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EVALUATION OF THE THERMAL PROFILE OF A SOLAR PHOTOVOLTAIC COLD ROOM LOADED WITH MANGOES

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ABSTRACT

In this work we present the results of the study conducted on the characterization of a cold storage room containing mangoes. The study was carried out at the Energy Department of IRSAT/CNRST of Burkina Faso. The device used is a cold storage room powered by solar photovoltaic energy for the conservation of agricultural food products (mangoes, onions or potatoes). Cold being expensive to produce, it is imperative to insulate the walls of the storage room properly. This is why, after the design and construction of the cold storage room, it was necessary for us to characterize it during the phase of mango conservation. Temperatures of the internal and external walls of the warehouse were measured and simulated to establish their profiles. Due to the insulation, the internal temperature of the cold room is reduced comparatively to the external temperature. Indeed, the difference between the maximum external and internal temperature can reach 20°C. The northern and eastern walls are the hotter wall due to their exposure to solar radiation respectively in the morning and in the afternoon. The time phase shift of the southern wall is 3 to 4 hours. It appears that the cold storage room studied has good thermal profiles for the conservation of agricultural products

KEYWORDS: Cold room, conservation, solar photovoltaic, Temperatures profiles, simulation.

Nomenclature

Pne	:	external northern wall	**Spee**	:	area, of the external, eastern wall,m^2
Pse	:	external southern wall	**Spei**	:	area, of the internal eastern wall , m^2
Poe	:	external western wall	**Spni**	:	area, of the internal northern wall,m^2
Pee	:	External eastern Wall	**Spoe**	:	area, of the external western wall,m^2
Pni	:	internal northern wall	**Spsi**	:	area, , of the internal southern wall,m^2
Psi	:	internal southern wall	**m**	:	mass, kg
Poi	:	internal western wall	**mpni**	:	mass of the internal northern wall, kg
Pei	:	internal eastern wall	**mpsi**	:	mass of the internal southern wall, kg
Plaf	:	Ceiling	**mpoi**	:	mass of the internal western wall, kg

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Planch	:	Floor	**mpee**	:	mass of the external eastern wall, kg
Sol ou planch ext	:	external floor	**mpne**	:	mass of the external northern wall, kg
S	:	area, m^2	**mpoe**	:	mass of the external western wall, kg
Spne	:	area, external northern wall, m^2	**mpei**	:	mass of the internal eastern wall, kg
Spoi	:	area, internal western wall, m^2	**mpse**	:	mass of the external southern wall, kg
Spse	:	area, external southern wall, m^2	**e**	:	Thickness, m
T	:	Temperature, ° C	e_{al}	:	thickness of aluminum, m
Tcv	:	temperature of the celestial vault, ° C	$e_{polystyrène}$	:	expanded polystyrene thickness, m
Tfe	:	external fluid temperature, ° C	φ_{GN}	:	global solar flux incident on the outer northern face, $W.m^{-2}$
Tpne	:	external northern wall temperature, ° C	**hce**	:	coefficient of heat transfer by convection between the ambient air and the external wall, $W.m^{-2}.K^{-1}$
Tpni	:	internal northern wall temperature, ° C	**hci :**	:	coefficient of heat transfer by convection between air and internal walls, $W.m^{-2}.K^{-1}$
Tpsi :	:	internal southern wall temperature, ° C	**hrsol**	:	coefficient of heat transfer by radiation between the outer wall and the ground, $W.m^{-2}.K^{-1}$
Tpse	:	external southern wall temperature, ° C	**hrciel**	:	radiative heat transfer coefficient between the outer wall and the celestial vault, $W.m^{-2}.K^{-1}$
Tpoi	:	internal western wall temperature, ° C	**hpni**	:	coefficient of convective heat transfer between air and the internal north wall, $W.m^{-2}.K^{-1}$

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Tpee :	:	external, eastern wall temperature ° C	**hpsi**	Coefficient of heat transfer by convection between the air and the inner south wall, $W.m^{-2}.K^{-1}$
Tpoe	:	external western wall temperature, ° C	**hpei**	Coefficient of heat transfer by convection between the air and the wall is internal, $W.m^{-2}.K^{-1}$
C_P	:	Constant pressure constant heat, $J.kg^{-1}.K$.	**hpoi**	Coefficient of heat transfer by convection between air and the internal west wall, $W.m^{-2}.K^{-1}$
Pf	:	cooling capacity, W	**Pni→Poi**	The internal face of the northern wall radiates towards the internal face of the western wall
Qresp	:	mango breathing heat, kJ / kg.24	**Psi→Poi**	The internal face of the southern wall radiates towards the internal face of the western wall
Qre	:	daily heat quantity per air renewal, kJ	**K**	overall exchange coefficient, $W.m^{-2}.K^{-1}$

1. INTRODUCTION

A cold storage room is a building or group of buildings designed to store certain products under well-defined temperature and relative humidity conditions [1]. The role of cold storage rooms is to keep food products in a good state of quality and to extend their availability for later consumption. This storage and conservation system is based on the production of cold. The cold storage room designed at IRSAT is temperature positive [2].

In Burkina Faso, fruit and vegetable sub-sector is expanding. However, it faces enormous difficulties related to the conservation of products. A very large part of production is lost during the period between production and consumption, often reaching 22% [3]. Cold storage can reduce this post-harvey. Conventional cold rooms consume a lot of electrical energy and their energy source generate pollutants (greenhouse gases, sulfur oxides, nitrogen oxydes etc.). Their energy cost makes them inaccessible to producers. The production sites are generally located in rural areas, without electricity [4]. Poor road conditions and low local consumption lead to poor sales, increasing the loss of products. Refrigeration and air conditioning consume high amount of energy and are therefore expensive to achieve. For this reason energy efficiency is essential in developing cold storage room. Hence it is important to properly insulate the walls of the cold room. Indeed, the insulation has a great importance on the general functioning of the installation. Too low, it facilitates heat entry through the walls and the running time of the compressor is above normal. Too high, it can maintain humidity in a cold room because the heat inlets through the walls being weak, the running time of the compressor will be insufficient to maintain the hygrometric degree at a value compatible with the good conservation of the stored foodstuffs [5]. Even if the

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use of cold for food conservation dates back to antiquity, cold is the first food conservation technique that preserves the original qualities of the foodstuff [6].

The same product storage parameters at all points in cold rooms can hardly be achieved [7], [8], [9]. Disparity in humidity, temperature, and a no-monotonous air flow are the factors behind this uneven distribution. Other authors have shown that these same factors exist in refrigerated trucks [10], display cases [11] and domestic refrigerators [12]. The presence of the product and cooling equipment causes an irregular distribution of the air flow [13], but also of the breathing heat, which is a source of temperature heterogeneity [14]. This is why the heat transfer coefficient between the air and the product at different positions in the cold room varies, inducing different cooling rates of the products [15]. [16] The stacked products are cooled by the phenomenon of conduction [17]. The major handicap of refrigeration in the cold room is the cooling time [18]. Indeed the cooling rate of the products depends on several factors [19], [20]. It is imperative to maintain the relative humidity of the air at high values (90-98%) to avoid mass losses (weight) of the product [21]. The transfer of heat, mass and air flow in a cold room is complex [22].

This work presents the results of the study conducted on the characterization of a solar photovoltaic cold chamber loaded with mangoes. The study was carried out in Burkina Faso. During the study, the temperatures of the internal and external walls of the cold room were measured and simulated.

2. MATERIALS AND METHODS

The material used to carry out the different experiments consists of a cold room, mangoes which has been described elsewhere [2]. It consists mainly of a 32 m^3 chamber connected to an air cooled compressor/condenser unit placed inside a technical room located along the eastern wall of the refrigerated cold room. The system is supplied with electrical energy by a mini photovoltaic plant of 5 kWp. This power is provided by 20 modules of 250 Wp each of which are grouped in two strings, one of 12 modules and the other of 8 modules. Two hybrid inverters of 5 KVA supply both cooling units. An energy storage system consisting of 24 batteries of 2V-500Ah each ensures the continuity of the supply of electricity at night and during days of low sunshine.

In the cold storage room the evaporators are placed below the ceiling and are in forced convection with the fans placed on the front panel, thus causing air circulation. The air leaving the evaporator horizontally flows above and through the products. When circulating among cartons, crates, bins, the air cools the products and always returns to the evaporator.
The equipment used to collect temperature, solar radiation and humidity are described below.

- ***Midi LOGGER GL 220***: a 10 logger channel data with the channels connected to type K thermocouples. The logger has a margin of error of ± 5.2°C for a range of values between 0°C and 100°C and ± 3°C for a range of values between 100°C and 300°C.
- ***Midi LOGGER GL 200A***: a 20 logger channel data with the channels connected to type K thermocouples. The logger has a margin of error of ± 5.2°C for a range of values between 0°C and 100°C and ± 3°C for a range of values between 100°C and 300°C.
- All **thermocouples** are of K type. They were checked for calibration at the freezing and boiling points of the water.
- Two (02) ***hygrometer*** MSR 145S units were used to measure indoor and outdoor relative humidity every ten minutes. The ambient (outside) temperature (To) and the ambient relative humidity (RHo) were measured in the shade to avoid the effect of direct solar radiation.
- The power of the solar radiation is measured using a ***pyranometer*** placed on the experimental site during the days of measurement. It is connected to the data logger. The pyranometer has a margin of error of ± 1%.

A humidifier (Airmate CF402RI) has ensured the humidity level of the required air in the cold room.

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Figure 1 : Overview the interior of the storage room with mangoes

The storage phase of the mangoes in the cold room lasted for about seven (07) weeks from June 14thto August 2nd2017. During this experimental phase, the temperatures of the internal and external walls and the temperature of the internal air in the warehouse were measured in order to establish their profiles. We define the type of heat and mass transfer equations to simulate the temperatures of these walls over 12 months using Mathlab software (R2017a).

The cold room has a parallelepiped shape, the equations of thermal transfers at the level of the walls have been described according to the three modes of thermal transfer namely conduction, convection and radiation. In the cold room, the air is in forced convection between the six walls, the walls are subjected to long wavelength radiative heat exchanges between them, there are air infiltrations (gain or loss) that we have neglected. In the cold storage, the heat sources to overcome are the amount of daily heat per air change (Q_{re}), the cooling capacity (P_f), and the respiration heat of mangoes (Q_{resp}).The surfaces of the outer walls are subjected to convective heat exchanges with the air, radial solar heat exchanges (long and short wavelengths) with the celestial vault on the one hand, and the ground on the other hand, to heat conduction towards the inside of the chamber. From the outer side to the inner side, each wall of the chamber is made of 1 mm thick alumna sheet, 10 cm expanded polystyrene layer, 1 mm thick alumna sheet. The determination of parameters such as temperature has been made under certain assumptions, namely: heat transfer takes place in the direction perpendicular to the walls, the walls are assumed to have a uniform composition, as well as the floor and ceiling, the walls receive a constant density flux, the fluid is Newtonian and incompressible, the thermo-physical properties of the fluid (ρ_{air}, Cp_{air}, λ_{air}) are constant over time, on a given surface, the solar radiation flux received at each instant is uniform at any point on this surface. Thus the basic thermal transfer equations were established at the different walls and inside the cold room.

External walls

The temperature variation of the external North wall is given by the following relationship:

$$\frac{dT_{pne}}{dt} = \frac{1}{m_{pne} \cdot C_P} \cdot \{S_{pne} \cdot [h_{ce} \cdot (T_{fe} - T_{pne}) + K \cdot (T_{pni} - T_{pne}) + h_{rciel} \cdot (T_{cv} - T_{pne}) + h_{rsol} \cdot (T_{sol} - T_{pne})] + S_{pne} \cdot \varphi_{GN}\} \quad (1)$$

There are six external walls, so there are as many equations.

- **Internal walls**

The temperature variation of the internal north wall is given by the following relationship:

$\frac{dT_{pni}}{dt} = \frac{1}{m_{pni} \cdot C_P} \cdot S_{pni} \cdot [h_{ci} \cdot (T_{fi} - T_{pni}) + K \cdot (T_{pne} - T_{pni}) + h_{r(pni \to poi)} \cdot (T_{poi} - T_{pni}) + h_{r(pni \to pei)} \cdot (T_{pei} - T_{pni}) + h_{r(pni \to psi)} \cdot (T_{psi} - T_{pni}) + h_{r(pni \to plaf)} \cdot (T_{plaf} - T_{pni}) + h_{r(pni \to planch)} \cdot (T_{planch} - T_{pni})]$ (3)

There are also six inner walls, so there are as many equations.

- **Indoor air**

The variation in the temperature of the air inside the chamber is given by the following relationship**:**

$$\frac{dT_{air}}{dt} = \frac{1}{m_{air} \cdot c_{p_{air}}} \{[S_{pni} \cdot h_{pni} \cdot (T_{pni} - T_{air}) + S_{pei} \cdot h_{pei} \cdot (T_{pei} - T_{air}) + S_{poi} \cdot h_{poi} \cdot (T_{poi} - T_{air}) + S_{psi} \cdot h_{psi} \cdot (T_{psi} - T_{air}) + S_{plaf} \cdot h_{plaf} \cdot (T_{plaf} - T_{air}) + S_{planch} \cdot h_{planch} \cdot (T_{planch} - T_{air})] + Q_{re} - P_{frigorifique} + m_{mangue} \cdot Q_{resp}\}$$

3. RESULTS AND DISCUSSION

The main results established during the cold room evaluation are described through the measured thermal wall profiles. The results of the simulation of these profiles are also described and analyzed below, as well as the thermal response of the cold room. Figure 2 presents a typical temperature and solar radiation of the experimental site during the testing period. Maximum ambient temperature is commonly around 35°C and the maximum solar radiation is close to 900 W/m^2. Fluctuations exhibited on the figure are due to cloudy sky since the testing period is situated inside the rainy season.

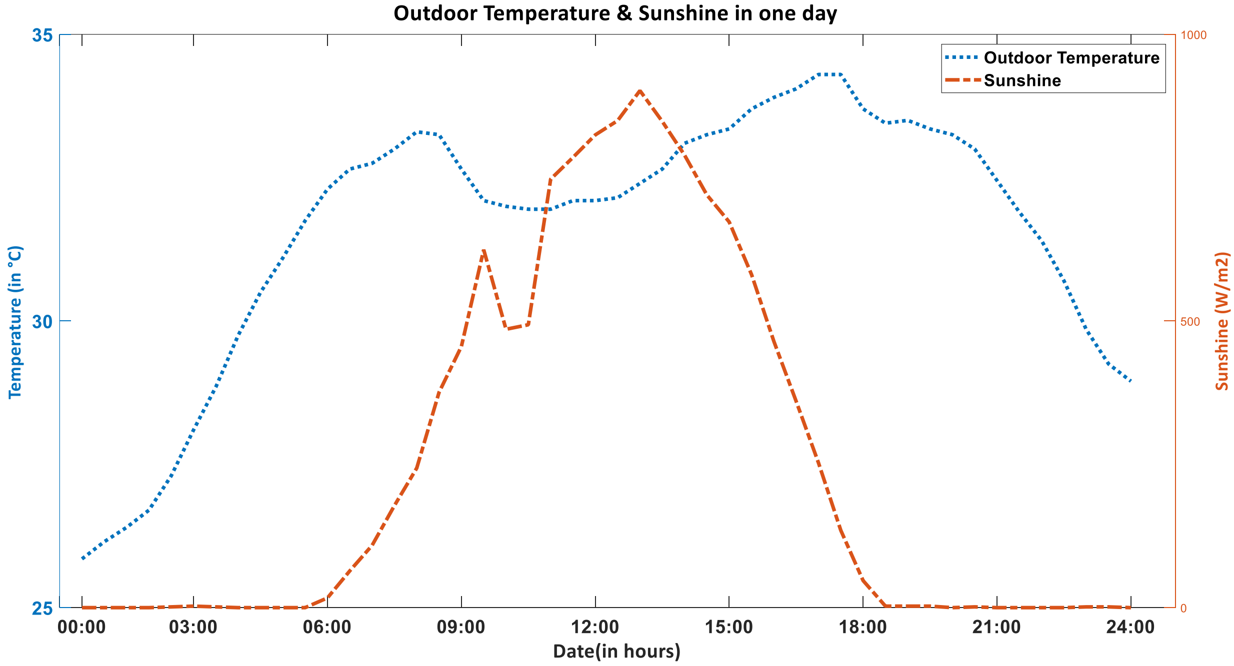

Figure 2 : solar radiation and temperature profiles measured on June 18th 2017.

Figure 3 presents the interior and exterior daily average temperatures of the different walls (North, South, East and West) of the cold storage. Cooling induces differences between outer and inner daily average temperatures which can be as high as 26 ° C as it can been noticed for the eastern wall. This latter wall has the highest difference observed between an inner and outer side of the different walls because the engine room is located on the eastern side of the storage. The different patterns exhibited by these figures show that the amplitudes of inside wall temperature are lower than that of the outside wall. Therefore, we conclude that the insulation is efficient.

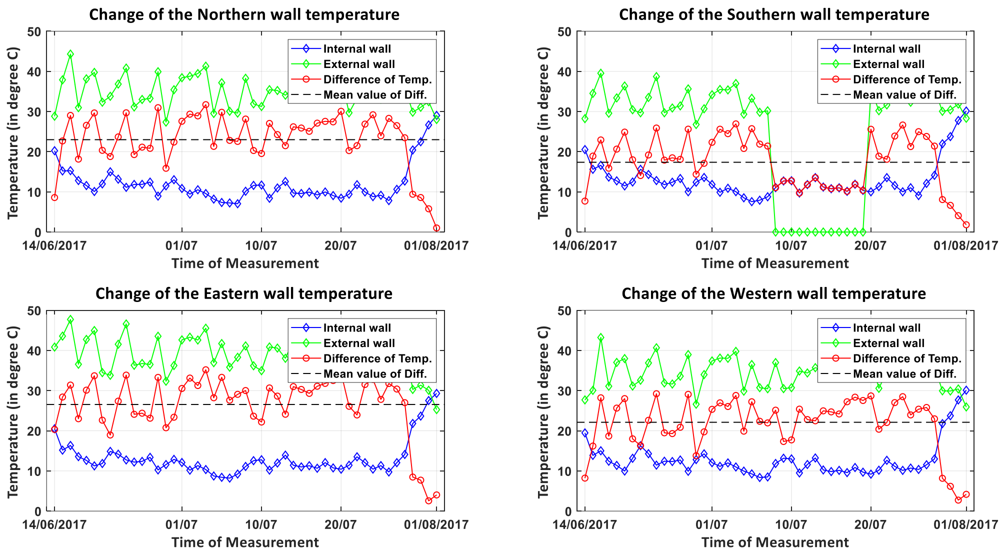

Figure 3 : Internal and external average daily temperatures of the eastern wall of the cold storage room.

Table 1 : Maximum and average differences of the daily average temperature of the walls of the storage room.

Walls	***Maximum temperature differences, °C***	***Average temperatures differences, °C***
North	31.7	23.0
South	26.9	17.4
East	35.2	26.5
West	29.2	21.7

The highest values on the maximum temperature difference is obtained for the eastern wall with 35.2°C.This is also the wall that shows the maximum on the average daily temperatures difference with 26.8°C. The smallest values for the maximum and average temperature differences are observed on southern wall. The south side should be the hotter one due it exposure to the sun but there is a tree on this side which constitutes a protection shield.

Figure 4presents the changes in the external temperatures of the west, north, south and east walls. During the period of our experiment, there was rain and wind so that the thermocouples placed on the outside walls often blown off. Overall, the eastern and at a lesser extent, the northern and western had the highest external wall temperature. But the temperature of the eastern wall is abnormally high because it is located in the engine room. No values were recorded from 08/07/17 at 09h 52min to 20/07/17 at 8h 57min due to thermocouples failure.

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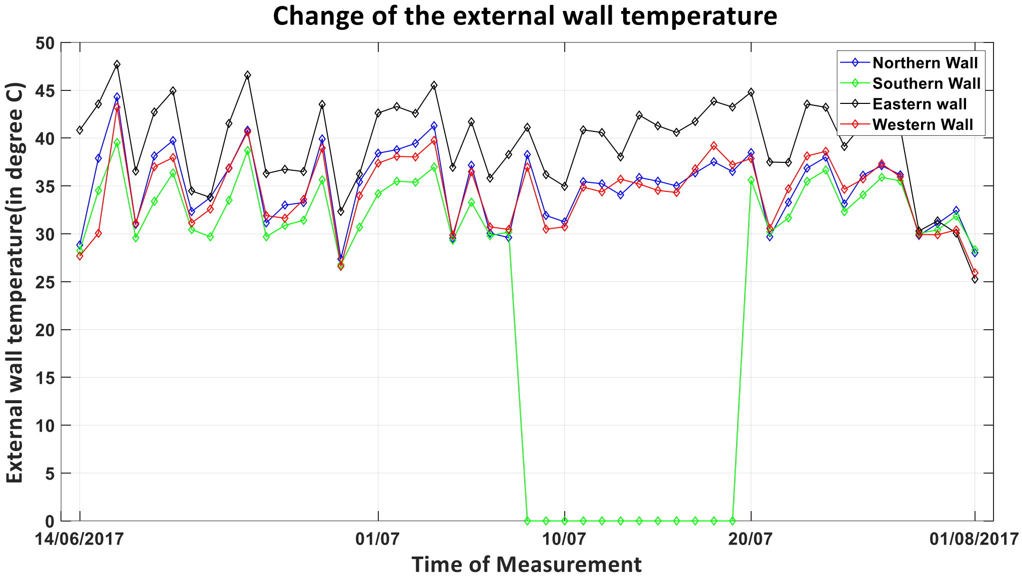

Figure 4: Evolution of external wall temperatures.

Figure 5 gives an overview of the temperature changes of the internal walls. We note that the temperature difference between the interior walls is less than 2°C. This small difference of 2°C between the different walls indicates the uniformity of the cold room temperature. The temperature rise exhibited on the limits of the figure corresponds to the end of our experiment. The average temperature of these walls varies between 10°C and 15°C, which are the setting points of the refrigeration unit in accordance with of the recommended temperatures of 10° to 12°C required for good conservation of mango [23]

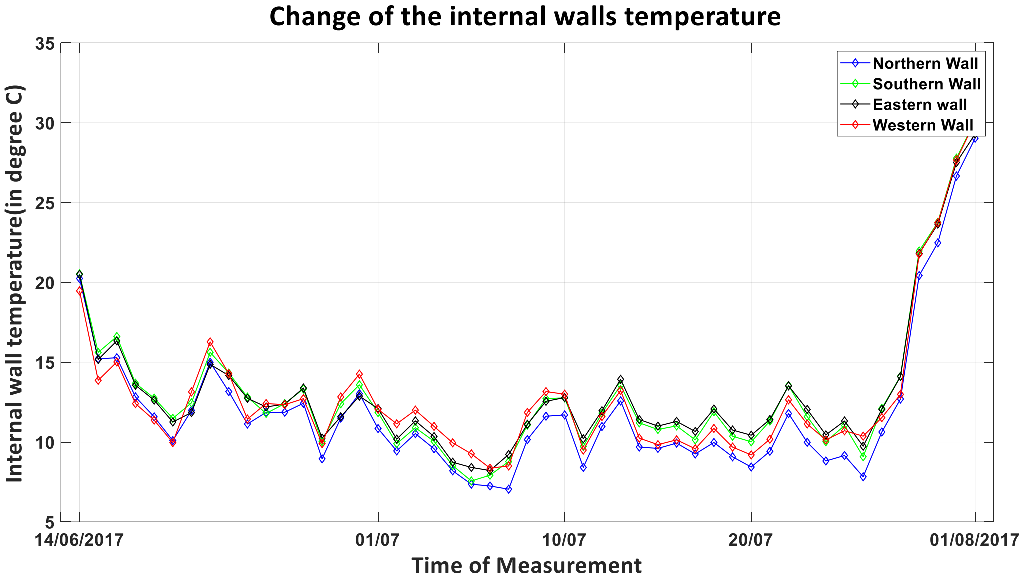

Figure 5: Evolution of the internal temperature of the walls.

Measured and simulated indoor and outdoor temperatures of the East, West, North and South walls are presented on Figure 6 which also presents the evolution of simulated air temperatures inside and outside the cold store over 12 months.

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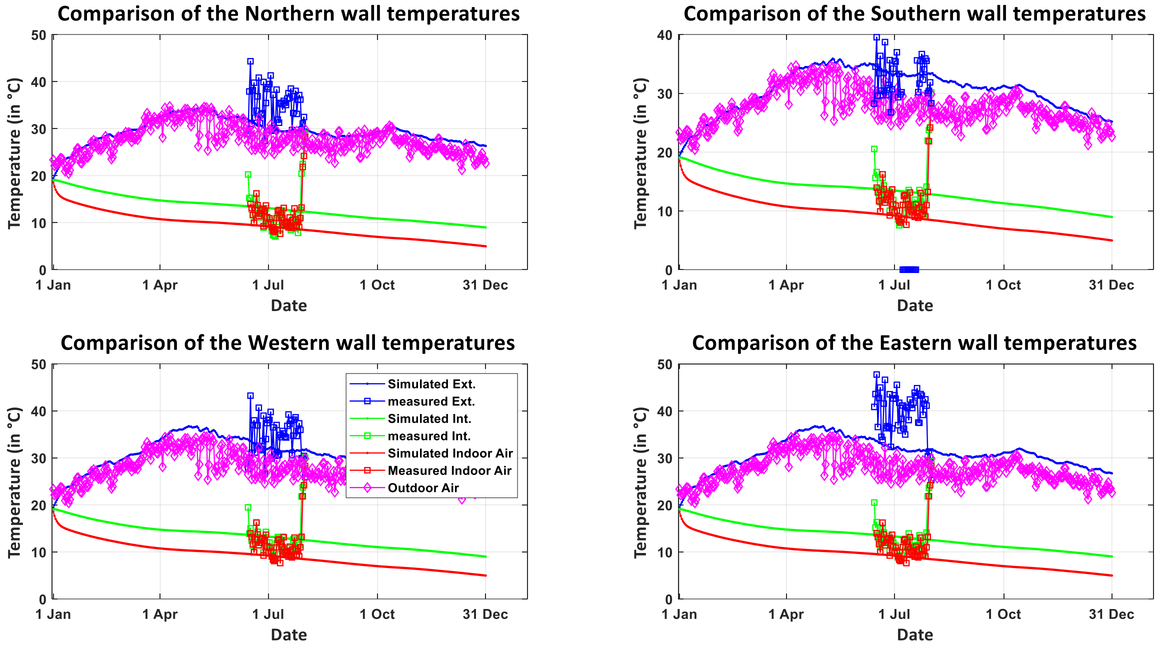

Figure 6: Evolution of indoor and outdoor wall temperatures measured and simulated indoor air, simulated outdoor fluid over 12 months.

Table 2 is showing an overview of the average differences of simulated and experimental temperature for internal and external walls as well as internal air temperature.

Table 2 : Average differences of simulated and experimental temperature for internal and external walls as well as internal air temperature.

Parameters	simulated	Experimental
Indoor air temperature	9.01	11.9
Average daily interior and external temperature differences		
Western wall	19.0	21.7
Eastern wall	19.0	26.5
Southern Wall	20.1	17.4
Northern wall	17.2	23.0

Figure 6 shows the measured and simulated curves of the different walls of the cold store. An average difference of 4°C between the simulated values of the internal walls and the internal air is observed. On the other hand, the simulated values of the external walls and the external fluid (external air) are confused. The measured and simulated values of the south outer wall are confused. The measured and simulated values of the West wall are also confused, while the measured values of the East wall are higher than the simulated values. The east wall is located in the technical room containing the compressor and condenser, its temperature is abnormally high. As for the North wall, it is the sunniest because the declination of the sun is positive in the North and negative in the South at this time of year in our site (the experiment took place from June 14 to August 02, 2017). Figure 6 also shows that the measured and simulated values of the internal walls do not totally coincide. Indeed, thermocouples instead of measuring the temperature of the walls measured the air temperature, because they were poorly bonded to the walls. This is why the measured values of the inner walls and the inner air are abnormally confused because our measuring device is the centre of the chamber, but next to the wall these gaits are normal, and we can also add that the breathing heat of the mangoes has been minimized in the calculation codes. Indeed, it is another source of temperature heterogeneity [14]. The measured values of the indoor air are slightly higher than those simulated, this is due to the fact that very often the cold room door was opened.Figure 7 below provides an overview of the evolution of simulated outdoor wall temperatures over 12 months.

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Depending on the time of year, the East-West, South and North walls are sunnier. Indeed, in Figure 7, from January to February the East and North walls arethe warmest, from February to April the East wall is the sunniest, from April to May and from September to October it is the West wall even if it is not very visible, from June to September the South wall is the warmest, from November to December the East and North walls are clearly sunny, the meteorological data used in our simulation are those of the city of Ouagadougou and not those of our site because non-existent

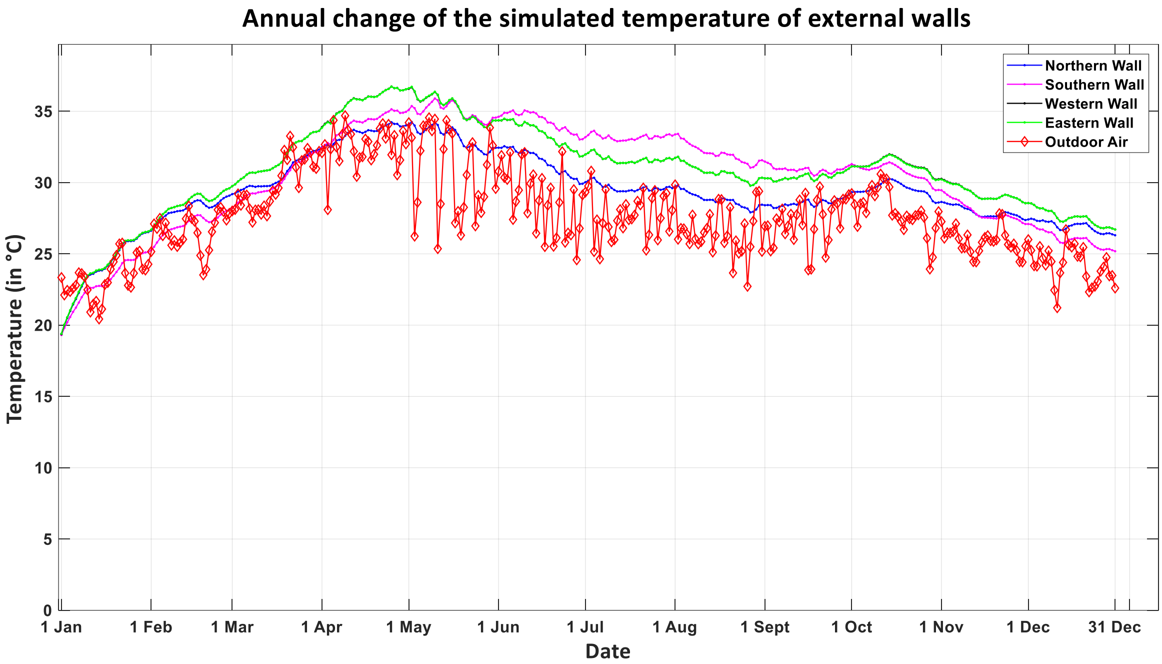

Figure 7: Evolution of simulated external wall temperatures compared to those of the external fluid over 12 months.

Figure 8 provides an overview of the evolution of wall interior temperatures and indoor air temperatures simulated over 12 months. We note that the average temperature difference between the interior walls is less than 2°C. The average temperature difference between the temperatures of the internal walls and the indoor air is 4°C overall.

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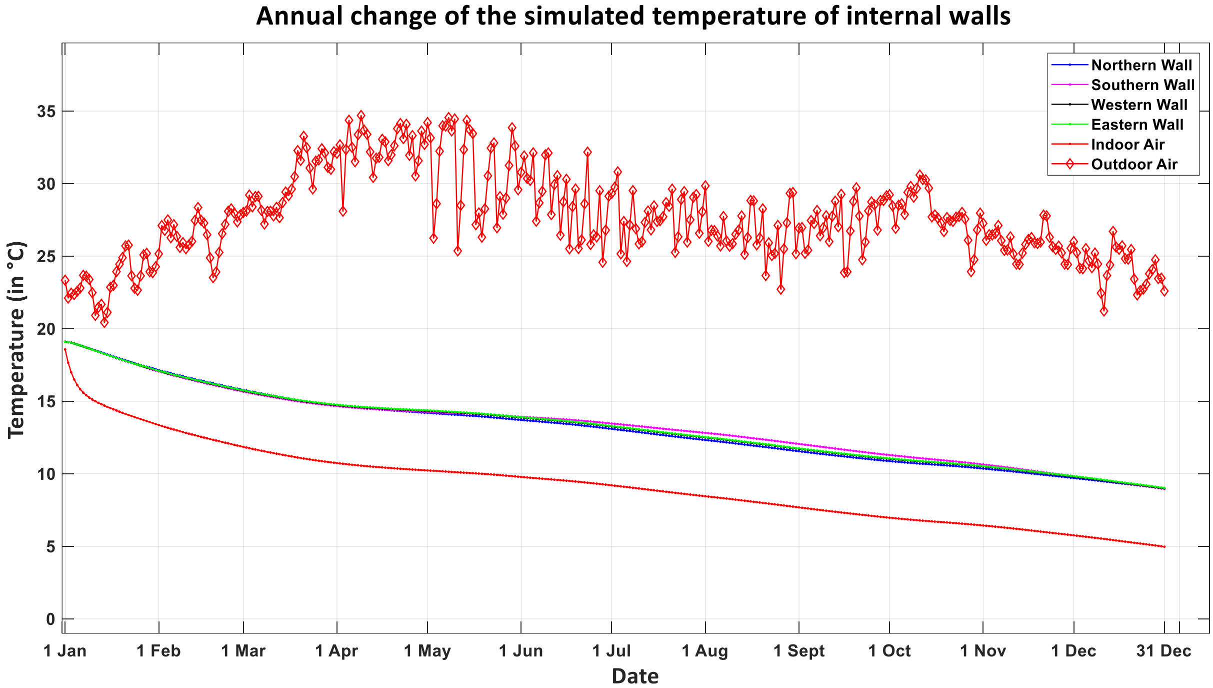

Figure 8: Evolution of simulated indoor wall temperatures and indoor air temperatures compared to those of the outdoor fluid over 12 months.

Figure 9 gives presents the profiles of the measured and simulated air temperatures in the cold room. There is an average difference of 3°C between the simulated and measured values. As a reminder, the simulation is spread over 12 months, while the mango conservation phase lasted from June 14 to August 2, 2017

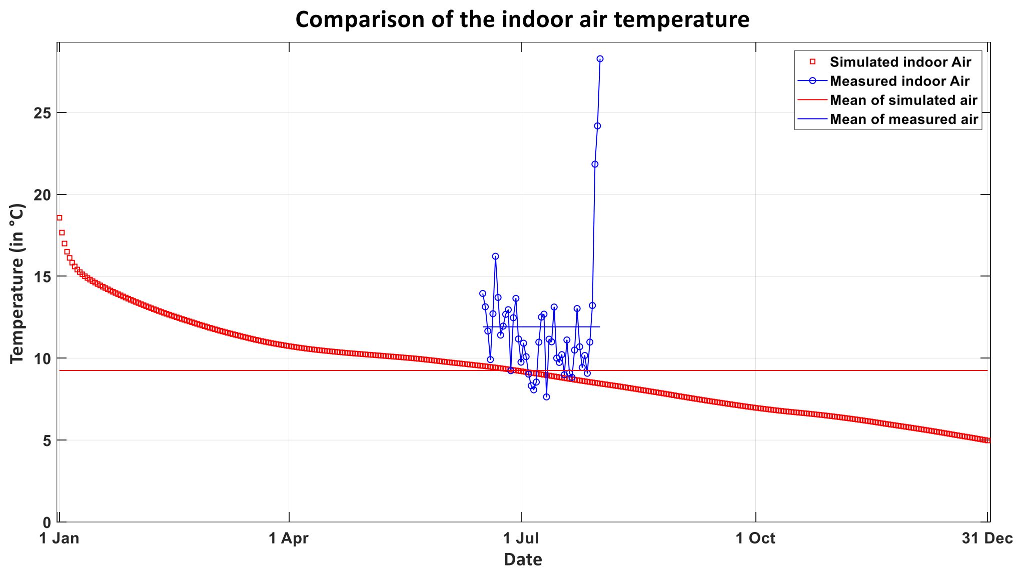

Figure 9: Evolution of measured and simulated air temperatures in the cold room.

The temperature of the air inside the chamber decreases from January to the end of March around 10°C, increases from April to June around 13°C and from June to December it tends towards 5°C.Figure 10 shows the damping and phase shift of the west and south walls temperatures during a typical day. When the outside

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temperature reaches its maximum, the inside temperature takes 3 to 4 hours to reach its maximum, which results in a phase shift of 3 to 4 hours.

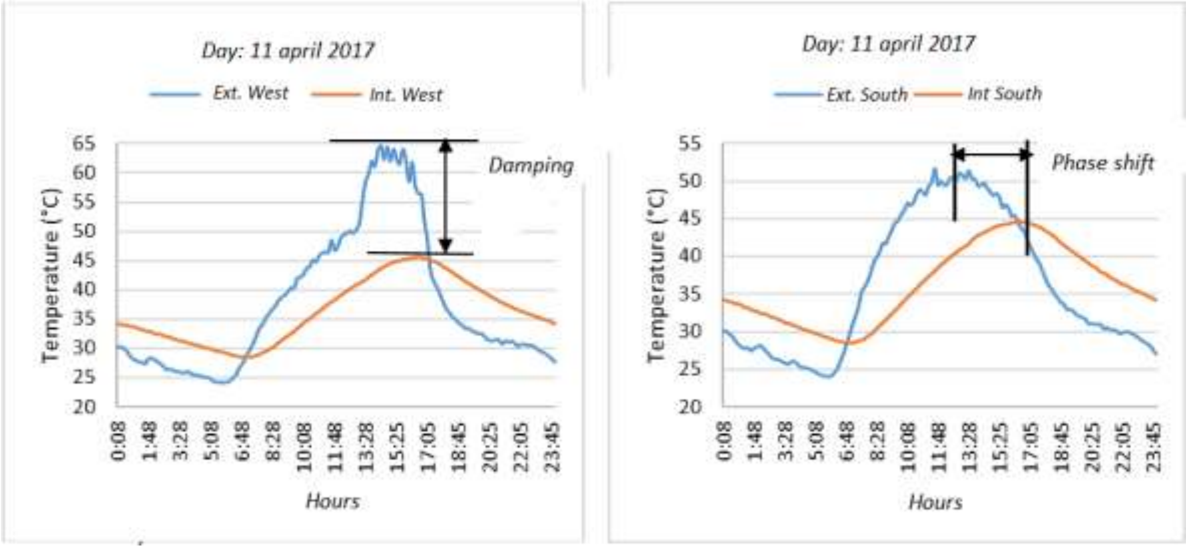

Figure 10: Evolution of the external and internal temperatures of the West and South walls (11/04/2017).

The damping of the interior temperature due to the insulation of the walls varies from 5 to 20 °C, i.e. a damping factor varying between 0.39 and 0.61.For active buildings such as cold rooms, a low inertia (3 to 4 hours of phase shift) is compensated by the inertia of fruits and vegetables which is higher.

4. CONCLUSION

During this work we have measured and simulated the temperatures of the internal and external walls of the cold storage room and establish their profiles. On average, the temperature differences between the internal and external walls, measured in the cold room, are all above 20°C, while the average difference of the simulated temperatures is around 19°C. The simulation resulted to a maximum value of the outside temperature of 35°C , but in reality it was 45°C. At the same time, an average difference of 4°C is observed between the simulated values of the inner wall and the inner air; on the other hand, the outer air imposes its thermal behaviour on all the outer walls and the inner air on all the inner walls. The simulation and experience showed that: the measured and simulated values of the outer walls coincide, the average temperature difference between the inner walls was less than 2°C, proof of the uniformity of the cold room temperature. While the average difference between the simulated and measured values of the chamber air temperature is 3°C. The measured values of the inner walls and the inner air temperature abnormally overlap because our measuring device is the centre of the chamber, but when adjacent to the wall these profiles are normal. Indeed, thermocouples instead of measuring the temperature of the walls measured the air temperature, because they were poorly bonded to the walls. The outside temperatures on the northern and eastern walls are higher than those of the others, although sometimes this is not clearly visible in the figures. The phase shift of the south wall is 3 to 4 hours. Due to the insulation, the internal temperature of the cold room is damped against the external temperature. The variation in the temperature of the internal air in the chamber over the course of a year makes it possible to keep different speculations in turn depending on the period. However, with regard to the quality of the insulation used, the cold room has good thermal profiles for the conservation of agricultural products.

5. ACKNOWLEDGEMENTS

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REFERENCES

[1] I.I.F. « « Les techniques du froid dans les pays chauds en développement » ». 1976.
[2] Compaoré R. M. C. « Réalisation d'une chambre froide solaire photovoltaïque pour la conservation des produits agricoles : application au stockage des mangues ». *Afrique SCIENCES*. 2018. Vol. 14, n°5, p. 346-358.
[3] PARROT L. « Analyse de la chaîne de valeur mangue au B urkina Faso ». *CIRAD*. mars 2018. p. 6.
[4] Dipankar N. B., Ganguly A. « Solar thermal–photovoltaic powered potato cold storage – Conceptual design and performance analyses ». *Applied Energy*. 2016. Vol. 165, p. 308–317.
[5] A.Coulibaly. « chambres froides ». 2003.
[6] COMMERE B., BILLIARD F. « La chaîne du froid dansl'agroalimentaire ». *Techniques de l'ingénieur*. septembre 1999. p. p23.
[7] Mirade P. S., Daudin J. D. « Computational fluid dynamics prediction and validation of gas circulation in a cheese-ripening room. » . *International Dairy Journal*. 2006. Vol. 16, p. 920-930.
[8] Chourasia M. K., Goswam T. K. « Steady state CFD modeling of airflow, heat transfer and moisture loss in a commercial potato cold store ». *International Journal of Refrigeration,*. 2007. Vol. 30, p. 672-689.
[9] Kolodziejczyk M., Butrymowicz D. . « CFD modelling of vegetable cold storage chamber. » . *ICR 2011*. 2011.
[10] Moureh, J. et al. « Air velocity characteristics within vented pallets loaded in a refrigerated vehicle with and without air ducts. » *Int. J. Refrigeration*. 2009. Vol. 32, p. 220-234.
[11] Cortella G. « CFD aided retail cabinets design. In: Sun, D.-W. (Ed.), Computational Fluid Dynamics in Food Processing ». *In: Sun, D.-W. (Ed.), Computational Fluid Dynamics in Food Processing*. 2007. p. 83-101.
[12] [Laguerre O., Derens E., Palagos B. « Study of domestic refrigerator temperature and analysis of factors affecting temperature: a French survey. » *Int. J. Refrigeration*. 2002. Vol. 25, p. 653-659.
[13] Ho S. H., Rosario L., Rahman M. M. « Numerical simulation of temperature and velocity in a refrigerated warehouse. » *International Journal of Refrigeration*. 2010. Vol. 33, p. 1015-1025.
[14] Ben Amara S. « Ecoulements et transferts thermiques en convection naturelle dans les milieux macro-poreux alimentaires application aux r_efrigerateurs menagers. » *Doctorat de l'Institut National Agronomique Paris-Grignon, Paris.* 2005.
[15] Flick D. et al. . « Modélisation des écoulements et des transferts lors du refroidissement de fruits et légumes conditionnés en palettes. » . *20th international congress of Refrigeration IIR-IIF, Sydney, 6.* 1999.
[16] Mirade P. S. . « CFD Modeling of Indoor Atmosphere and Water Exchanges during the Cheese Ripening Process ». *Computational Fluid Dynamics in Food Processing. CRC Press*. 2007.
[17] Kitinoja L., Kader A. A. « Temperature and relative humidity control », in Small-Scale poste handling practices: Amanual for horticultural crop ». *4th édition., University of California, Davis*. 2002.
[18] Brosnan T., Sun D. « « Precooling techniques and applications for horticultural products – a review » ». *International Journal of Refrigeration*. 2001. Vol. 24, n°2, p. 154 170.
[19] Alvarez G., Flick D. « « Analysis of heterogeneous cooling of agricultural products inside bins Part I: aerodynamic study » ». », *Journal of Food Engineering*. 1999. Vol. 39, n°3, p. 227-237.
[20] Qian Z. « « A CFD modeling system for air flow and heat transfer in ventilated packing systems during forced-air cooling of fresh produce. » ». *Massey University*. 2002.
[21] Tassou S. A., Xiang W. « , « Modeling the Environment Within a Wet Air-Cooled Vegetable Store » ». *Journal of Food Engineering*. 1998. Vol. 38, p. 169-187.
[22] Smale N. J., Moureh J., Cortella G. « A review of numerical models of airflow in refrigerated food applications. » *International Journal of Refrigeration*. 2006. Vol. 29, p. 911-930.
[23] Sawadogo-Ligani H. « Composition chimique et valeur nutritive de la mangue Amelie (Mangifera indica L.) du Burkina Faso. » *Journal des Sciences*. 2001. Vol. 2, n°1, p. 35-39.