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One thousand thermal cycles of magnesium chloride hexahydrate as a promising PCM for indoor solar cooking

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ABSTRACT

Cooking is the major necessity for people all over the world. It accounts for a major share of energy consumption in developing countries. There is a critical need for the development of alternative, appropriate, affordable methods of cooking for use in developing countries. There is a history for solar cooking since 1650 where they are broadly divided into direct or focusing type, box-type and indirect or advanced solar cookers. The advanced solar cookers have the advantage of being usable indoors and thus solve one of the problems, which impede the social acceptance of solar cookers. The advanced type solar cookers are employing additional solar units that increase the cost. Therefore, the solar cooker must contain a heat storage medium to store thermal energy for use during off-sunshine hours. The main aim of this paper is to investigate the influence of the melting/solidification fast thermal cycling of commercial grade magnesium chloride hexahydrate ($MgCl_2{\cdot}6H_2O$) on its thermo-physical properties; such as melting point and latent heat of fusion, to be used as a storage medium inside solar cookers. One thousand cycles have been performed in a sealed container under the extra water principle. The thermo-physical properties are measured using the differential scanning calorimetric technique. It is indicated that $MgCl_2{\cdot}6H_2O$ with the extra water principle and hermetically sealing of the container is a promising phase change material (PCM) for cooking indoors and during law intensity solar radiation periods. It is also found from the melting/solidification behavior of $MgCl_2{\cdot}6H_2O$ that it is solidify almost without supercooling; except in few cases where it showed maximum of 0.1–3.5 °C of supercooling.

1. Introduction

Scientists all over the world are searching for new and renewable energy sources to reduce CO_2 emission from the consumption of fossil fuels. Solar energy has an enormous potential for the heating and cooling of buildings, drying agricultural crops, desalinization of sea water, cooking, etc. However, solar energy is intermittent, unpredictable, and available only during the day. Hence, its application requires efficient thermal energy storage systems so that the collected heat during sunshine hours may be stored for later use. On the other hand, energy consumption for cooking in developing countries is a major component of the total energy consumption, including commercial and non-commercial energy sources. The different types of solar cookers developed for cooking are (i) direct or concentrator type [1] (ii) box-type [2] and (iii) indirect or advanced type [3]. Box-type solar cookers are more popular due to their simplicity of handling and operation. The focusing and box-type solar cookers are for outdoor applications. The advanced solar cookers have the advantage of being usable indoors and thus solve one of the problems, which impede the social acceptance of solar cookers [4]. The advanced type solar cookers are employ additional solar units that increase the cost and the cooking process can not be done in the evening or on cloudy days [5]. Therefore, the solar cookers must contain a heat storage medium to store thermal energy for use during off-sunshine hours.

Few papers have appeared concerning the use of phase change materials (PCMs) as storage media inside solar cookers [6–9]. Review papers on thermal energy storage with PCMs and applications, particularly solar cookers are recently published [10–13]. Most of the authors have used PCMs with melting temperatures (T_m) lower than the cooking temperature (100 °C) [9]. Therefore, it is necessary to develop a solar cooker with a PCM with appropriate melting point ($T_m > 110$ °C) for cooking various kinds of food [7]. The used PCM must be stable after repeated melting/solidification cycles and also show good compatibility with the container. Some papers are reported concerning the compatibility of the used PCMs with the container [14–18]. Also, the effect of melting/solidification cycles on the thermo-physical properties of the PCMs is still of considerable interest. Accelerated thermal cycle tests of acetamide, stearic acid and paraffin wax for solar-thermal latent heat storage applications are performed by Sharma et al. [19]. They indicated that paraffin wax and acetamide have shown reasonably

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