APPLYING THE CHAB CONCEPT AT HORTICULTURAL TUNNEL GREENHOUSES HEATED WITH BIOMASS

APLICAREA CONCEPTULUI CHAB LA SOLARIILE HORTICOLE ÎNCĂLZITE CU BIOMASĂ

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Abstract: *For heating tunnel horticultural greenhouses in cold season applies the concept CHAB (Combined **H**eat **A**nd **B**iochar production) which synergistically incorporating thermal energy and biochar production from biomass gasified with TLUD process that produces fuel gas and 12..15 % biochar. Biochar is a vegetal active carbon, sterile, pH > 9 and a high adsorption capacity, used as agricultural amendment and carbon sequestration. Sold with 400...1000 €/t can get zero or negative costs for heat produced. Simulate experiments were performed to a model of the 200 m^2 tunnel greenhouses are grown tomatoes. For heating in four cold months consumed 13 t chopped and dried tomato stalks and resulting 1.8 t biochar which incorporated in the ground leads to a negative balance of -6.34 t.CO_2/year. Average daily cost for fuel is 5,91 €/day without a biochar recovery and -4.78 €/day for a biochar recovery with price of 680 €/t in EU.*
Keywords: *tunnel greenhouse, biomass, CHAB, biochar, simulation*

Rezumat: *Pentru încălzirea solariilor tunel în lunile mai reci se aplică conceptul CHAB (**C**ombined **H**eat **A**nd **B**iochar production), care încorporează sinergic producerea de energie termică şi biochar din biomasa gazeificată cu procedeul TLUD care produce gaz combustibil şi biochar. Biocharul este un cărbune activ, steril, cu pH > 9 şi cu o mare capacitate de adsorbţie, utilizabil ca amendament agricol şi pentru sechestrarea carbonului în sol. Comercializat la 400..1000 €/t se pot obţine costuri zero sau negative pentru energia termică produsă. Experimentele simulate s-au efectuat cu un modelul de solariu de 200 m^2 în care se cultivă tomate. Pentru încălzirea în patru luni reci se consumă 13 t vrejuri de tomate, tocare si uscate, din care rezultă 1,8 t biochar care introdus în sol duce la un bilanţ negativ de -6.34 t.CO_2 /an. Costul zilnic pentru biomasa este de 5.91 €/zi fără valorificare biochar, iar prin valorificarea biocharului cu 680 €/t este de – 4.78 €/zi.*
Cuvinte cheie: *solariu, biomasă, CHAB, biochar, simulare*

INTRODUCTION

It is essential for the health of the population increase zonal production of vegetables for consum all winter. In Romania cold season vegetable production comes about 2/3 of unheated greenhouses. To increase the production of vegetables in cold season, by increasing the use time of tunnel greenhouses, is

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required simple heating systems, with low-cost for investment and operation. (Murad et al., 2013)

As an economic and ecological alternative to current ways of using agricultural waste biomass is proposed synergistic concept called **CHAB** (**C**ombined **H**eat **A**nd **B**iochar production) that incorporates production of heat and biochar (BCH). It can thus achieve optimal recovery of biomass energy as both economically and environmentally.

In the paper (Murad et al., 2011a) has addressed the issue of heating small tunnel greenhouses with burning corn, technologically viable but can not produce biochar, making it less economical and ecological than CHAB concept application.

BCH is a charcoal with a very high porosity, produced from the controlled pyrolysis of biomass in environments with a sub stoichiometric concentration. It has a carbon content of 75-90%, is sterile and has a high adsorption capacity (McLauglin, 2009). A quality biochar must not contain volatile materials and heavy metals. (Schmidt, 2012). Main ecological and economic use of BCH is the amendment to increase fertility of agricultural soils, representing the most economical and ecological way of sequestering atmospheric carbon. BCH is currently solde at prices varied from 600 to 4850 €/kg.bch; prices are highly dependent on local conditions. The average price in the EU is 680 €/t.bch (Tomlinson, 2013).

For the implementation of the concept CHAB can use TLUD process gasifier to produce both fuel gas and biochar. The fuel gas is combusted with a very good yield $\eta_{comb} \approx 0.98$ in a high turbulence burner. With the TLUD process can gasifying a wide variety of agricultural waste and other biomass source, chopped to 10..50 mm and the moisture below 20%. Transport distances less than 15 km, mechanical processing with low energy consumption and drying with natural ventilation can provide an average cost of 40 €/t.bm and a very low cost thermal energy produced, estimated at up to 5 €/GJ, which is 6 times as less than that obtained from diesel (Murad et al., 2011b), (Murad and Dragomir, 2012), (Tillman, 2012).

MATERIAL AND METHOD

In table 1 are shown the main characteristics of residual biomass for 8 species of vegetable crops in Romania, processed for use as fuel for combustion or gasification. Weight and moisture vegetable waste biomass varies with the tcrop and the density of planting. Initially collect whole biomass waste of which the leaves are mechanically separated from stalks; average remains only 20% of initial mass. (Callejon-Ferre et al., 2011); (GcBiomass-GreenhousesCrop); Among cultures analyzed stands out tomato crop that produces high-density residual biomass at 8.7 t/ha with an energy potential of 110 GJ/ha, equivalent to 3.988 L diesel. For optimal use in TLUD gasifier biomass must be chopped to 10-50 mm and dried up to 10% MC. From TLUD gasifier results in average 14% biochar and 86% from biomass is gasified and converted completely into heat witt mean yeld $\eta_{gasif} \approx 0.93$. In this study will be used to heat residual biomass from tomato crop. The characteristics of the processed biomass gasified with TLUD are shown in table 2 (Sima et al., 2013).

To carry out experiments to simulate especially a tunnel greenhouse consists of 28 QUONSET-Metric type base module 6 m, 3 m high, 1.2 m pitch, which has a ground area of 200 m^2, and a volume of 475 m^3. It is covered with a double foil of polyethylene, inflatable and high thermal resistance (Murad et al., 2013).

In greenhouse grown tomatoes varieties Romanian-VIDRA, for which is experimental data for breath and sweating. In order to protect the plants from contact with air currents too hot, the maximum temperature of the jets is limited to 40°C, which required a constant rate D_{av} = 2300 m^3/h air which is heated tunnel greenhouse (Murad et al., 2013).

Figure 1 shows the block diagram of the heated solarium with a hot air system that uses two modules BGM (Biomass-Gasification-Module). The two modules are coupled to the input heat exchanger operating at a constant flow rate of the heated air and consequently has a minimum yield of 85%.

Table 1.

Processed biomass from greenhouses crop residues

Crop Species	BM sorted (dm)	LHV (dm)	Moist-ure	LHV (wet)	BM sorted (wet)	BCH (mean)	LHV BCH (mean)	LHV BM (gasif)	Energy content (gasif)
	t/ha	MJ/kg	%	MJ/kg	t/ha	%	MJ/kg	MJ/kg	GJ/ha
Courgette	3.20	14.67	10.00	13.20	3.56	14.00	18.50	12.34	37.74
Cucumber	3.84	14.36	10.00	12.92	4.27	14.00	18.50	12.02	44.09
Aubergine	4.32	19.27	10.00	17.34	4.80	14.00	18.50	17.15	70.81
Tomato	7.84	17.14	10.00	15.43	8.71	14.00	18.50	14.93	111.82
Bean	3.68	19.86	10.00	17.87	4.09	14.00	18.50	17.77	62.49
Green pepper	4.48	17.69	10.00	15.92	4.98	14.00	18.50	15.50	66.36
Water melon	3.84	16.42	10.00	14.78	4.27	14.00	18.50	14.17	52.00
Melon	5.28	15.49	10.00	13.94	5.87	14.00	18.50	13.20	66.59
Mean	***4.56***	***16.86***	***10.00***	***15.18***	***5.07***	***14.00***	***18.50***	***14.64***	***63.99***

Table 2

Processed tomato wastes from gasification

Features	UM	Input Biomass	Biochar	Gasified Biomass
Relative mass	%	***100.00***	***14.00***	***86.00***
Oxygen	%	40.98	3.70	47.05
Hydrogen	%	5.98	2.10	6.62
Ash	%	2.74	19.50	0.00
Water	%	10.00	0.00	11.63
LHV	MJ/kg	15.20	18.60	14.64
Average bed density	kg/m^3	225.00	180.00	-
Procesed biomass	t/ha	8.70	1.22	7.48
CO_2 balance	t/ha	0.00	-3.34	0.00

Two module BGM type GAZMER® T-31/100 are used, the size of the reactors was determined by the possibility of using chopped biomass with bed density of 200..300 kg/m^3. Rated power module is 23 ± 3 kW. (Murad and Dragomir, 2012)

The block diagram in figure 1 shows the structure of the simulation program SERMGB52.DP (product SOFTEROL®) developed to study the microclimate of tunnel greenhouses. Simulated system consists of four subsystems: the microclimate of the greenhouse, air heater, power unit with two modules BGM, automatic control subsystem. For model of the greenhouse microclimate process block diagram have revealed specific parameters: temperature T_{in} and humidity φ_{in} of air input flow D_{in}; airflow exhaust D_{ev} and recirculated D_{rec}.

Power unit subsystem has two modules BGM biomass loaded which hourly consumptions C_{bm1} and C_{bm2} (kg.bm/h) depending on gasification D_{ag} air flow (kg.air/s) tuned with air dampers C_{ag1} and C_{ag2}. Produced combustible gas is burned with D_{ar} air flow adjustment with C_{ab} air damper.Flue gas enters the heat exchanger and transfer heat to greenhouse air input flow. (Murad et al., 2013)

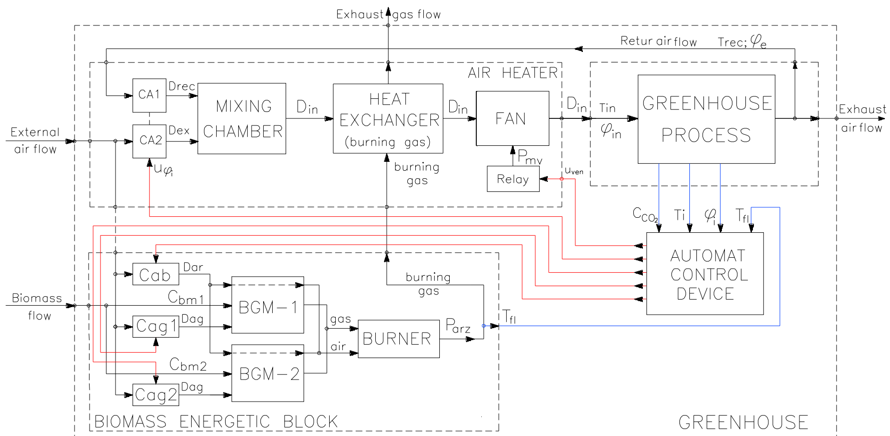

Fig.1 - Block diagram of a heated tunnel greenhouse with energy modules TLUD

Automatic control subsystem is responsible to adjust parameters defining the microclimate in the greenhouse: indoor temperature Ti, indoor humidity Ui and control of thermal group. (Murad et al., 2011a)

For simulated experiment we chose a typical day for November in Ilfov country. The average daily temperature was 5.2 °C and a mean amplitude of 4.2 °C. Temperature control loop setpoint is 22 °C for the day and 17 °C for the night, relatively high values imposed by tomato crop. Adopted a reference humidity of 70% typical of protected crops.

RESULTS AND DISCUSSIONS

In table 3 are summarized the results of simulated experiments to heat the tunnel greenhouse in October (15 days) and November, and for February and March (15 days). The first important result is the consumption of biomass for heating season, it is 13.0 t.bm/season and require a deposit with volume of 52 m^3. Another valuable feature is the average specific daily consumption of biomass for heating in cold seazon c_{bms} = 11.40 kg.bm/K•day.

From TLUD biomass gasified results for all heating season 1.82 t of biochar that can capitalize to 400 - 1000 €/t.bch, or can be incorporated as an amendment to agricultural soils with a negative annual balance -6.34 t.CO_2. In tunnel greenhouse with soil surface of 200 m^2 can be entered 3 kg.bch/m^2·year, about 600 kg.bch; remaining in the first year of use and about 1.2 t.bch incorporated in the other soils or commercially exploited.

Table 3

Simulated experimental results

Features	U.M.	oct.	nov.	feb.	mar.	Total season
Heating days	day	**15**	**30**	**28**	**15**	**88**
Average outside temperature	grade C	7.00	5.20	5.60	7.00	5.94
Average indoor temperature	grade C	18.90	18.90	18.90	18.90	18.90
Average biomass consumption	kg.bm/K*day	11.40	11.40	11.40	11.40	11.40
Average monthly consumption	t.bm/mth	2.035	4.685	4.245	2.035	13.001
Average proportion of BCH	kg.bch/kg.bm	0.140	0.140	0.140	0.140	0.140
Monthly BCH production	t.bch/mth	0.285	0.656	0.594	0.285	1.820
Bed density chips	t.bm/m^3	0.250	0.250	0.250	0.250	0.250
Useful volume storage biomass	m^3	8.140	18.742	16.981	8.140	52.002
Balance of CO_2 sequestration	t.CO_2	-0.992	-2.285	-2.070	-0.992	-6.340

Table 4 presents four variants for assessing the influence of biochar recovery product on specific costs for winter heating fuel used. It appears that from 400 €/t.bch specific cost becomes negative, and the average price recovery in the EU area of 680 €/t.bch specifc becomes strongly negative cost -4.78 €/day, which helps accelerate return on investment in the heating system

Table 4

Specific costs for heating

Features	U.M.	Variant 1	Variant 2	Variant 3	Variant 4
Heating days	days/season	88	88	88	88
Biomass consumption in cold season	t.bm/season	13.000	13.000	13.000	13.000
BCH production	t.bch/an	1.820	1.820	1.820	1.820
Choped biomass costs	€/t	40.00	40.00	40.00	40.00
Cost biomass for heating	€/sezon	520.00	520.00	520.00	520.00
Price biochar as amendment	€/t	**200.00**	**300.00**	**400.00**	**680.00**
Income from sale biochar	€/sezon	276.64	414.96	553.28	940.57
Daily cost uncompensated biomass	€/zi	5.91	5.91	5.91	5.91

CONCLUSIONS

To extend the use time of tunnel greenhouses introduced the synergistic concept CHAB for optimal ecological and economic use of biomass derived from vegetable waste in TLUD gasifiers which produces heat and about 14% biochar

The tunnel greenhouse of 200 m^2 with controlled microclimate can be used as well in the cold seazon with a biomass consumption of 13.0 t.bm/seazon from arising and 1.82 t of biochar, which is incorporated into the soil produce negative annual balance in value of - 6.34 t.CO_2/year. It appears that the recovery biochar with a price of 400 €/t.bch up lead to negative specific costs for fuel used in heating, producing profit.

Developed a model for simulation of a tunnel greenhouses heated with TLUD gasifiers and optimal automatic control. The model developed for the simulation is a powerful base for research and development in the field. Results requires an experimental validation on a real tunnel greenhouse for both confirm simulated experiments results and to determine the real economic issues derived from the extension of use in the cold season.

It can be concluded that the investment in a heating of tunnel greenhouses under CHAB concept, which local harvestable biomass is gasified with TLUD process, it can quickly recover, produce both profits, and more importantly - provide more fresh vegetables in the cold season.

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