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RESEARCH ARTICLE

THERMAL STUDY AND FORMULATION OF BRIQUETTES BASED ON KAPOK-PLASTER WOOL FOR THE INSULATION OF LOCAL OVENS SUITABLE FOR GRILLING MEAT

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ABSTRACT

This work focuses on the development of insulators for meat grilling equipment. Indeed, the meat grilling sector in Burkina Faso is booming and uses very energy-intensive ovens. Very often, these ovens encounter thermal insulation problems at the level of the envelope. This is why this work aims to reduce the energy losses of equipment through the insulation of the walls. The insulators were made from a mixture of plaster and kapok wool which is a local insulator. The choice of these materials is based on their low cost, ease of access, biodegradability and ease of manufacture. The characterization tests of these insulators have shown very interesting results from the thermal and energy point of view. The thermal conductivities of the insulators developed are between 0.089 and 0.357 W/mK and they resist temperatures from 150°C to 400°C

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INTRODUCTION

Following the march for energy savings launched by developing countries, we have chosen to work to save biomass. Indeed, more than 2.7 billion people use biomass, animal waste for domestic cooking (Magrini *et al.,* 2017). As for Burkina Faso, it represents about 85% of the energy consumed in households (Dao, 2019). The massive use of this energy considerably affects forest resources. The regression rate of forest formations is estimated by FAO at 105,000 ha, or 4% on average, while the Ministry of the Environment and Sustainable Development estimates it at 107,626 ha/year (Ministère de l'Environnement et du Développement Durable, 2013). Faced with the seriousness of the situation, several studies have been carried out in order to save this vital commodity which is becoming increasingly rare. Indeed, there are several innovations such as improved wood, charcoal and gas stoves, solar cookers, pressure cookers (Serge Wendsida, 2021; Serge Wendsida, 2021; Gaël Lassina, 2020; DrissaOuédraogo, 2020; DrissaOuédraogo, 2020; Serge Wendsida, 2020). Unfortunately, all these innovations do not concern the grilling sector which is an emerging sector and which is developing at very high speed.

Indeed, the study we conducted on meat grilling equipment shows that this sector is very energy-intensive and generates enormous energy losses due to the lack of insulation of the walls of the equipment (Gaël Lassina, 2020). It is in this context that we conducted a study aimed at developing insulators suitable for equipment that operates at high temperatures. The field of high temperature insulation encounters many problems because most low conductivity materials are very brittle and do not withstand high temperatures (Ebert, 2015). In addition, materials that are resistant to high temperatures (glass wool, rock wool, polystyrene) are very expensive and are not biodegradable. Some can cause cancer if inhaled or ingested (Brown, 2012). Our goal is to develop an insulation accessible to all, easy to manufacture, and biodegradable. The type of insulation we have developed is in the category of composite materials. To do this we have chosen kapok wool which has a low thermal conductivity (0.03 to 0.04W/mK), very accessible and biodegradable (Voumbo, 2008). A study on kapok wool for thermal insulation at low temperatures (in refrigeration) showed very interesting properties. The stabilization test of kapok wool with plaster and cement did not give satisfactory results because they were used as a binder (Voumbo, 2008). Here, we use kapok wool to create pores in the plaster and then proceed to their characterization.

Image1 : Kapok woolweighing

Image 2 : Plasterweighing

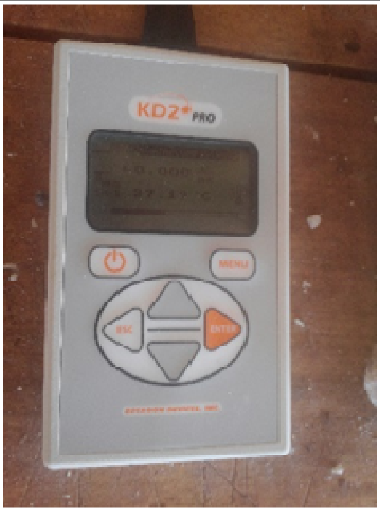

Image 3 : Analyseur KD2-Pro

Image 4 :Drill

Image 5 : Oven

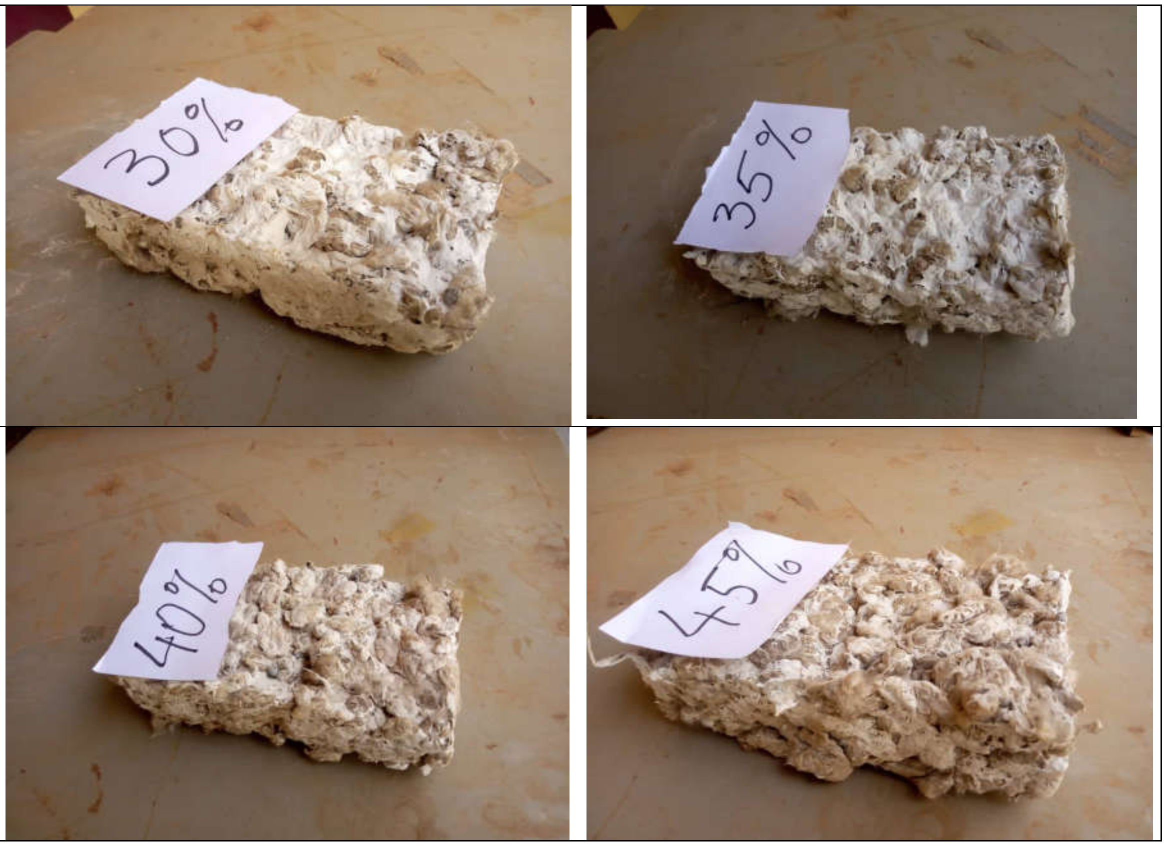

Figure 1. Formulation of insulating briquettes

MATERIALS AND METHODS

Materials

We used the following material

- For the manufacture of the bricks of the wool of kapok, the plaster, a sensitive balance and a mold of 20cmx10cmx4cm.
- For the characterization of bricks, a KD2 Pro thermal property analyzer, a drill and an oven.

Methods

In order to develop insulators for high temperature insulation, we made a dosage by varying the percentage of kapok wool until the mixture was more stable and made briquettes of dimensions 20cm x 10cm x 4cm. The blend is stable up to 40% kapok wool. Beyond this percentage, the bricks are no longer mechanically stable. After drying the insulators, we proceeded to the characterization with the KD2 Pro. For each type of brick we took measurements at three different places on each brick and took the average. Thus we measured their thermal conductivities, their volumetric heat capacities, their thermal resistances and their thermal diffusivities.

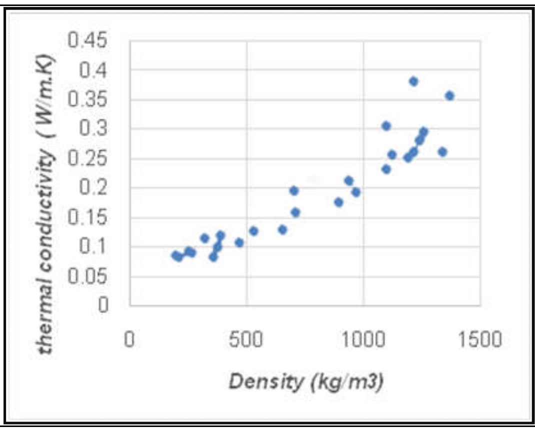

Figure 3 :Curve of variation of the thermal conductivity according to the density

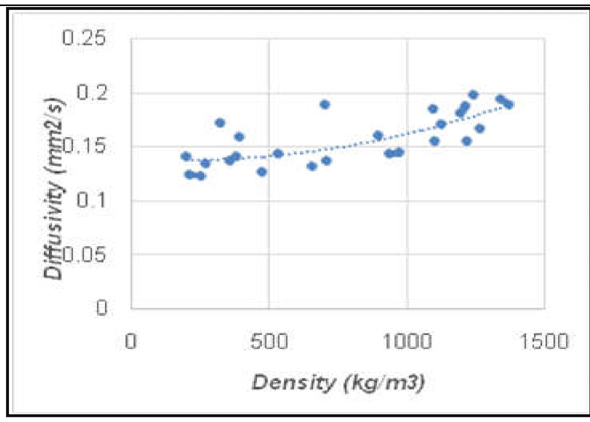

Figure 4 : Curve of variation of the diffusivity according to the density

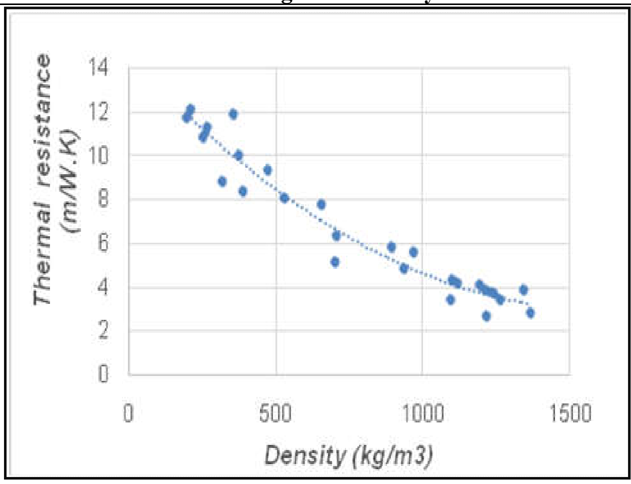

Figure 5 :Curve of variation of the thermal resistance according to the density

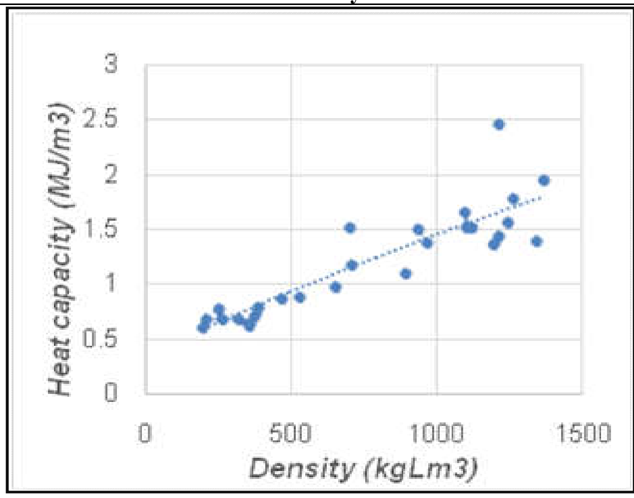

Figure 6 :Curve of variation of the specific heat according to the density

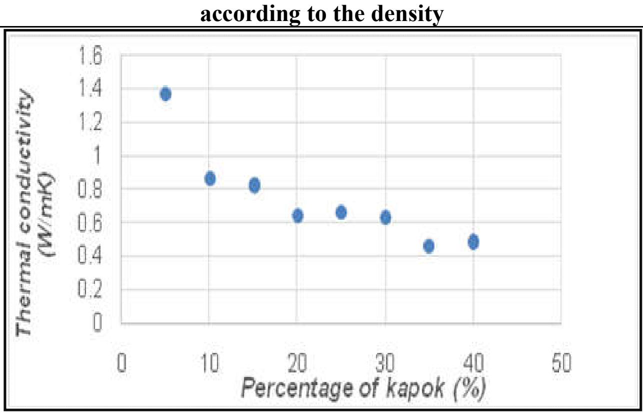

Figure 7 :Curve of variation of the thermal conductivity according to the mass rate of kapok

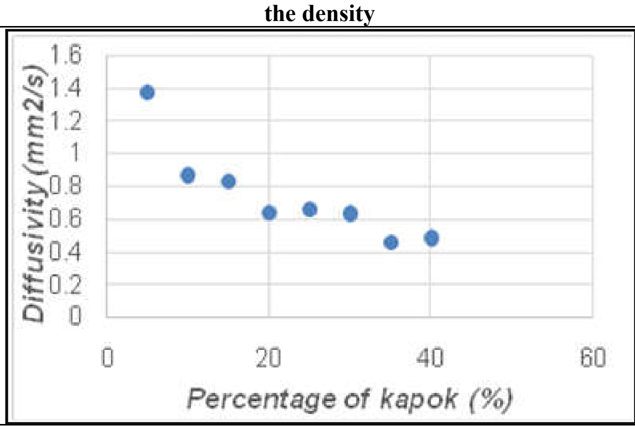

Figure 8 :Diffusivity variation curve as a function of kapok content

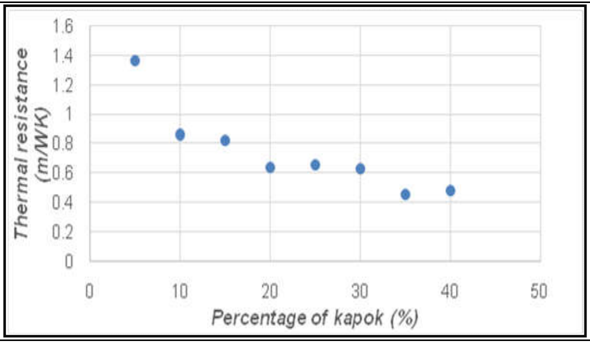

Figure 9. Curve of variation of the thermal resistance according to the mass rate of kapok

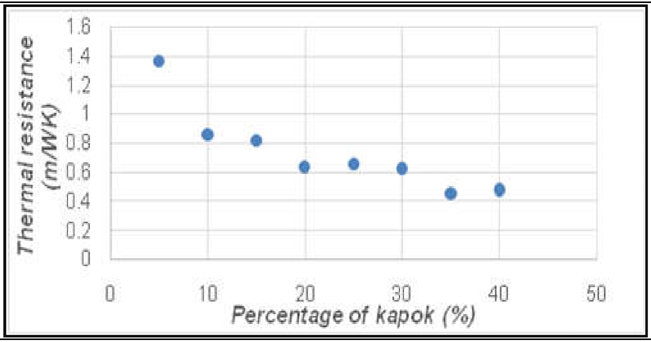

Figure 10. Curve of variation of the specific heat according to the rate of kapok

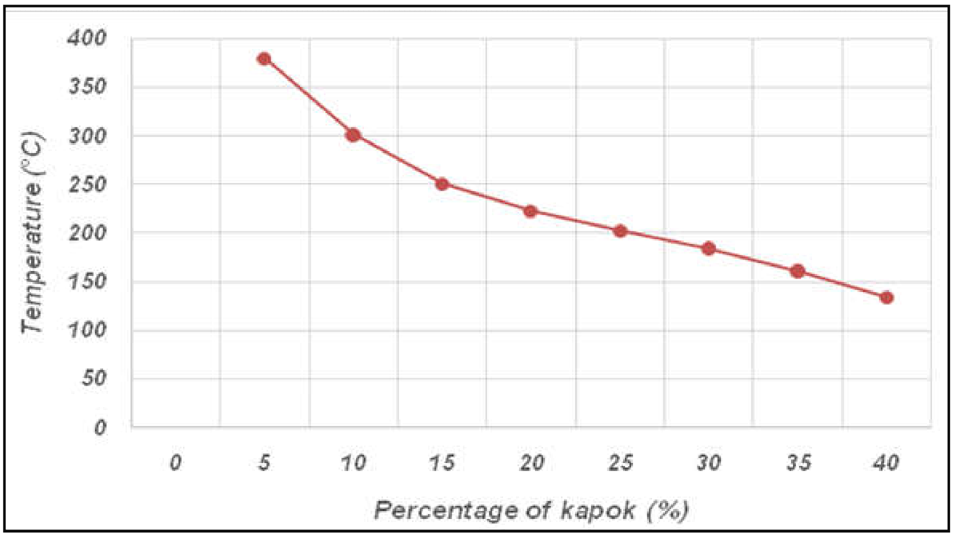

Figure 11. Resistance to temperature according to the mass percentage of kapok wool

At the end of this study, we did a last test on the resistance to temperature in order to know if the insulators are suitable for high temperatures. We used a laboratory furnace in which the bricks were introduced to determine their cracking temperatures.

RESULTS

Thermophysical characteristics according to the density: Figures 3, 4, 5 and 6 represent respectively the evolution of the thermal conductivity, the diffusivity, the thermal resistance and the specific heat capacity of the bricks according to their densities. Figure 3 shows that the thermal conductivity decreases when the mass percentage of kapok wool increases, which implies that the density is increasingly low. Indeed, when the rate of kapok wool is high in the brick, the insulating power is higher. The thermal conductivity of the insulators is between 0.089 and 0.242 w/m.K. All of these values are between the thermal conductivity of kapok wool 0.03 to 0.04W/mK and that of plaster which is 0.35W/mK. The values of thermal conductivities show that we have good thermal insulators because the conductivity of thermal insulators is less than 0.1 w/mK. Figure 4 shows that diffusivity varies little. Diffusivity is the speed of heat transfer through the entire mass of a material, and more specifically, it characterizes the ability of a material to transmit a temperature signal from one point of this material to another. In our case, it decreases slightly when the rate of kapok wool increases. This shows that although the bricks have different compositions, they all have good insulation. Figure 5 shows that the thermal resistance increases rapidly when the rate of kapok wool increases. Indeed, the more wool there is in the composition of the brick, the more the thermal resistance increases.

Thermal resistance is the resistance of a material to heat transmission. So when the amount of wool increases, the resistance to heat transmission increases remarkably. This proves that the addition of kapok wool to plaster makes it possible to develop materials that oppose the transmission of heat. Figure 6 shows that the specific heat for its part decreases when the percentage of kapok wool increases. Density is a very important criterion in thermal storage. Heavier materials store more heat. So when the wool composition increases, the brick becomes light and the specific heat decreases. This reduces the brick storage factor which reduces energy losses due to storage in the walls of equipment operating at high temperatures.

Thermophysical characteristics according to the kapok wool content: Figures 7, 8, 9 and 10 respectively show the evolution of the thermal conductivity, the diffusivity, the thermal resistance and the volumetric heat capacity of the bricks according to the mass ratios of kapok wool in the mixture. The thermal conductivity and the volumetric heat capacity decrease when the percentage of wool increases. Thermal resistance, on the other hand, increases with the percentage of wool. The diffusivity is almost constant. Overall, the mixture of kapok wool with plaster gives the bricks very interesting insulation properties. These results are very interesting for insulation at low temperature, however at high temperature a second test on the resistance to temperature is necessary.

Temperatureresistance: Temperature resistance is the key factor in our study. We introduced the insulators into the oven and gradually increased the temperature until the brick cracked. This study allowed us to represent in Figure 11 the cracking temperature as a function of the mass percentage of kapok wool in the brick. Figure 11 shows that the temperature resistance decreases as the percentage of kapok wool increases.

Kapok wool is a highly flammable material, which is why it cannot be used for high temperature insulation. The addition of plaster had essentially two roles: the mechanical stability of the insulation and the increase in resistance to temperature. The plaster has a melting temperature of The increase in the quantity of wool causes a drop in the ignition temperature.

CONCLUSION

The study carried out on the mixture of plaster and kapok wool has made it possible to develop a set of insulators which have very interesting characteristics for high temperature insulation. Indeed, the thermal conductivity of the insulators is between 0.089 and 0.242 w/m.K and a thermal diffusivity of the order of 0.15 mm2/s. These characteristics make these bricks competitive insulators at high temperatures and could be used to insulate the walls of grill ovens and other equipment that operates at high temperatures. However, they must be protected by refractory materials which have greater resistance to temperature..

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