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Solar Thermal Disinfestation of Grain

Utilising solar energy as a possibility for the thermal disinfestation of grain with a 12 % w.b. moisture content was tested. For this solar energy was collected with a 1 m² solar collector. The necessary 60°C grain temperature, which is a lethal temperature for all insects, was achieved under normal field conditions in Germany. To determine if the heating system could work as a continuous-flow system, a model collector was developed, which has an absorber powered by infrared energy. With an absorber temperature of 80°C and at a mass grain flow rate of 22 kg/h, it was proven that thermal grain disinfestation is possible.

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Keywords

Solar energy, thermal disinfestation, insects in grain stores

Food grains are the major dietary source for humans. Cereal grains constitute about 71 % of the typical diet of local population of Africa. During storage, food grains are subjected to many factors, which cause deterioration and losses. Most losses result from infestation by biological agents. Losses of about 30 % have been reported in tropics and subtropics, which provide optimum conditions for pests multiplication. The most common method of pests control in stored grain is the use of chemical insecticides, because they are cheap and could be used to react to an infestation when it is discovered. Serious problems have been identified for the future. The main problems are health and environmental hazards, increasing costs, regulatory restrictions and growing amount of insect resistance. Moreover, pesticide residues in grains are becoming increasingly unacceptable in markets. Therefore, a need has been created for a simple, safe and effective method for insect control. The use of high temperature is one of the promising methods that provide a residue-free rapid alternative. This method is safe, effective and has the potential for high market acceptance, but its use has been seriously constrained by its high energy requirement [1].

Extensive research was done concerning thermal disinfestation [1, 2, 3] and researchers found that temperature of 60 °C for less that 2 minutes is lethal to the most heat resistance insect species *Rhyzopertha dominica* (lesser grain borer) [4]. This temperature for such short time has no adverse affect on the grain quality [5].

Materials and methods

The experiment took place at the Institute for Agricultural Engineering, Göttingen University in summer 2003. A solar collector (100 • 100 cm), flat-plate type, was constructed from simple materials. The collector was made of black painted metal as absorbing material covered with a glass sheet, with 22.5 mm gap. Polystyrene was used as insulation material to reduce heat loss at the collector bottom. Wood was used for collector sides insulation and as a frame. Under the absorber, wheat kernels were filled in 4.5 cm and 2.0 cm deep. Solar radiation was measured using a pyranometer. Ambient, collector and grain temperatures were measured using resistance temperature detectors (PT100). Collector temperature was measured at 1.0 cm above the absorber, in the collector centre and 10 cm from the edge. Sensors at the same positions, 1.0 cm under the absorber, were used to measure the grain temperature. The grain initial moisture content was 10 % w.b.

To test the possibility of reaching lethal grain temperature for all insect of 60 °C in a dynamic system, a heating tunnel was designed and constructed to allow grain heating as it flows. The heating tunnel was 300 • 25 cm with variable height (1 - 4 cm). It is constructed from a black metal plate as absorbing material, polystyrene for insulation and a wooden frame. The absorber was heated using electric heaters instead of solar energy. Because the absorber temperature is the main factor for the heat transfer into the product, and for experimental reasons, it was more useful and easier to apply infrared energy to provide a certain absorber temperature to study the heating effect. Absorber temperature was adjusted by controlling heater temperature and the heaters-absorber distance. Heaters temperature was controlled by regulating their voltage. The absorber temperature of 80 °C was applied. The absorber temperature was monitored by a digital infrared-temperature measurement device. Resistance temperature detectors (PT100) with a contact area of 3 mm² were used for grain temperature measurement. Grain temperature was monitored and recorded for different positions inside the heating tunnel. The sensors were installed along the tunnel at distances of 30, 110, 190 and 270 cm from grain entrance. In each of these positions, sensors were located in the centre, 4 cm from the centre and 8 cm from the centre. All the sensors are located 1 cm under the absorber. Recorded temperature data were transferred to a computer via a digital multimeter model 2001. Grain wheat, Magnus variety of 10 % moisture content was used for the experiment. Initial grain temperature was

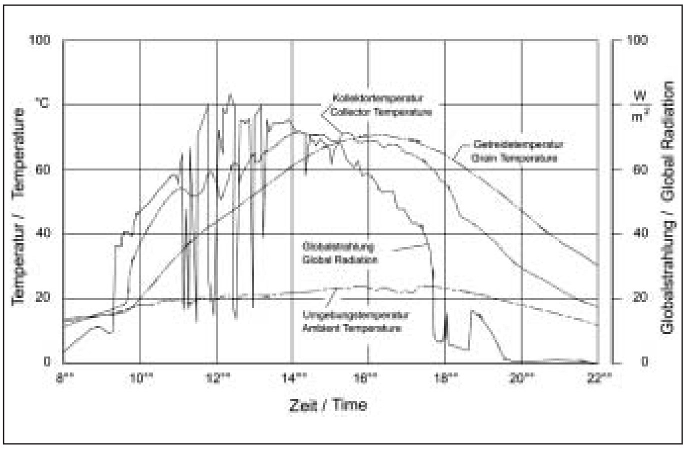

Fig. 1: Global radiation, collector-, grain- and ambient-temperature for a grain depth of 2 cm during solar disinfestation, collector surface 1 m^2

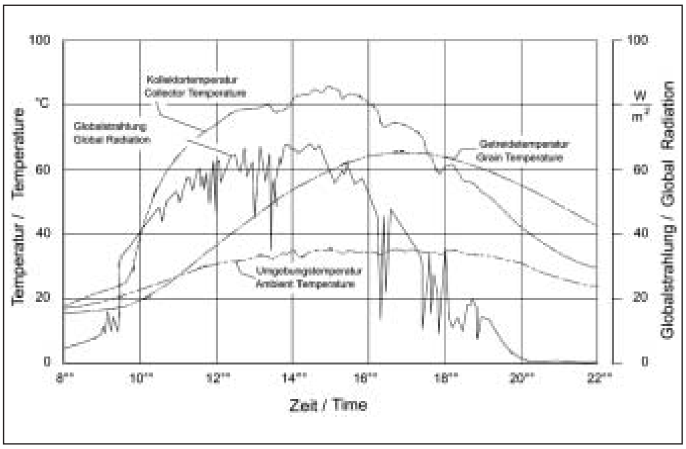

Fig. 2: Global radiation, collector-, grain- and ambient-temperature for a grain depth of 4.5 cm during solar disinfestation, collector surface 1 m^2

30°C. Grain depths inside the tunnel were 2 and 4 cm. The tunnel was tilted 35° to allow automatic grain flow. The grain flow rate was adjusted using a cell-wheel at the grain outflow.

Results

Results for static state experiment were shown in *Figures 1 and 2*. Collector, grain and ambient temperature and solar radiation were explained. Grain and collector temperature are means of 2 readings. From the figures, it is clear that, by using the solar collector, grain temperature of 60 °C or more could be obtained in static case. For grain depth of 2.0 cm, grain temperature similar to absorber temperature could be achieved. By increasing grain depth, grain temperature is decreased, but still temperature above 60 °C was recorded. This means that such solar system could be used for thermal disinfestation of stored grain

Figure 3 explains heating progress in the dynamic state experiment. Both grain depths (2 and 4 cm) gave the same temperature. To attain a temperature of 60 °C at the end of the tunnel, the maximum flow-rate was found to be 22 kg/h. Grain temperature increased by about 1 °C for every 10 cm of heating-tunnel length.

Above results show that it is possible to heat grain in a continuous-flow system by maintaining absorber temperature of 80 °C. Lethal grain temperature could be obtained with a mass flow rate of 22 kg/h. The experiments will be continued to get complete understanding of the process and to obtain higher mass flow rates. With these results it might be possible to provide a testing device in pilot plant scale to find out whether solar radiation might be effective for thermal disinfestation of grain especially in developing countries.

Literature

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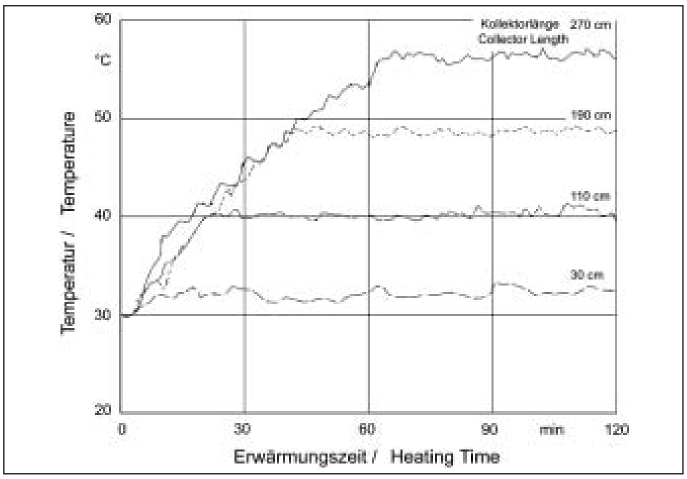

Bild 3: Einfluss einer Absorbertemperatur von 80 °C auf die Getreidetemperatur im Abstand von 1 cm unterhalb des Absorbers, spezifischer Getreidefluss 22 kg/h.

Fig. 3: Grain temperature at 1.0 cm under the absorber in different positions inside the heating tunnel using an absorber temperature of 80 °C, specific grain flow 22 kg/h