GREENHOUSE HEATING WITH BIOMASS

INCĂLZIREA SERELOR CU BIOMASĂ

MURAD E.[1], MAICAN E.[1], HARAGA G.[1], BIRIŞ Ş.S.[1]
e-mail: erolmurad@yahoo.com

Abstract. *In cold season, the greenhouses can provide local market with fresh vegetables at competitive prices if production costs are low, especially for fuel production. From economic and environmental considerations it will be studied a vegetable greenhouse heated with hot air generator that burn biomass with an almost null CO_2 balance. Biomass used can be in the form of pellets of corn stalks, creeping stalks or other wooden materials, and corn kernels. Burning is done with a multifunction burner for granular biomass - pellets or corn kernels, burner developed in recently research. The aim is to conduct a greenhouse microclimate for a cold winter day through simulated experiments with the CLIMASERE software developed in Free Pascal 2.1.2 at U.P.B. It makes a comparison between heating with biomass and LPG or diesel economic both legally and environmentally.*
Key words: greenhouse, heating, biomass, simulation

Rezumat. *În anotimpul rece serele pot asigura piaţa locală cu produse vegetale proaspete la preţuri competitive dacă costurile de producţie sunt mici, în special cele pentru combustibil. Din considerente economice şi ecologice se studiază un modul de seră pentru legume încălzit cu un generator de aer cald, în care se arde biomasă şi cu un bilanţ aproape nul de CO_2. Biomasa utilizabilă poate fi în forma de pelete din tulpini de porumb, vrejuri sau orice alt material lemnos, precum şi porumb boabe. Arderea se realizează cu un arzător multifuncţional pentru biomasă granulară – pelete sau boabe de porumb recent dezvoltat în activitatea de cercetare. Se studiază microclima din seră pentru o zi geroasă de iarnă prin experimente simulate cu softul CLIMASERE dezvoltat în Free Pascal 2.1.2 la U.P.B. Se face o comparaţie între încălzirea cu biomasă şi cea cu GPL sau motorină atât din punct de vedere ecomomic cât şi ecologic.*
Cuvinte cheie: seră, încălzire, biomasă, simulare

INTRODUCTION

In cold season, the greenhouses can provide fresh vegetables to local market with at competitive prices if production costs are low, especially for fuel production. In actual conditions of instability of fossil fuel prices and of the requirement to reduce CO_2 emissions the focus is laid on renewable energy use in greenhouses, especially biomass because it can provide lower costs for heat production. For this, the easiest way is the burning or gasification densified biomass, wood pellets or other agricultural biomass: corn stalks and sunflower, stalks, miscellaneous, etc. In terms of the primary costs, chopped and dried local biomass is much cheaper, but it requires a surplus of labor for processing, which can provide more jobs and can contribute to sustainable development of agriculture through the increasing of a energy

[1] University POLITEHNICA Bucharest, Romania

independence, too (Adams S. et al., 2008; Garcia J. L. et al., 1998; Murad E., 2002.; Murad E. et al, 2008; Popovska-Vasilevska Sanja, 2007).

In this paper the microclimate is studied in a mini greenhouse of vegetables heated with hot air that is distributed through a flexible tube with slots for jets, suspended near the ridge of the greenhouse profile. Thus, the hot-water heating system to reduce both was given up initial investment and to increase the controllability of the microclimate from greenhouse with controlled ventilation. We chose to study one cold winter day from Ilfov area, in order to make comparison between heating with biomass and LPG or diesel, both of economically and ecologically. Simulated experiments were conducted with the CLIMSERE program of microclimate simulation in greenhouses. This software was developed in Free Pascal at the Biotechnical Systems Department from University POLITEHNICA Bucharest.

MATERIAL AND METHOD

The greenhouse of tunnel type under study is about the size 6m (breadth) x 25m (length) x 2,7m (max. height), with galvanized pipe frame with circular profile that is coated with a double presurized polyethylene film. The placement of heat generator group is presented in figure 1.

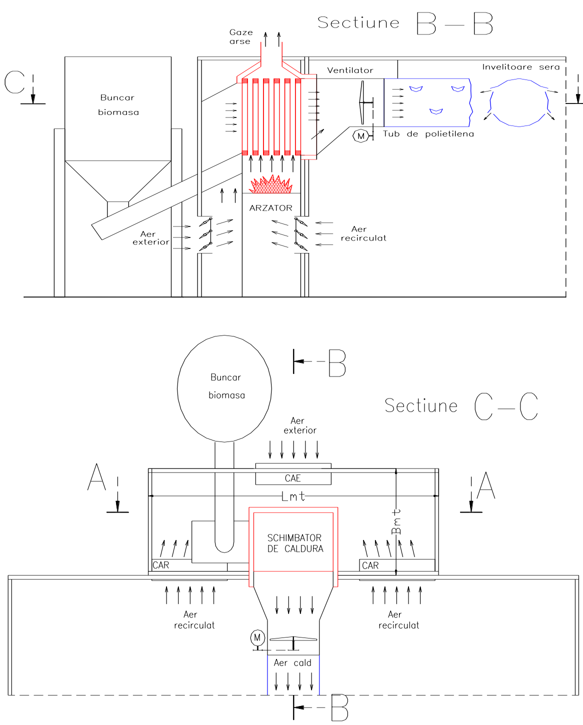

Fig. 1 – Scheme of the heat generator group: B-B vertical section; C-C horizontal section

The greenhouse has a soil surface of S_{sol}=150 m^2 and a volume of V_{ser}=271 m^3. It is heated with hot air distributed by a flexible polyethylene tube with cuts for hot air jets.

The air is heated with a heat exchanger: burned gases-air of ignitubular type with cross current with an exchange area of 3.6 m^2. The input air in greenhouse is obtained by mixing a D_{arec} recirculated air flow adjusted with CAR valves, with an external air flow D_{aex} adjusted with CAE valves to ensure both the concentration of O_2 and CO_2 and indoor humidity, in the greenhouse.

The D_{aev}=D_{aex} air flow exhausted from greenhouse can ensure the maintenance of humidity in the greenhouse. To achieve controlled and stable distribution of hot air the version with D_{av}=ct. was adopted constant flow of air for heating.

Fig. 2 - Granular biomass burner

For heat production is used a multifunctional burner for granular biomass - pellets or corn, a newly developed system in research at the Department of Biotechnical Systems of the UPB, shown in figure 2 (Murad E. et al., 2008; Murad E. et al., 2008). The thermal power can be varied through continous adjusting of the flow of D_{vcomb} granular material distributed in the chamber for burning.

The inferior calorific power for pellets is q_{pel}=17 MJ/kg and for maize is q_{pb}=15 MJ/kg. For this case a burner was chosen a burner with a nominal hourly volume flow of 20 dm^3/h; which ensures a nominal power P_{arzn}= 60 kW.

The heat exchanger has a very simple construction, especially designed for this type of application where the flame temperature does not exceed 900°C.This results in a low cost an essential aspect for the initial investment in a greenhouse. Effective balance of the heat exchanger is at least 85% and NTU (Badea A. et al., 2003) type analysis shows that it remains almost constant throughout the range of use because the greenhouse is heated with a D_{av} constant flow of hot air to maintain the jets speed and the uniformity of temperature.

For the alternative economic study and greenhouse heating was also analyzed with a two-stage diesel burner of RIELLO ECO 7/2 type as well as and with an LPG burner with continous adjustment of power between the minimum and maximum flow rate of RIELLO 40GS10/M type.

Automatic internal temperature adjustment is done with digital PID algorithms for biomass burner and LPG burner and with an extended bipositional algorithm for diesel burner. For diesel and LPG the real combustion temperature is higher and hence the SC balance rises to 88%. To adjust the indoor humidity was used a PID adjustment algorithm which controls the D_{aev} air flow exhausted from greenhouse (Ramírez-Arias A., 2005; Yildiz I., 2006).

In order to determine the quantities that characterize the microclimate as well as energy consumption in a cold winter day with outside temperature between -5... -25°C, simulated experiments were conducted with the CLIMSERE simulation program in which the following sizes changes were analyzed: T_i(ºC) inner temperature, U_i(%) relative indoor humidity, P_{srad} (W/m^2) solar radiation, evaporation of the water from soil and on plants ($kg./s.m^2$), CO_2 concentration ($kg.CO_2/m^3$).

For the simulation model were used the energy and mass balances were used for indoor air, indoor humidity and CO_2 concentration (Ramírez-Arias A., 2005; Yildiz I., 1993; Yildiz I., 2006).

For solar radiation model a mathematical model was chosen of the following form:

$$P_{srad}(t)=C1+C2\cdot time+C2\cdot time^2 \quad (W/m^2) \qquad (1)$$

where: *time* is time in hours.

The coefficient values were determined by linear regression from meteorological data for the South region, in Bucharest - Ilfov area.

For mass flow of water evaporation from the soil and leaves surface leaves was used a relatively simple model (Yildiz I., 1993; Yildiz I., 2006):

$$D_{aptr} = K_{tr}\cdot P_{srad}\cdot S_{sol} \quad (g/h) \qquad (2)$$

where: K_{tr} is evapotranspiration coefficient [$(g/m^2h)/(W/m^2)$].

RESULTS AND DISCUSSIONS

Results of simulated experiments are presented in graphs in figures 3 and 4, which correspond to the heating with pellets and diesel.

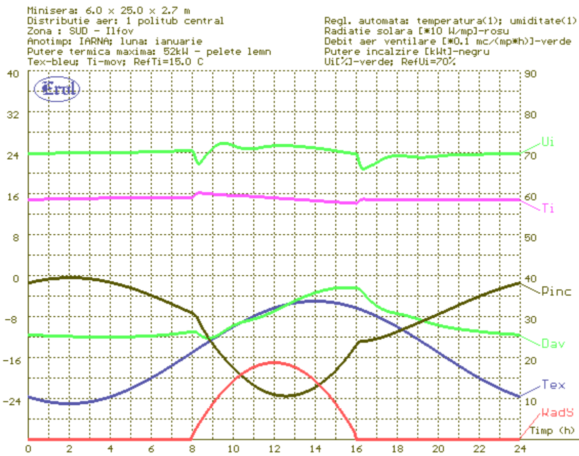

Fig. 3 – The results of simulated experiment for heating with pellets

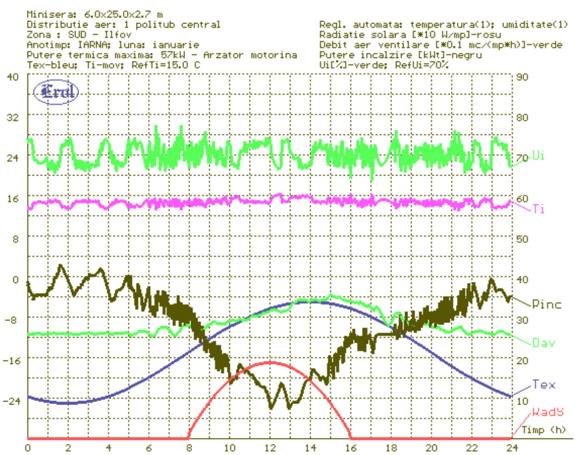

Fig. 4 The results of simulated experiment for heating with diesel

It appears that when using the diesel for heating, because of the adjusting algorithm used to control two-stage burners, thermal power required for heating has relatively large variations because hot air heating system has a very low thermal inertia. As a result it is found that both the indoor temperature and indoor humidity have relatively more large variations from the imposed reference.

When biomass is used there are very good performances by adjustment, which indicates that the studied acclimatization system has a high level of controllability, which allows rigorous maintaince of the parameters of the greenhouse microclimate and thus the production increating in terms of quality and quantity.

Table 1 summarizes the performance of the control of greenhouse microclimate parameters. It appears that changes indoor temperature and humidity are higher for diesel use because bipositional algorithm with cannot achieve more with the PID control algorithm better performances are obtained as it applies to the burners adjustable fuel flow. Better dynamic performance is obtained with LPG burner because it has a much faster response to commands than the biomass burner which has a much higher inertia.

Table 1

Performances of adjustment of the microclimat parameters

Size	UM	Fuel			
		Diesel	LPG	Pellets	Maize
Indoor temperature	^{o}C	12,8/16,3	14,9/15,1	14,2/16,1	14,3/15,9
Indoor humidity	%	64/78	68/71	66/72	66/72
Temperature of the hot air jet	^{o}C	16,8/44	19,7/38,3	19,7/38,2	19,7/38,3
Heating power mim/max	kW	6,8/43,0	10,6/39,5	10,6/39,5	10,6/39,5

Table 2

Fuel consumption an heating costs

Size	UM	Fuel			
		Diesel	LPG	Pellets	Maize
Inferior calorific power	MJ/kg	42	45,7	17	15
Density	kg/dm^3	0,86	0,56	0,45	0,8
Fuel Unit Price	lei/kg	5,93	4,18	0,77	0,65
Fuel Unit Price	€/kg	1,4	0,98	0,16	0,15
Specific primary energy price	€/GJ	33,22	21,52	9,41	10,2
Daily energy requirement	kWh/day	667	673	672	672
Daily consumption	kg/day	64,9	61,3	176,2	199,7
Fuel Cost	€/day	90,55	60,29	28,19	30,54
Specific Fuel Cost	$€/m^2day$	0,6	0,4	0,19	0,2
Price relative specific	%	100	66,58	31,13	33,73
Specific CO_2 emission	kg/kg	2,74	2,89	0	0
Daily emission	kg/day	177,83	177,16	0	0

Table 2 summarizes the results of experiments for fuel consumption heating costs and CO_2 emissions. It appears that the use of biomass in the form of pellets or maize grain is more convenient both economically, up 33% compared to the costs for diesel fuel and ecologically reducing CO_2 emissions by about 178 kg/day to a daily average temperature -15°C. Taking into account the average temperature of the heating period of 190 days, which is the sample area of 2,3°C, a reduction can be estimated of at least 14,3 tons of CO_2 in cold season or of 93,35 $kg.CO_2/m^2$.

CONCLUSIONS

1. We studied the heating of a vegetable greenhouse with biomass compared to the use of diesel or LPG to determine both the quality parameters of microclimate adjustment and economic and environmental aspects. The greenhouse of 150 m^2 is heated with hot air and for a very cold winter it day requires a maximum heating power of only 40 kW, which is about 0,27 kW/m^2.

2. For heating, we used a burner of granular biomass, with continuous adjustment of the flow of biomass, developed at the Department of Biotechnical Systems of the U.P.B. in the PNCD-I 2007-2011 national research program.

3. It appears that using biomass for heating reduces the daily heating expens with around 67%. For the heating period of 190 days with average temperature of

2,3°C the specific cost is 16,07 €/m^2 compared to 32,17 €/m^2 for LPG and 48,26 €/m^2 for diesel. In the past five years the price of maize grain was 0,5 lei/kg, which makes that this to can ensure the lowest costs for heating.

4. The performances in microclimate adjustment are also very good when using and in of biomass burner which makes the heating costs be the crucial parameter for selecting a heating system.

5. In the frosty day we studied, the emission of CO_2 reduce by about 178 kg/day for a daily average temperature of -15°C. So, can be throughout the heating period a reduction of emission of at least 93,35 kg.CO_2/m^2 can be estimate.

6. It was realized a simulation program of the greenhouses heated by hot air generators in which biomass is burned. This software can be used and improved for other greenhouse sizes and and heating systems.

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