drying irradiation higher than 200kW/m^2 in all the locations analyzed in Botswana. The wind velocity was found to be of average 4 m/s, relative humidity for both winter and summer averaged 51 % and sky clearness index was above 80%. All these are favorable conditions for solar drying. For commercial preservation, the use of mixed-mode solar dryer with additional enhancement of energy and photo-voltaic (P-V) ventilation was recommended.

Key words: Botswana, insolation, mixed-mode, potential, preservation, solar drying, tomatoes

Résumé

Sur le plan global, la chaîne de valeur agricole est négativement influencée par des pertes post-récoltes estimées à 30 - 50%. Des technologies de stockage efficace et moins couteux pour réduire les énormes pertes post-récoltes sont rares en Afrique Sub-Saharienne. Le Botswana reçoit une abondance de rayons solaires mais il y a très peu d'évidence sur l'utilisation des technologies de séchage solaire pour préserver les produits. Cet article présente les résultats d'une étude sur le potentiel de préservation commerciale des tomates à l'aide d'une technologie de séchage solaire à mode mixte en milieu rural au Botswana. L'étude a i) évalué les besoins et pratiques en préservation des produits agricoles en se référant particulièrement aux produits nécessitant de préservation; ii) évalué les facteurs qui favorisent le séchage solaire incluant les conditions environnementales et solaires thermiques; iii) évalué les technologies disponibles afin de déterminer les différents types de séchoirs solaires et iv) évalué le potentiel d'usage d'une technologie améliorée de convection d'air forcé à mode-mixte tout en considérant les différentes options possibles de stockage d'énergie thermique vue l'intermittence de la source d'énergie solaire. L'enquête menée a révélé la tomate comme le produit ayant le plus grand potentiel de préservation à l'aide de technologie de séchage solaire. L'évaluation des niveaux d'énergie solaire a indiqué une suffisance d'irradiation solaire supérieure à 200kW/m2 dans toutes les localités étudiées au Botswana. La vélocité moyenne du vent était estimée à 4 m/s, l'humidité relative moyenne en hiver et en été à 51% et l'index de dégagement des nuages supérieur à 80%. Toutes ces conditions sont favorables au séchage solaire. Pour une préservation commerciale, l'utilisation de séchoir solaire à mode mixte avec une meilleure énergie et ventilation photo- voltaïque a été recommandée.

Mots clés: Botswana, isolation, mode mixte, potentiel, préservation, séchage solaire, tomates

Introduction

Postharvest losses globally and particularly in sub-Saharan Africa including Botswana are significantly high and a threat to food security in terms of perpetuating hunger and poverty among the vulnerable population (Ekechukwu, 1989; UBOS, 2010). A recent survey by Ebangu *et al.* (2015) indicated that tomato suffers the highest postharvest losses of the agricultural produce of Botswana. Based on this information, the tomato is a worthy target for preservation. Preservation is needed to save or conserve surplus produce from a bumper harvest to make it available later. Food preservation by drying can be very effective in reducing produce waste by drying the excess or overripe produce. Practices that are currently being used to dry agro-produce are predominantly based on open-sun traditional drying where the product is simply left out in the sun until it is sufficiently dry. This method inherently suffers from high product losses due to inadequate drying, fungal growth, general contamination, encroachment from pests such as birds, rodents, insects etc. Open sun drying is thus associated with food safety risks. Lack of control over drying times as well as the inherently long drying times restrict use of this method to small scale home use rather than the medium to large scale commercial use.

Conventional dryers commonly available worldwide use convectional hot air cabinet or tunnel systems where hot air heated by electric heating elements is blown across the product placed in the cabinets/tunnels to dry the material. The energy-requirements for these equipment are quite intensive. Thus, rural communities and most dealers in agro-produce cannot afford the use of these technologies. Hence, dryers that use cheaper sources of energy are therefore highly desirable. Solar drying technology appears to be the most attractive method for adoption in countries endowed with abundant sunshine especially in Africa (Simate, 2003; Bala *et al*., 2009). Unfortunately, the application of solar drying technology in Botswana is visibily minimal. In this regard, there is an ongoing research to develop a solar dryer for use in a rural setting in Botswana (Doymaz, 2005; Janjai, 2012).

Materials and methods

A survey using questionnaires, interviews and secondary data from the Ministry of Agriculture and Forestry was conducted in Botswana. From the data obtained, general information about agro-produce, their postharvest losses and need for preservation was evaluated. The physical and biochemical properties of the wet and dried tomatoes that need to be preserved were analysed for compatibility with preservation by solar drying technology. The relevant information was obtained from literature regarding temperature profile and initial moisture content and final moisture content of the wet and dried tomato. Botswana Meteorological Department provided data on climatic conditions of Botswana. The average daily temperatures, relative humidity, rainfall, and solar irradiance were deduced from the data. The evaluation of extraterrestrial irradiance at sampled locations of Botswana was carried out.

The standard categorisations of solar dryers obtained from literature was applied in the analysis of different types of dryers. Categorisation of solar dryers was in respect of loading capacity, energy flow and airflow. This categorisation method was described by Ekechukwu (1999) and Leone *et al*. (2002). Different types of dryer designs are depicted in Figure 1.

Determination of type mixed-mode dryer as the most appropriate design was done by the method of weighted assignment of values to the dryer type/factors matrix. The design of mixed-mode dryer was enhanced for reliable commercial solar drying. The approach used to enhance performance was to fill in the operation gap created by intermittency of solar

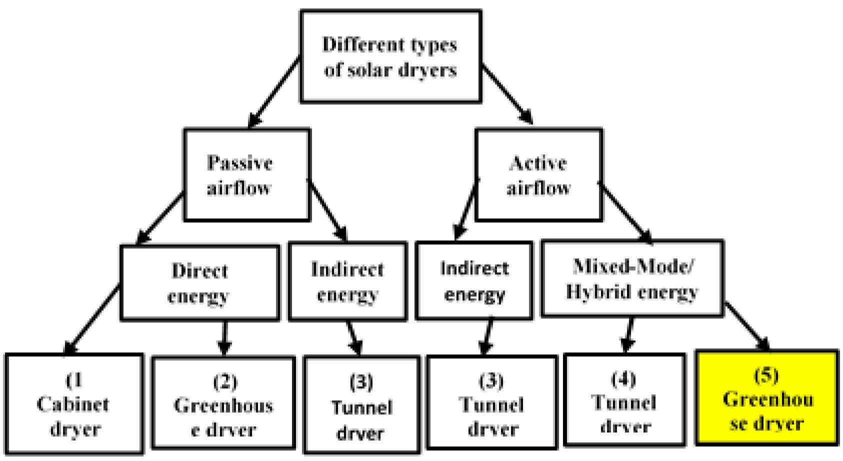

Figure 1. Categorisation of solar dryers applicable for drying tomatoes (Adapted from Ekechukwu (1999) and Leon *et al.* (2002) .

source. The solar collector with thermal energy storage stones was incorporated into the design to increase efficiency and to prolong drying when the sun is off at night. Additionally, an electric heater source was brought in as an auxiliary energy source. The embodiment of the enhancement is depicted in Figure 2.

Research application

Postharvest losses of agro-produce in Botswana. Figure 3 shows the results of the comparative loss magnitudes of agricultural products obtained from the recent survey on

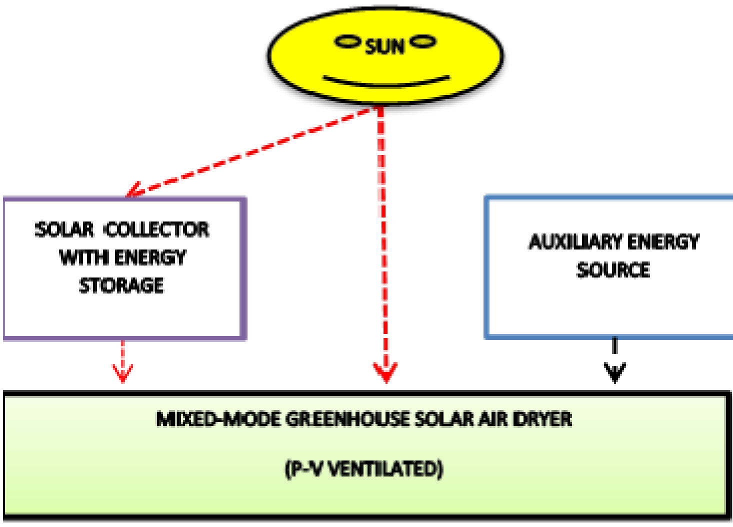

Figure 2. Schematic plan of enhancing the mixed-mode solar dryer system for commercial effectivene

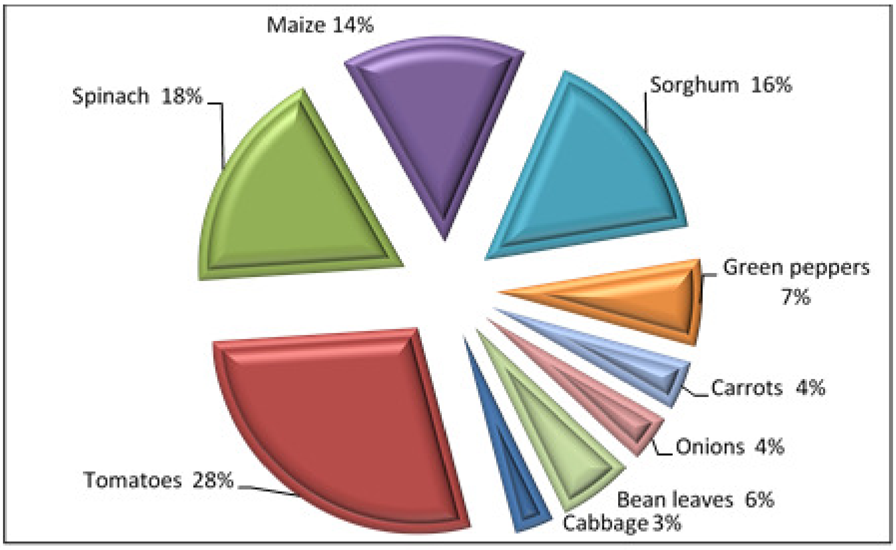

Figure 3. Pie chart of agro-produce loss ranking in Botswana (Ebangu *et al.*, 2015).

postharvest losses in Botswana. The ranking was made for the postharvest losses incurred in 2014 for each agro-produce in Botswana.

Tomato properties. Tomatoes were the most vulnerable agro-produce in Botswana that needed to be effectively preserved for later use. The initial moisture content of tomatoes was 96% and the equilibrium moisture content 10%, maximum tolerable temperature 60 °C and drying temperature 45 °C. It is nontoxic and nonvolatile, but easily absorbs moisture (hygroscopic). This information was vital in choosing the type of solar dryer design.

Evaluation of solar irradiation in Botswana. Solar irradiation at strategic points representing various latitudes in Botswana, namely, Pandamatenga (18.53), Gaborone (24.65), Kasane (17.82), Maun (19.99), Ghanzi (21.70) and Tshabong (26.02) are shown in Figure 4.

Choosing the applicable type of solar dryer. Table 1 is a matrix of dryer type factors that influence the type of dryer and the corresponding score for the six practical designs of dryers. The mixed mode dryer emerges to be the best suited for the commercial preservation of tomatoes.

Enhancing the mixed-mode solar dryer design. The configuration of the solar drying technology of mixed-mode design comprises of the solar collector and the greenhouse drying chamber as the two major components. The drying chamber receives direct solar energy as well as indirect energy from the collector, thus mixed mode. The system is ventilated by photo-voltaic energy source to sustain the forced airflow.When the solar insolation is low or off at night, electric heater serves as auxiliary energy supply.

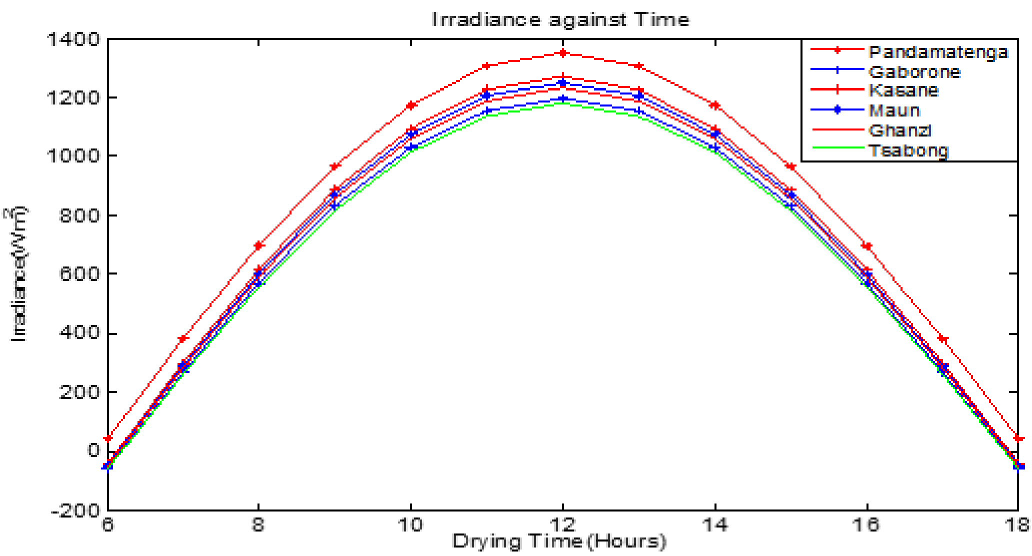

Figure 4. The hourly solar irradiance for 12 hrs in Botswana (Ketlogetswe *et al.*, 2007; Kalogirou, 2013).

Table 1. Evaluation of types of dryers for best performance by the dryer-factor/dryer-type matrix

S/N	Dryer-types/Dryer-factors	Passive direct cabinet dryer	Passive direct greenhouse dryer	Passive indirect tunnel dryer	Active indirect tunnel dryer	Active mixed-mode tunnel dryer	Active mixed-mode greenhouse dryer
1	Loading capacity [Scoring: lowest=1.... highest=5].	1	2	3	3	3	5
2	Mode of airflow [Scoring: Natural=1, Forced=2]	1	1	1	2	2	2
3	Mode of energy flow [Scoring: Direct=1, Indirect=1, Mixed-mode=2]	1	1	1	1	2	2
4	Alternative, energy [Not applicable=0, seldom used=1, Often used=2]	0	0	1	1	2	2
5	Total score	3	4	6	7	9	11

Source: Weighted assignment of values by researcher

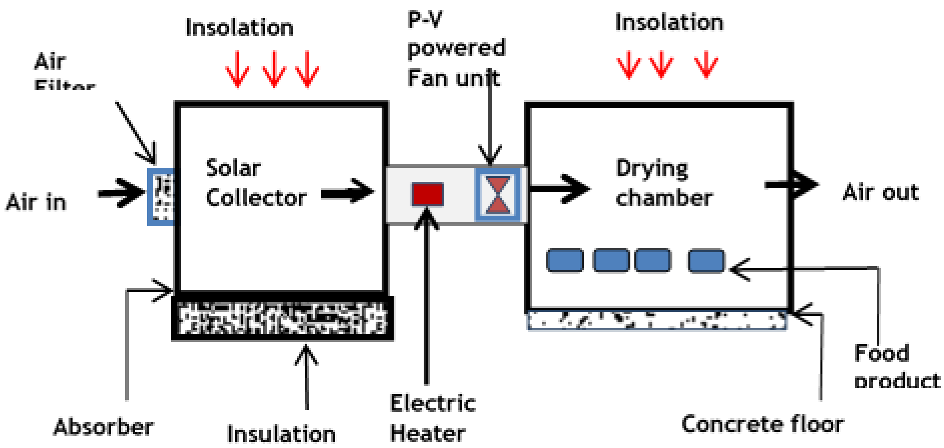

Figure 5. The schematic drawing of the physical model of mixed-mode solar dryer for commercial preservation of tomatoes. Source: Researcher

Additionally, the solar collector is designed as double pass with porous medium composed of energy storage stones to improve the efficiency of operation. It also discharges the stored thermal energy to prolong the drying process.The solar dryer physical model is depicted in Figure 5.

Conclusion

Botswana's weather and tomato characteristics are favourable for application of solar drying technologies. There is therefore a high potential of commercial preservation of tomatoes under the conditions of Botswana using enhanced mixed-mode solar drying technology.

Acknowledgements

This research was made possible through a capacity building competitive grant Training the Next Generation of Scientists provided by Carnegie Cooperation of New York through the Regional Universities Forum for Capacity Building in Agriculture (RUFORUM). The University of Botswana and Gulu University are gratefully acknowledged.

References

Bala, B., Morshed, M. and Rahman, M. 2009. Solar drying of mushroom using solar tunnel dryer. In: *Proceedings of the International Solar Food Processing Conference*.

BHM. 2010. Post harvest preservation and processing technologies for Botswana horticultural market produce. Botswana Horticultural Market. pp. 1-7.

Burden, J.W. 1989. Prevention of Post-Harvest Food Losses: Fruits, Vegetables and Root Crops A Training Manual. FAO.

Cheapok, C. and Pornnareay, P. 2000. Introducing solar drying in a developing country: the case of Cambodia. In: Proceedings of World Renewable Energy Congress VI, Part IV, Brighton.

Doymaz, I. 2005. Sun drying of figs: An experimental study. *Journal of Food Engineering* 71 (4): 403-407.

Ekechukwu, O. 1999. Review of solar-energy drying systems I: An overview of drying principles and theory. *Energy Conversion and Management* 40 (6): 593-613.

FAO, WFP. 2015. The State of Food Insecurity in the World, 2015. FAO, Rome, Italy.

Fox, T. 2013. Global food Waste, Not Want . IMechE. England and Wales.

Janjai, S. 2012. A greenhouse type solar dryer for small-scale dried food industries: development and dissemination. *Int J Energy and Environ* 3:383-98.

Kalogirou, S.A. 2013. Solar energy engineering: Processes and systems. Cademic Press.

Ketlogetswe, C., Fiszdon, J.K.and Seabe, O.O. 2007. Solar chimney power generation project - The case for Botswana.

Simate, I. 2003. Optimization of mixed-mode and indirect-mode natural convection solar dryers. *Renewable Energy* 28 (3):435-453.

Sontakke, 2015. Solar Drying Technologies: A review.

UBOS. 2010. Uganda National Household Survey 2009–2010. Socio-economic module. Uganda Bureau of Statistics Kampala, Uganda.