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ENERGY CONSUMPTION FOR DIFFERENT GREENHOUSES' STRUCTURES

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Abstract: In this paper influence of greenhouses' structure was estimated for four different double plastic covered greenhouses in winter lettuce production. Plastic coverings are introduced as mean of making this kind of plant production more efficient. Also, as a mean of lowering energy consumption, the tunnel structures are proposed. Four different double plastic covered greenhouses were used for energy analysis. Two tunnel types, 9 x 58m and 8 x 25m covered with double PE folia, and two gutter connected plastic covered greenhouses. One greenhouse is 2 x 7 m wide and 39 m long and the other 20 x 6.4 m wide and 42 m long. Results have shown the lowest energy consumption for gutter connected greenhouses. Energy out/in ratio was also higher in gutter connected greenhouse. Highest energy consumption was obtained in tunnel greenhouse 8 x 25m.

Key words: plastic covered greenhouse, tunnels, gutter connected structures, lettuce, energy, energy productivity

Introduction

Plant production in greenhouses is one of the most intensive parts of agricultural production. It is intensive in production per surface area and in the whole annual production, but also in the sense of energy consumption, labor, costs and investments. Various greenhouses' structures and coverings are offered to producers in order to reduce costs and save energy. The biggest problem is in winter production when additional heating and light are necessary. In that period construction and covering characteristics perform all their qualities.

The aim of this paper is estimation of greenhouses' energy consumption and energy efficiency for winter lettuce production regarding energy input and obtained energy output in Serbian region.

Material and Method

Influence of greenhouse's structure was estimated for four different double plastic covered greenhouses. Two tunnel types, 9 x 58 m and 8 x 25 m covered with double 180 m PE UV IR folia (fig. 1), a gutter connected plastic covered greenhouse 14 x 39 m with 50 m inner folia and 180 m outside folia, and multi-span greenhouse 20 x 6.4 m width and 42 m long with 20 m inner folia and 180 m outside folia (figs. 2 and 3).

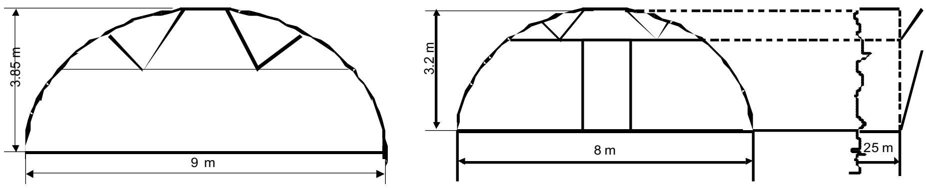

Fig. 1 Tunnels covered with double inflated folia

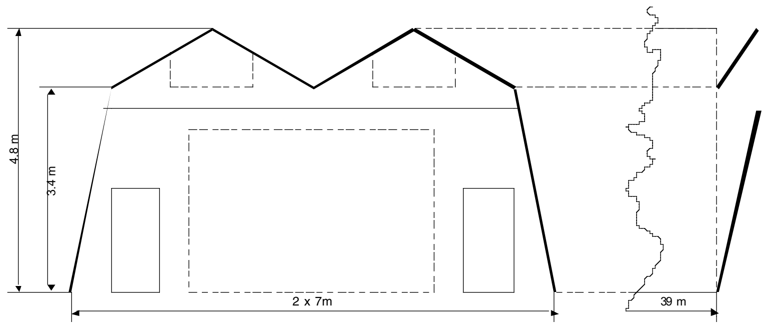

Fig. 2 Gutter-connected greenhouse covered with double folia

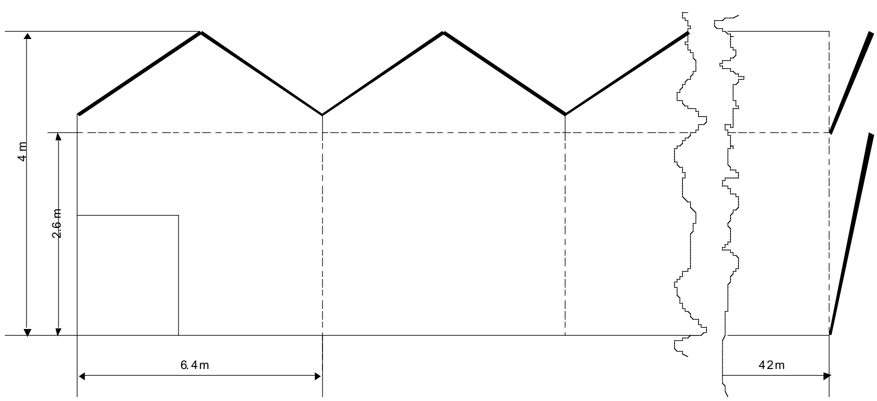

Fig. 3 Multi-span greenhouse covered with double folia

The experiment was carried out at private property near Novi Sad (Serbia) on 19°51 altitude and 45°20N latitude with 84 m above see level. Lettuce greenhouse production was estimated regarding energy consumption and energy productivity for the period of autumn – winter 2003/04.

The method used [2] is based on energy input analysis (definition of direct and indirect energy inputs), energy consumption for given plant production and energy efficiency. On the basis of lettuce production output (kg of lettuce) and energy input, energy input/kg of product, energy out/in ratio and energy productivity were estimated as follows:

$$\text{Energy input/kg of product (EI)} = \frac{\text{energy input for production [MJ/ha]}}{\text{output [kg/ha]}} \quad (1)$$

$$\text{Energy out/in ration (ER)} = \frac{\text{energy value of production [MJ/ha]}}{\text{energy input for the production [MJ/ha}} \quad (2)$$

$$\text{Energy productivity (EP)} = \frac{\text{production [kg/ha]}}{\text{energy input for the production [MJ/ha}} \quad (3)$$

Statistical analysis included linear regression model. The parameter that described construction was greenhouse volume per one meter of its length [m^3/m] which adequately gives the difference in tunnel and multi-span greenhouse structures.

Results and Discussion

Lettuce was produced on white / black mulch folia with 25 m thicknesses that was 2 m wide and already have had openings for the lettuce planting. 20 plants were planted on 1 m^2. In table 1 direct energy input (energy for heating and fuel for technical systems) and indirect energy inputs (fertilizers, plant protection chemicals, water for irrigation, human labor, usage of technical systems and boxes for lettuce packaging) are presented.

Tab. 1 Direct and indirect energy inputs for greenhouses

	Direct and indirect energy input [MJ]			
	Tunnel 9 x 58 m	Tunnel 8 x 25 m	Gutter-connected greenhouse 14 x 39 m	Multi-span greenhouse 128 x 42 m
Greenhouse heating	3338.82	1117.32	3235.51	1077.99
Fuel for technical systems	165.75	55.56	164.37	57.36
Fertilizers	385.44	--	421.02	208.06

Fungicides, pesticides	15.12	3.36	13.44	1.57
Technical systems	4.04	4.04	4.04	4.8
Water for irrigation	268.53	115.08	16.18	1.68
Boxes	141.90	39.30	140.70	10.44
Human labor	375.00	375.00	375.00	54.42
Total energy input [MJ]	4694.60	1709.66	4370.26	1850.70
Specific energy input [MJ/m^2]	8.99	8.55	8.00	6.89

Results have shown that specific energy input was higher in single tunnel greenhouses than in gutter connected structures. This is in accordance with literature [1, 4] which states that the reason for this is ratio between production area and roof and wall area. In the cases of gutter-connected and multi-span greenhouses this ratio is relatively big comparing to single greenhouses. Smaller greenhouse's area also means smaller transfer of heat through the walls which means lower energy consumption for heating.

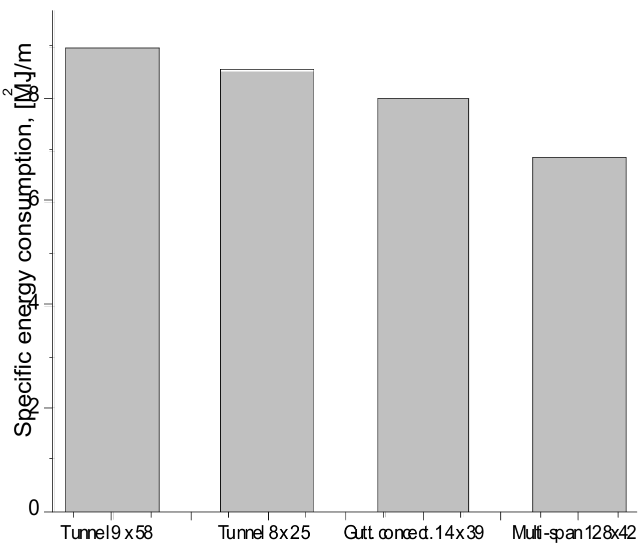

Fig. 4 Specific energy consumption for the greenhouses

Energy output was calculated based on energy value for lettuce and obtained yield.

Tab. 2 Lettuce yield and energy output in greenhouses

	Yield [kg]	Energy output [MJ]	Specific energy output [MJ/m^2]
Tunnel, 9 x 58 m	2753.60	1266.66	2.43
Tunnel, 8 x 25 m	808.00	371.68	1.86
Gutter-connected greenhouse, 14 x 39 m	2968.80	1365.65	2.50
Multi-span greenhouse, 128 x 42 m	1634.80	752.01	2.80

The highest energy output was obtained in gutter-connected greenhouse and the lowest in the smallest tunnel. The reasons for this are more uniform microclimatic conditions and lower percentage of damage caused by the nearness of the covering material. Comparison of varieties of single greenhouse tunnels showed higher energy output in larger tunnels.

Energy analysis

Based on measured energy inputs and energy output the parameters for energy analysis are estimated (table 3). It can be seen (fig. 5) that gutter connected greenhouse had lowest specific energy consumption and that highest value was calculated for tunnel 8 x 25 m. This is in accordance with data from literature [5].

Tab. 3 Parameters for energy analysis

Energy parameter	Tunnel 9 x 58 m	Tunnel 8 x 25 m	Gutter-connected greenhouse 14 x 39 m	Multi-span greenhouse 128 x 42 m
Energy input / kg of product (EI) [MJ/kg]	1.70	2.12	1.47	1.13
Energy efficiency (ER)	0.27	0.22	0.31	0.41
Energy productivity (EP) [kg/MJ]	0.59	0.47	0.68	0.88
Specific volume of greenhouse [m^3/m]	27.00	20.10	54.00	416.80

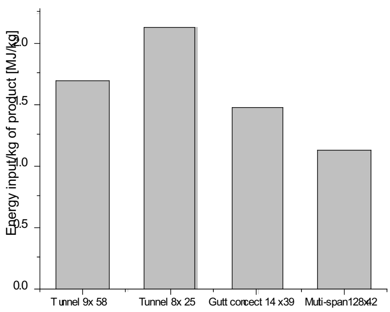

Fig. 5 Energy input / kg of product

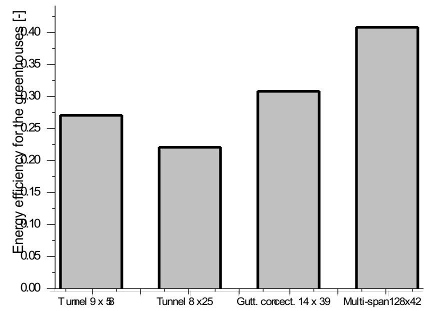

Fig. 6 Energy efficiency

Applied statistical method of linear regression showed that regression model is not significant (R=0.77; F=2.98; significance F = 0.22). Equation obtained (eq. 4) shows that decreasing of energy inputs in conditions of larger specific volume is not significant.

$$y = 1.86 - 0.001x \quad (4)$$

Based on given results it is possible to conclude that greenhouse constructions have no influence on energy parameters (eq. 5, 6).

$$y = 0.25 + 0.003\,x \qquad (R=0.92;\ F=10.87;\ \text{significance } F = 0.08) \qquad (5)$$

$$y = 0.47 + 0.00099\,x \qquad (R=0.87;\ F=6.07;\ \text{significance } F = 0.13) \qquad (6)$$

However, lower energy input and higher energy output caused the highest energy efficiency in the case of gutter connected greenhouses (fig. 6). Tunnel 8 x 25 m was estimated as greenhouse with lowest energy efficiency. Concerning energy productivity (fig. 7) the gutter connected greenhouse showed the highest values. Reasons are great energy output end the lowest specific energy input.

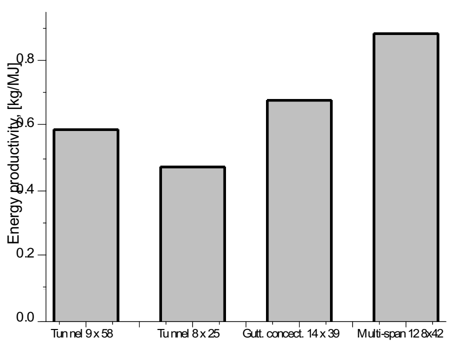

Fig. 7 Energy productivity

Conclusions

Specific energy consumption shows different values for varieties of greenhouse constructions. The lowest values were obtained for gutter-connected greenhouse (8.00 MJ/m^2) and the highest for tunnel 8 x 25 m (8.99 MJ/m^2). Gutter-connected greenhouse showed the lowest energy input per kg of product (1.47 MJ/kg) in relation to tunnel 8 x 25 m that had 2.12 MJ/kg.

Linear regression models have shown that greenhouse structure had no significant influence on energy input, energy efficiency and productivity.

Value for energy efficiency varies from 0.47 up to 0.68 and shows that region of Serbia is suitable for production in greenhouses.

Acknowledgements

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POTROŠNJA ENERGIJE U OBJEKTIMA ZAŠTIĆENOG PROSTORA

Abstrakt: Obzirom da je proizvodnja u zaštićenom prostoru grana poljoprivrede sa najvećom potrošnjom energije i najvišim godišnjim troškovima, proizvođačima se na tržištu nude različiti oblici konstrukcije, pre svega konstrukcije tunel tipa u varijantama sa jednostrukom i dvostrukom folijom, kao ekonomski i energetski najefikasniji. U radu su analizirani, sa aspekta potrošnje energije, najčešće korišćeni oblici konstrukcije objekata zaštićenog prostora na teritoriji Srbije. Analizirana su dva objekta tunel tipa, 9 x 58m and 8 x 25m pokrivena dvostrukom PE folijom i dva blok objekta takođe pokrivena dvostrukom PE folijom. Jedan od blok objekata je bio dvobrodni 2 x 7 m širine i 39 m dužine. Drugi blok objekat je bio 20 x 6.4 m širok i 42 m dug.

Rezultati pokazuju da blok objekti imaju nižu specifičnu potrošnju energije u odnosu na objekte tunel tipa. Blok objekti su, samim tim, pokazali i najbolji stepen iskorišćenja energije. Najniža energetska efikasnost je zabeležena za najmanji tunel (8 x 25 m).

Kljune reči: plastenici, tuneli, blok objekti, salata, energija, energetska efikasnost

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