Available online www.jsaer.com

Journal of Scientific and Engineering Research, 2023, 10(2):90-93

Research Article

ISSN: 2394-2630
CODEN(USA): JSERBR

Design and performance evaluation of a hybrid solar dryer for cassava flour in Benin

Schadrac Don de Dieu Agossèvi[1], Thierry Godjo[2]*, Joseph Dossou[1]

[1]Laboratory of Bioengineering of Food Process (LaBioPA), Faculty of Agronomic Sciences, University of Abomey Calavi, Benin
[2]Laboratory of Engineering Sciences and Applied Mathematics (LSIMA), National University of Science, Technology, Engineering and Mathematics of Abomey, Benin
* thierrygodjo@hotmail.com

Abstract The objective of the study was to design and implement a hybrid solar dryer (solar energy and agricultural waste combustion). The manufacturing process and the use of cossettes were diagnosed by a field survey in the cooperatives of the UCTM (Union des Coopératives Transformatrice de Manioc) of Sè and in the bakery Ouidah Pain. The designed and tested dryer reveals temperatures and relative humidities of the air in the drying chamber at 65°C and 10% during the day and 32°C for 88% at night. A solar collector and heat exchanger were used for air heating. The analysis of dried cassava cossettes samples was carried out on physicochemistry and food microbiology. Cassava cossettes obtained from 1.35mm, 3.47mm and 4.87mm thick flakes had a final moisture content of 9.65±1.23%, 12.05±0.66% and 14.52±0.71% respectively, compared to 14.10±0.31% for those from the cooperatives in the wet period. In the dry period, the same cossettes have a final moisture content of 5.47±0.91%, 9.10±4.96% and 19.48±1.93% compared to 12.36±0.65% for the cooperatives' cossettes. The normative value requires moisture content lower than 12%. The luminance L > 93 of all cossettes and the clarity ΔE < 12 meet the criteria of CEBENOR NB 03.06.006. On the other hand, the acidity level of the cossettes between 0.06 and 0.09 is higher than the normative value (0.05). The sanitary quality of the 1.35 mm cossettes from the point of view of yeasts and moulds complies with the standard (< 10/g CFU). The high presence of total mesophilic aerobic germs (2.5.106 CFU/g) had a negative impact on the cossettes during the rainy season. It is therefore imperative to focus on air filtration techniques and thermal regulation of the hybrid solar dryer.

Keywords Cassava, flakes, cosset, hybrid solar dryer, Benin

1. Introduction

In recent years, the consumption of wheat-based bread has increased enormously in developing countries because of their growing population, urbanization and the resulting changes in eating habits. However, Benin, like most developing countries, relies on importing wheat flour at over 100,000 tons [1]. To increase the domestic currency, following the increase in the cost of wheat and the difficulty of bakeries to bear the production costs, the Beninese government authorized by decree N°2008-571 of October 15, 2008, the use of cassava bread flour up to 15% in bread baking and pastry [2] according to the Beninese standard NB 03.06.006 edition 2007 of CEBENOR. The production of this flour by women's groups being artisanal, doesn't allow having a quality product [3]. Indeed, a study observed in North Benin that solar drying with ambient air [4], previously supported by the Root and Tuber Plant Development Program (PDRT) [5] does not yield cassava cossettes of better quality. However, research efforts [6] reveal a solar tunnel dryer using domestic gas as a thermal backup for drying cassava cossettes. In the face of economic vulnerability and low level of rural electrification, research prospects for solving food drying problem should be oriented on the use of local resources [7]. In this context, the present study aims at designing and implementing a hybrid solar dryer for drying cassava chips for processing into bread flour.

2. Material and Methods

The surveys were conducted in the Mono and Atlantic departments. Information was collected by means of questionnaires in six (06) cooperatives and in the Ouidah Pain bakery. The data collected concerned the process and materials, difficulties and production capacity. The value analysis approach and the functional analysis tools were adopted during the design work, which was oriented towards the use of local materials. Intermediate design objects such as the Functional Specifications, technical drawings from the numerical modelling done with Creo Parametric and the numerical model done with Creo Simulate were used to build the dryer. The cassava roots of variety RB 89509 were respectively provided by the cooperatives in wet period and by the insectarium of IITA-Benin in dry period. Each replicate of 1 kg of cossettes per sample was separately dried for 24 hours without interruption. The final moisture content was determined from the dry matter obtained according to the AACC 44-15A method cited by [8]. Regarding the color and clarity, they were measured using a CR-410 chromameter calibrated with white ceramic. Microbiological analyses were carried out on Total Aerobic Mesophilic Germs (TAMG) enumerated on Plate Count Agar (PCA) following the method described by [9]. Yeasts and moulds were counted by plating on Sabouraud medium with glucose [10]. The values obtained were recorded in the Excel spreadsheet and then analyzed using Minitab19 software.

3. Results and Discussion

The manufacturing process consisted of cutting the cassava and air-drying the cossettes on racks raised on stalks for three (03) days in the dry period and five (05) days in the wet period. The production capacity was 800 kg of cossettes per month for 1 kg/m2 and they were stored in recycled wheat bags. As demand was high, the production capacity of the cooperatives was not sufficient to cover the monthly orders of three (03) tons from the Ouidah Pain bakery.

Design and construction of the dryer

The need to increase and sustain production in the quality cassava cossettes value chain was identified using the horn tool. The involvement of the cooperatives helped define the components of the dryer. Indeed, [11] and [12] report that user involvement often has a positive impact. The materials identified were used to build the dryer. The dryer was made of plywood with a Neem wood frame. It is a two-in-one unit composed of a solar collector (0.5 m²) for air preheating and a drying chamber (0.5 m²) on the one hand, and a thermal booster for air heating on the other hand. The drying rack is raised to 50 mm from the internal surface of the dryer. It is covered with a 4 mm Plexiglas with a solar chimney made of rigid PVC pipes painted in black. The choice of Plexiglas supports the results of [13] which show that solar drying increases bread making capacity. Two vents allowed air to enter and exit the solar collector to enter the drying chamber. The absorbing surface of the solar collector was covered with black cloth and the hearth of the heater was made of clay. The local materials had provided good resistance to environmental hazards according to the perspectives of [7].

Operation of the dryer

During the day, cassava flakes exposed on the rack in the drying chamber, received forced air between 0.1 and 0.3 m/s with a flow rate between 10.5 and 19.2 m3/min at 60°C with 10% relative humidity, when it is at the entrance of the solar collector by natural convection between 0.2 and 1.08 m/s with a flow rate from 37.5 to 78.9 m3/min. The air temperature corresponding to that of the standard was confirmed by [11]. The observed temperature increase was due to the preheating of the air to 55°C by the absorbing surface and the greenhouse effect created in the solar collector and also in the drying chamber. The drying being by entrainment, the air at its exit by the chimney was at 45°C and 75% of relative humidity. When the sun disappeared, the thermal supplement was activated to avoid the re-wetting of the cossettes. For this purpose, the heat exchanger heater is supplied with air of 26 to 28°C through a ventilated channel. The air entering the dryer was at 45°C and 35% relative humidity and leaving at 30°C for 95% for 3 hours of combustion of 5 kg of sawdust.

Performance analysis

The normative criteria were: final moisture content, titratable acidity, color, luminance, yeasts and moulds and Total Aerobic Mesophilic Germs.

Wet period

The 1.35mm cossettes had a final moisture content of 9.65±1.23% meeting the standard (< 12%) compared to 12.05±0.66% of the 3.47mm cossettes and 14.10±0.31% of those of 4.87mm. The values of luminance (L) and brightness (ΔE) revealed a significant difference between the cossettes. The 1.35mm cossettes had 0.06% titratable acidity higher than the standard (0.05%) and lower than 0.07% of those of the cooperatives.

Dry period

The acidity level 0.06% of 1.35 mm cossettes above the norm was lower than 0.08% of those of the cooperatives. The final moisture content 5.47±0.91% of 1.35 mm cossettes and 9.10±4.96% of 3.47mm met the normative value (< 12%). The luminance (L ≥ 93) and clarity (ΔE ≤ 12) found that the cossettes met the set values.

Sanitary quality

The low presence of yeasts and moulds at the end of drying in the (Table 1) revealed the performance of the dryer in drying the cossettes. On the other hand, the high load of total flora above 200 CFU/g in some cossettes was due to the presence of airborne dust.

Table 1: Health quality of cassava cossettes

Cassava Cossettes	**Total flora (CFU/g)**	**% of Inhibition**	**Yeast and Moulds (CFU/g)**
Samples	Rehearsals	Microbial load	Microbial load
Thickness 1,35mm	Ep1E1	-	-
	Ep1E2	$2.5.10^{6}$	$2.2.10^{5}$
Thickness 3,47mm	Ep3E1	$2.1.10^{6}$	$1.8.10^{4}$
	Ep3E2	$1.6.10^{5}$	-
Thickness 4,87mm	Ep4E1	$6.2.10^{4}$	-
	Ep4E2	$8.2.10^{4}$	-
Cooperative	Coop	-	-
Beninese Standard		< 200	< 10

5. Conclusion

In view of the economic context and energy availability, the appropriate application is solar drying with an external heat source. This study highlighted the relationship between the different cossettes and the time of year with the studied dryer. Two cassava cossettes 1.35 mm and 3.47 mm meeting the normative criteria NB 03.06.006 were of sufficient quality for processing into flour for bread. Moreover, it was possible to increase the production capacity by 67% (838g/0.5m² against 500g/0.5m² of the cooperatives) for 1.35mm and 44.72%

(723.6g/0.5m²) for 3.47mm. With the sanitary quality observed, an air filtration system is essential to ensure better cossette quality.

References

[1]. Godjo et al. (2022). Feasibility study for energy recovery of peels resulting from cassava processing into gari: case of the mawudagba cooperative in Benin. International Journal of Advanced Research, Vol. 10(10). ISSN 2320-5407. DOI:10.21474/IJAR01/15560. pp. 907-922.

[2]. Yaou Bokossa, I. et al. (2012). Substitution of wheat flour by fermented cassava flour (lafu), in the preparation of bakery bread, 14, pp. 1-9.

[3]. FAO (2015). *Project on Strengthening Trade Relationships between Smallholder Producers and Buyers in the Root and Tuber Sector in Africa: GCP/RAF/448/EC*

[4]. Degnon, G. R. et al. (2018). Evaluation of the production conditions, physico-chemical and microbiological quality of cassava (Manihot esculanta Crantz) cossettes in the commune of Bassila (Nord-Benin), 12, p. 14. doi: https://dx.doi.org/10.4314/ijbcs.v12i3.36.

[5]. Fidafrique (2009). *New methods for drying cassava cossettess (PDRT)*. Benin: youtube. Available at: https://www.youtube.com/watch?v=3RK3zyyZ-fI&t=237s.

[6]. Houssou, A. F. P. *et al.* (2016). *Performance evaluation of a hybrid dryer for drying yêkè-yêkè (maize couscous) and gambari-lifin (refined maize flour) in Benin*, 27, pp. 151-159. Available at: https://www.researchgate.net/publication/328702942.

[7]. Yahaya, Y., Zabeirou, R. and Durandl, J.-M. (1986). Solar drying in Africa: Proceedings of the symposium held in Dakar', in Bassey, M. W. and Schmidt, O. G. (eds) Solar drying in Africa: Proceedings of the symposium held in Dakar, Senegal, 21-24 July 1986. Dakar: International Development Research Centre, pp. 127-148.

[8]. Ballogou, V. Y., Batcho, S. K. A. D. and Dossou, J. (2019). *Improvement of the traditional Moringa oleifera leaf tea production process in Benin*, 2, pp. 71-81.

[9]. Humeau, L. (2010). *Gelose pca*, 33(0), p. 2. Available at: commercial@humeau.com.

[10]. Bio-Rad (2007). *Agar medium C (Sabouraud agar with glucose)*, p. 2. Available at: www.foodscience.bio-rad.fr.

[11]. Amouzou, K., Gnininvi, M. and Kerim, B. (1986). Solar drying in Africa, in Bassey, Michael W., and Schmidt, O. G. (eds.) *Solar drying in Africa*. Togo: International Development Research Centre, pp.280-301.

[12]. Godjo, T. (2010). Scenarios to foster user participation in the design of small scale agricultural and food processing equipment in sub-Saharan Africa countries. In Proceedings of the 11th Biennial Participatory Design Conference (pp. 247-250).

[13]. Dufour, D. *et al* (1995). Food processing of cassava, in Egbe, T. A. et al (eds) *Food processing of cassava*. ORSTOM édi. PARIS, pp. 400-417.