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Solar cooking development in Algerian Sahara: Towards a socially suitable solar cooker

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ABSTRACT

This paper presents a review of research works and studies carried out in the development of solar cooking in Algerian Sahara. The review is performed in such way to focus on diverse box type solar cookers that have been realized by the solar heating research team at the Research Unit in Renewable Energies in Sahara Medium (URER/MS-Adrar, Algerian Sahara). Research started with the realization of a simple solar box cooker with a tilted absorber-plate, then the construction of a double exposure solar cooker and then the development of a novel non-tracking solar box cooker, which is equipped with a fixed asymmetric compound parabolic concentrator (CPC) as booster-reflector and its absorber-plate, is in a form of a step. The last cooker can be fixed at a south building wall with its rear opening in kitchen; it can be more user friendly. This will allow a freedom of interactive cooking and it does not require the user to go out in the sun during its use. These qualities promote its uptake and made it a socially acceptable device.

Contents

1. Introduction

In Algeria, almost the whole country is supplied with electricity, natural gas and butane gas. These are all used for supply domestic needs. However, the problem of energy cost and the increasing energy consummation constitute an important ecological and economic constraint on the environment preservation and the sustainable development. Solar energy is a suitable solution to limit deforestation caused by the exploitation of firewood to provide domestic energy needs and to minimize the abusive use of energy derived from the fossil sources. Algerian Sahara lies in the sunny belt of the world. This area receives abundant daily sunshine and an average solar insolation of about 2650 kWh/m²/year [1].

Under these conditions, all solar energy applications could be developed and the solar cooking constitutes an attractive one. Cooking is an important part of daily food preparation in commercial and residential settings. The application of heat alters the composition of food products to enhance taste, texture, digestibility and shelf-life [2]. In the isolated Saharan areas; the use of heat for food cooking is very expensive when the conventional energy sources are used and induces

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disastrous consequences on the ecosystem by exploiting wood of the remaining trees in these areas.

In order to develop and popularize the use of solar cookers in Algerian Sahara, a research project was launched in 2004 by the Research Unit in Renewable Energies in Saharan Medium at Adrar, which is located at 27°53′N latitude and 0°17′W longitude. The Adrar area has a surface of 424,948 km²; it enjoys an average of about 3500 sunshine hours per year [1] and an annual average daily total solar irradiation on a horizontal surface of about 22.8 MJ/m² [3]. In addition, the sky is usually clear and it rarely rains. Under these conditions; solar cooking has a high potential of diffusion and constitutes a real opportunity in the domestic sector in this area.

This paper is a compilation of the research studies which were carried out to develop a socially acceptable solar cooker for the remote areas of Algerian Sahara and in particular Adrar region.

2. Principle of solar cooking

Solar cooking consists to use solar energy to cook food and prepare it for human consumption. To carry out this; it is necessary to:

- Collect the solar radiation;
- Convert it to heat;
- Retain the heat and transmit it to food through cooking pot walls.

This can be carried out by using a hot box type which depends on the green house effect. It consists of a well-insulated box with a black interior. Food is placed in cooking pots deposited on an absorber plate installed in the hot-box. The cover of the box usually comprises two glasses that lets solar radiation enter the box but keeps the re-radiation heat in the infrared region escaping. When a cooking pot is deposited on the absorber plate of a box-type solar cooker well-directed towards the sun; the heat transfer towards the food inside the cooking pot is carried out under the following conditions (Fig. 1)

- The absorber plate is irradiated on its upper surface; by natural convection, it transmits most of the absorbed radiation which is converted into heat towards the internal air. By conduction; it transmits a fraction of its heat towards the base of the cooking pot which is in direct contact with the absorber plate. Through the thermal wall resistance of the cooking pot; this fraction of heat is transferred to the food kept inside.
- The lid of the cooking pot absorbs a maximum of solar radiation but this surface remains not effective in the mechanism of heat flow to the food. Indeed; food is not in direct contact with the lid and it always remains an air gap between the upper surface of the food and the lid. The lid which becomes hot will generate, by natural convection, a current of hot air which circulates inside the box.
- The side surface of the cooking pot is partially irradiated and the heat carried by the air circulation inside the box, reaches the food via the side walls of the pot.

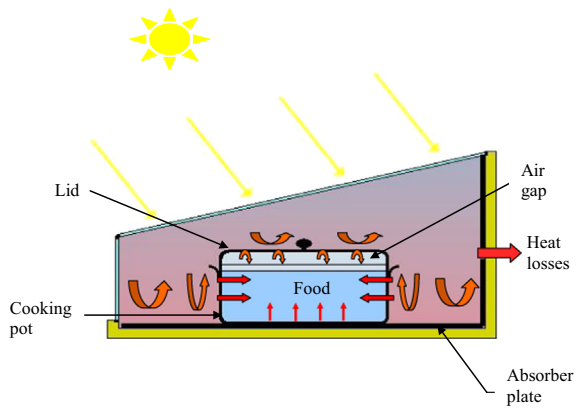

Fig. 1. A schematic diagram illustrating heat exchanges in a solar box cooker.

3. Solar cookers classification

In this study, available solar cookers are classified under two groups:

- Direct ones with integrated solar reflector–collector;
- Indirect ones with separate solar reflector–collector (split).

In the first group, we find the cookers whose collector and the place where the cooking pot is deposited, form one same unit. There are two types: The box type solar cookers which can be simple or provided with plane reflectors, and the concentrating ones. In box type solar cookers, the cooking pot is deposited in a well-insulated box and in the concentrating ones; the cooking pot is placed at the focus of a concentrating mirror.

In the second group, we find the cookers which are made in two distinct parts: A solar collector to collect and convert solar radiation into heat and an insulated cooking chamber for the installation of the cooking pot. These two parts are connected by ducts to allow the circulation of the heat transfer fluid and bring the heat to the cooking chamber. According to their collectors, we distinguish two types: Those with flat-plate collectors and those with concentrators.

Compared to those of the first group, the indirect solar cookers have the advantage of laying out the cooking chamber inside the kitchen. These cookers are complex and expensive; for more effectiveness their collectors are equipped with heat pipes. They must be the subject of a meticulous study when designing the home.

The parabolic solar cooker concentrates the direct solar radiation on the cooking pot which is installed in the focus of the parabolic concentrator. This type of cooker does not require a cooking chamber for the installation of the cooking pot. Indeed, the cooking chamber generates more obstruction which gene the reception of solar radiation, but the thermal losses become important under a strong wind. The use of this cooker requires a great attention for the concentrator orientation and to avoid the burns dangers. Since this type of cooker exploits the direct radiation, its operation under partially covered sky becomes practically impossible.

The box type solar cooker is simplest; it is about a hot-box directly exposed to the direct and the diffuse solar radiation. In order to improve the collected radiation, plane reflectors can be fixed on the box and oriented to reflect solar radiation towards the absorber plate. Box type solar cookers can be fabricated with locally available materials and they are easy to operate; they require only few interventions of the user for their orientations towards the sun, but reached temperatures are moderate and cooking times remain long.

Several models of solar cookers were built and distributed in the rural world through planet. In Africa and in the sub-Saharan area; popularization of solar cooking is supported by several organizations to fight against deforestation and meet populations needs in remote areas deprived of conventional energy resources like Tchad, Mali, Niger, Burkina-Faso and others…

With the actual ecological and economic current constraints, it is more than ever necessary to develop solar cooking in Algeria and particularly in its south regions.