

**SOLAR HEATING SYSTEM USING PARABOLIC  
COLLECTOR FOR THERMAL OPTIMUM  
CONDITIONS OF BIOGAS  
PRODUCTION IN WINTER**

By

**SARA MOHAMED GAMAL EI-DIN HASSAN**

B. Sc. Agric. Sc. (Agricultural Engineering), Ain Shams University, 2013

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## **ABSTRACT**

**Sara Mohamed Gamal El-Din Hassan: Solar Heating System Using Parabolic Collector for Thermal Optimum Conditions of Biogas Production in Winter, Unpublished M.Sc. Thesis, Department of Agricultural Engineering, Faculty of Agriculture, Ain Shams University, 2019.**

Due to the growing demand of energy, a lot of studies were directed to anaerobic digestion. Anaerobic digestion is influenced by several factors. Fermentation temperature is one of these factors. Both temperature range and temperature fluctuations affect greatly biogas production. It is difficult to attain the required optimum temperature in cold climates. Therefore, the digester needs to be supplied with external thermal energy to reach the desired temperature.

The aim of this study is to enhance the fermentation temperature inside the digester by supplying the required thermal energy to be within the optimum range (mesophilic range) for biogas production during winter “cold days” via solar energy technique.

The experiment was carried out at Solar Energy Laboratory, Department of Agricultural Engineering, Faculty of Agriculture, Ain Shams University through December 2018 and January 2019. Two 50 L digesters were used in the experiment. One was insulated and connected to a parabolic trough (treatment), while the other operated at the ambient temperature (control). The temperature in the treatment digester was raised by pumping water, which was heated via solar radiation, into a simple heat exchanger that was installed inside the digester. The treatment digester is also equipped with a mechanical stirring shaft to maintain a homogenic slurry and to guarantee the thermal distribution throughout the digester. A simple tracking circuit was used to navigate the parabolic trough collector automatically towards the sun throughout the day. The results show that the average temperature in the control digester through the experiment was 21.5 °C, while it was 27.08 °C in the treatment digester. This means that the parabolic trough collector enhanced the fermentation temperature in the

treatment digester by 20.6%. The accumulative biogas yields of the control digester and the treatment digester through the experiment were 9684.7 mL/kg. T.S. ( $0.0304 \text{ m}^3$ ) and 24649.69 mL/kg. T.S. ( $0.0774 \text{ m}^3$ ) respectively. By comparing both productivities, it was found that the productivity of the treatment digester was 2.5 times more than the productivity of the control digester.

**Keywords:** Anaerobic digestion, Biogas productivity, Fermentation temperature, Solar energy, Parabolic trough, Heat exchanger, Solar tracking, Control unit.

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## LIST OF ABBREVIATIONS

| Abbreviation         | Definition  |
|----------------------|---|
| A                    | Surface area  |
| A <sub>a</sub>       | Aperture area   |
| AD                   | Anaerobic digestion                                     |
| A <sub>r</sub>       | Receiver area   |
| C                    | Specific heat   |
| CR <sub>g</sub>      | Geometrical concentration ratio                         |
| D                    | Parabola width  |
| D <sub>out</sub>     | Evacuated tube outer diameter                           |
| d <sub>out</sub>     | Serpentine outer diameter                               |
| ET                   | Evacuated tube  |
| <i>f</i>             | Focal length  |
| G <sub>b</sub>       | Incident solar beam radiation Heat transfer coefficient |
| <i>h</i>             | Parabola depth  |
| HRT                  | Hydraulic retention time                                |
| HTF                  | Heat transfer fluid                                     |
| <i>I<sub>h</sub></i> | Solar radiation incident on horizontal surface          |
| K                    | Heat conductivity coefficient                           |
| <i>l</i>             | Absorber length   |
| <i>m</i>             | Mass flow rate  |
| n                    | Day number of year                                      |
| PTC                  | Parabolic trough collector                              |
| <i>Q</i>             | Heat load   |
| <i>Q<sub>L</sub></i> | Rate of heat loss from digester                         |
| <i>Q<sub>s</sub></i> | Received solar energy                                   |
| <i>Q<sub>u</sub></i> | Useful energy gained in the working fluid               |
| <i>Q<sub>w</sub></i> | Rate of heat transfer to manure                         |
| <i>t<sub>a</sub></i> | Ambient temperature                                     |
| <i>t<sub>s</sub></i> | Solar time  |
| R                    | Solar radiation   |

|          |                               |
|----------|-------------------------------|
| $\alpha$ | Solar altitude angle          |
| $\beta$  | Tilt angle of solar collector |
| $\delta$ | Solar declination angle       |
| $\Phi$   | Latitude angle                |
| $\omega$ | Hour angle                    |
| $\eta_0$ | Overall thermal efficiency    |