

ENERGY ASSESSMENT OF CONVENTIONAL AND ORGANIC PRODUCTION OF HEAD CABBAGE

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Abstract

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An energy assessment for the late production of the varieties Kyose 17, Balkan, Pazardzhishko podobreno and Pazardzhishko cherveno was carried out in order to determine the energy intensity of farm systems for conventional and organic production of head cabbage. Mineral fertilizer in quantities of $N_{11.5}P_{23.0}K_{24.4}$ (determined by soil fertility analysis) and pesticides of chemical origin in quantities of 0.60 kg a.i. herbicide, 0.55 kg a.i. fungicides and 0.52 kg a.i. insecticides were applied in conventional production. Authorized products of biological origin i.e. 300.00 L biofertilizer, 2.00 L biofungicide and 1.34 L bioinsecticides were used in organic production. It was found that conventional production needed up to 4864.81 MJ.da⁻¹ of energy while organic production required by up to 31.23% less energy per unit area of land. The variety with lowest energy intensity was Balkan variety, followed by Pazardzhishko podobreno variety with values of up to 4.65% and 2.44% respectively less in comparison to the energy intensity values of these varieties in conventional production. Most suitable for conventional production out of the trial varieties are the Kyose 17 and Balkan varieties while most suitable for organic production are the Balkan and Pazardzhishko podobreno varieties.

Key words: cabbage, farm systems, bioproducts, organic production, energy use

Abbreviation: a.i. – active ingredient

Introduction

Efficient energy use in agriculture nowadays is one of the main criteria for the implementation of sustainable, environmentally friendly and energy efficient production (Uhlin, 1998 and Jonge, 2004). Considerable attention is given to organic production, which is more energy efficient than conventional and represents a viable option for reducing energy consumption (Pimentel et al., 2005; Azeez and Hewlett, 2008).

Head cabbage is one of the major structure-determining crops in Bulgarian vegetable crops production. It is considered that its cultivation technologies are significantly energy saving in both conventional and organic production in addition to those of leek, onion and carrots (Azeez and Hewlett, 2008).

Energy parameters in conventional field tomato (Mihov et al, 2008, 2009), pepper (Mihov and Boteva, 2012) and broccoli (Mihov and Antonova, 2009) production have been determined in response to the current requirements in agriculture to optimize energy resources in Bulgaria. However research and assessment of energy efficiency technologies for vegetable growing is still limited.

The aim of this study is to conduct an energy analysis of head cabbage production under conventional and organic conditions.

Material and Methods

The research was carried out in field conditions at Maritsa Vegetable Crops Research Institute (MVGRI)

in Plovdiv in the period from 2008 to 2010. MVCRI is located at 42°10'N latitude 24°45'E longitude and 160 m above the sea level. Four Bulgarian head cabbage open pollinated varieties were used in this study. Kyose 17, Balkan, Pazardzhishko podobreno and Pazardzhishko cherveno were studied in both conventional and organic production.

The experiment was conducted using the block method with four replications with 20 plants per replication. The experimental plot size was 9.60 m². Crops were grown according to the technology for late field production on high flat bed by 90+70/60 cm transplanting scheme. The seedlings were produced in the open field, with dates of sowing and transplanting from 16th to 20th June and from 25th to 30th July respectively. Planting of seedlings was done manually.

The experiment was set on meadow-cinnamic soil. Mineral fertilizer in quantities of N_{11.5}P_{23.0}K_{24.4} (determined by soil fertility analysis) were broadcast homogeneously and incorporated prior to planting on the soil surface and pesticides of chemical origin in quantities of 0.60 kg a.i. herbicide, 0.55 kg a.i. fungicides and 0.52 kg a.i. insecticides were applied in conventional production. Authorized products of biological origin i.e. 300.00 L biofertilizer (Lumbrical), 2.00 L biofungicide (Timorex) and 1.34 L bioinsecticides (NeemAzel T/C, Pyrethrum FC EK and Pyrus) were used in organic production.

During the vegetation period 15 gravity irrigations with an irrigation rate of 30 m³ took place. 8 mechanized spraying operations with chemicals, 3 mechanized and 2 hand hoeing operations were carried out in conventional production. 10 mechanized spraying operations with bioproducts, 4 mechanized and 4 hand hoeing operations were carried out in organic production. At the end of the vegetation in both farming systems 4 hand harvests took place.

The obtained results for the total yield (kg.da⁻¹) of the four varieties cabbage in both, conventional and organic production were processed statistically using dispersion analysis (Lakin, 1990).

The parameters of the energy analysis were determined using established formulas. The energy equivalents used in the research are presented in Table 1. The energy equivalents of the seedlings (kg) and the bioproducts (L) were calculated by the authors by using

Table 1
Energy equivalents

Parameters	Unit	Energy equivalent, MJ.unit ⁻¹	References
Inputs			
Pesticides (a.i.)			
herbicides	kg	238.00	Helsel, 1992
fungicides	kg	92.00	Helsel, 1992
insecticides	kg	238.00	Helsel, 1992
Chemical fertilizers (a.i.)			
N	kg	64.40	Singh et al., 2002
P ₂ O ₅	kg	11.96	Singh et al., 2002
K ₂ O	kg	6.70	Singh et al., 2002
Bioproducts			
biofertilizer	L	2.98	Calculated
biofungicides	L	10.10	Calculated
bioinsecticides	L	21.60	Calculated
Diesel oil	L	56.30	Singh et al., 2002
Machinery	h	62.70	Singh et al., 2002
Human power			
technicians	h	2.30	Yaldiz et al., 1993
farm-workers	h	1.96	Yaldiz et al., 1993
Seedlings	kg	2.36	Calculated
Polyethylene wrapping	kg	88.50	Alkon, 1997
Water for irrigation and sprinkling	m ³	0.63	Yaldiz et al., 1993
Outputs			
Cabbage	kg	1.2	Singh et al., 2002

a calorimeter. The energy equivalents of the remaining costs were previously used by the researchers Helsel (1992), Yaldiz et al. (1993) and Singh et al. (2002) for estimating the energy inputs in agricultural production.

The natural indexes of diesel oil (L), machinery (h) and human power (h) including those of the technicians, and farm-workers were determined on the basis of modal technological cards.

Results and Discussion

The structure of the energy inputs of both, conventional and organic production, is presented in Tables 2a and 2b respectively. The yields of cabbage production and the parameters of energy analysis are shown

Table 2a
Structure of energy inputs in conventional production

Consumption	Varieties											
	Kyose 17			Balkan			Pazardzhishko podobreno			Pazardzhishko cherveno		
	Quantity, unit.da ⁻¹	Total energy equivalent, MJ.da ⁻¹	%	Quantity, unit.da ⁻¹	Total energy equivalent, MJ.da ⁻¹	%	Quantity, unit.da ⁻¹	Total energy equivalent, MJ.da ⁻¹	%	Quantity, unit.da ⁻¹	Total energy equivalent, MJ.da ⁻¹	%
Pesticides (a.i.), kg	1.67	317.16	6.52	1.67	317.16	6.59	1.67	317.16	6.62	1.67	317.16	6.92
herbicides	0.60	142.80	2.94	0.60	142.80	2.97	0.60	142.80	2.98	0.60	142.80	3.11
fungicides	0.55	50.60	1.04	0.55	50.60	1.05	0.55	50.60	1.06	0.55	50.60	1.10
insecticides	0.52	123.76	2.54	0.52	123.76	2.57	0.52	123.76	2.58	0.52	123.76	2.70
Fertilizers (a.i.), kg	58.95	1182.38	24.30	58.95	1182.38	24.58	58.95	1182.38	24.67	58.95	1182.38	25.79
nitrogen	11.55	743.82	15.29	11.55	743.82	15.46	11.55	743.82	15.52	11.55	743.82	16.22
phosphorus	23.00	275.08	5.65	23.00	275.08	5.72	23.00	275.08	5.74	23.00	275.08	6.00
potassium	24.40	163.48	3.36	24.40	163.48	3.40	24.40	163.48	3.41	24.40	163.48	3.57
Diesel oil, L	23.88	1344.44	27.64	23.63	1330.37	27.65	23.60	1328.68	27.72	22.78	1282.51	27.97
Machinery, h	15.14	949.28	19.51	15.00	940.50	19.55	14.92	935.48	19.52	14.28	895.36	19.53
Human power, h	98.12	194.89	4.01	95.86	190.44	3.96	94.72	188.19	3.93	84.91	168.85	3.68
technicians	7.57	17.41	0.36	7.50	17.25	0.36	7.46	17.16	0.36	7.14	16.42	0.36
farm-workers	90.55	177.48	3.65	88.36	173.19	3.60	87.26	171.03	3.57	77.77	152.43	3.32
Seedlings, kg	15.09	35.61	0.73	15.09	35.61	0.74	15.09	35.61	0.74	15.09	35.61	0.78
Polyethylene wrapping, kg	6.30	557.55	11.46	6.00	531.00	11.04	5.90	522.15	10.89	4.74	419.49	9.15
Water for irrigation, m ³	450.00	283.50	5.83	450.00	283.50	5.89	450.00	283.50	5.91	450.00	283.50	6.18
Total inputs, MJ.da ⁻¹		4864.81	100.00		4810.96	100.00		4793.15	100.00		4584.86	100.00

Table 2b
Structure of energy inputs in organic production

Consumption	Varieties											
	Kyose 17			Balkan			Pazardzhishko podobreno			Pazardzhishko cherveno		
	Quantity, unit.da ⁻¹	Total energy equivalent, MJ.da ⁻¹	%	Quantity, unit.da ⁻¹	Total energy equivalent, MJ.da ⁻¹	%	Quantity, unit.da ⁻¹	Total energy equivalent, MJ.da ⁻¹	%	Quantity, unit.da ⁻¹	Total energy equivalent, MJ.da ⁻¹	%
Bioproducts, L	303.34	763.14	22.20	303.34	763.14	21.73	303.34	763.14	21.98	303.34	763.14	24.20
biofertilizer	300.00	714.00	20.77	300.00	714.00	20.33	300.00	714.00	20.56	300.00	714.00	22.65
biofungicides	2.00	20.20	0.59	2.00	20.20	0.58	2.00	20.20	0.58	2.00	20.20	0.64
bioinsecticides	1.34	28.94	0.84	1.34	28.94	0.82	1.34	28.94	0.83	1.34	28.94	0.92
Diesel oil, L	19.47	1096.16	31.88	19.78	1113.61	31.71	19.61	1104.04	31.80	18.34	1032.54	32.75
Machinery, h	11.74	736.10	21.41	11.96	749.89	21.35	11.84	742.37	21.38	10.88	682.18	21.64
Human power, h	79.11	157.05	4.57	82.73	164.18	4.68	80.70	160.18	4.61	65.55	130.33	4.13
technicians	5.87	13.50	0.39	5.98	13.75	0.39	5.92	13.62	0.39	5.44	12.51	0.40
farm-workers	73.24	143.55	4.18	76.75	150.43	4.28	74.78	146.57	4.22	60.11	117.82	3.74
Seedlings, kg	12.82	30.26	0.88	12.82	30.26	0.86	12.82	30.26	0.87	12.82	30.26	0.96
Polyethylene wrapping, kg	4.20	371.70	10.81	4.60	407.10	11.59	4.39	388.52	11.19	2.61	230.99	7.33
Water for irrigation, m ³	450.00	283.50	8.25	450.00	283.50	8.07	450.00	283.50	8.17	450.00	283.50	8.99
Total inputs, MJ.da ⁻¹		3437.91	100.00		3511.69	100.00		3472.01	100.00		3152.93	100.00

in Table 3. This data shows that ***the cabbage is energy effective culture per unit of area of land***. In conventional growing the costs detailed in Table 2a generate total energy inputs ranging from 4793.15 MJ.da⁻¹ to 4864.81 MJ.da⁻¹, but the energy outputs with the yield are higher and according to the varieties amount to from 4952.00 MJ.da⁻¹ to 5288.00 MJ.da⁻¹. The exception is Pazardzhishko cherveno variety, where the energy outputs are lower than the energy inputs of its production. The data obtained suggest energy outputs-inputs ratios R=1.09 in Kyose 17 variety, R=1.05 in Balkan variety and R=1.03 in Pazardzhishko podobreno variety. The energy effectiveness in Pazardzhishko cherveno variety lags behind the energy efficiency of the production of other cabbage varieties.

In organic production the total energy inputs are 29.12% lower for Kyose 17 variety, 27.35% lower for Pazardzhishko podobreno variety and 24.01% lower for Balkan variety. Because of the lower yield of variety Pazardzhishko cherveno the related energy inputs for diesel oil, machinery and human power for harvesting and transportation are reduced. Hence the total energy inputs are 31.23% lower. The bioproduct with the highest energy consumption ranging from 20.70% to 22.57% from the total energy inputs is the bio-fertilizer (Lumbrical).

The main reason for the energy effectiveness of organic farming is that it does not use inorganic nitrogen fertilizer (Pimentel et al., 2005; Azeez and Hewlett, 2008). The amounts of chemical fertilizers used for the purposes of this study are determined by precise

soil fertility analysis. With this method the energy consumption of nitrogen is 743.82 MJ.da⁻¹ lower than normal and amounts from 15.29% to 16.22% of the total energy inputs required for conventional production according to the variety. The energy consumption of diesel oil, machinery and human power have the largest share of up to 27.97% and 19.55% respectively. Due to the large energy equivalent of the raw material, the polyethylene wrapping results in significant energy consumption of 557.55 MJ.da⁻¹ in conventional and of 407.10 MJ.da⁻¹ in organic production.

The energy effectiveness per unit of production of cabbage, measured in MJ.da⁻¹ in conventional production proves best in variety Kyose 17 – 1.10 MJ.kg⁻¹, followed by varieties Balkan – 1.14 MJ.kg⁻¹, Pazardzhishko podobreno – 1.16 MJ.kg⁻¹ and Pazardzhishko cherveno – 1.38 MJ.kg⁻¹. In organic production Pazardzhishko podobreno variety has the lowest energy intensity followed by the Balkan variety with the energy intensity being 4.65% and 2.44% lower in comparison to the energy intensity values of these varieties in conventional growing. The energy intensity of Kyose 17 and Pazardzhishko cherveno varieties goes up by 6.18% and by 25.44% respectively mainly due to significantly lower yield compared to the yield of other varieties.

The conclusion from the analysis of the energy parameters is that varieties suitable for conventional production are Kyose 17 followed by Balkan and Pazardzhishko podobreno, while suitable for organic production are varieties Balkan and Pazardzhishko podobreno followed by Kyose 17.

Table 3
Energy parameters of farm systems

Varieties	Farm systems	Total inputs MJ.da ⁻¹	Yield, kg.da ⁻¹	Outputs, MJ.da ⁻¹	Energy intensity, MJ.kg ⁻¹	Energy productivity, kg.MJ ⁻¹	Output-inputs ratio, R
Kyose 17	Conventional	4864.81	4406.67	5288.00	1.10	0.91	1.09
	Organic	3437.91	2941.67***	3530.00	1.17	0.86	1.03
Balkan	Conventional	4810.96	4220.00	5064.00	1.14	0.88	1.05
	Organic	3511.69	3240.00***	3888.00	1.08	0.92	1.11
Pazardzhishko podobreno	Conventional	4793.15	4126.67	4952.00	1.16	0.86	1.03
	Organic	3472.01	3073.33***	3688.00	1.13	0.89	1.06
Pazardzhishko cherveno	Conventional	4584.86	3320.00	3984.00	1.38	0.72	0.87
	Organic	3152.93	1826.00***	2191.20	1.73	0.58	0.69

*** significant at p≤0.001

The survey results show that when considering organic production of cabbage it is necessary to include suitable varieties with greater biological potential for yield. Yield of over 3600 kg.da⁻¹ of cabbage would result in energy outputs of 4400 MJ.da⁻¹ and a potential energy profit from 14% to 16%.

Conclusions

Conventional production of head cabbage needs up to 4864.81 MJ.da⁻¹ of energy while organic production required by up to 31.23% less energy per unit area of land.

The variety with lowest energy intensity in organic production is Balkan variety, followed by Pazardzhishko podobreno variety with values of 4.65% and 2.44% respectively in comparison to the energy intensity in conventional production.

Energywise most suitable for conventional production out of the trial varieties are the Kyose 17 and Balkan varieties while most suitable for organic production are the Balkan and Pazardzhishko podobreno varieties.

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