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ENERGY BALANCE OF THE CARROT ROOT PROCESSING

ENERGETSKI BILANS DORADE KORENA MRKVE

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ABSTRACT

In this paper carrot open field production was analysed. Spring seeded carrot was used for root drying and summer seeded carrot was used for the fresh consumption. Average yields were 50 and 69 t/ha with the total energy input of 52.45 and 76.44 GJ/ha.

Total energy consumption in drying was 373 GJ/ha. Carrot root for the fresh market was stored for six months, then washed and packed with the total energy input of 99 GJ/ha. In the structure of energy inputs for drying, the highest share had the natural gas consumption and electricity and these were 74.52 and 19.73 %. In the case of fresh market carrot processing, the highest share in total energy input of 74.57 % had the electricity.In order to minimize the energy input in the process of drying, carrot should be seeded in spring and the one that is for the fresh consumption, should be seeded in summer.

Key words: *energy, carrot, storage, processing, drying, washing.*

REZIME

U ovom radu je analizirana njivska proizvodnja korena mrkve. Analizirana je proizvodnja iz prolećne setve namenjena za sušenje korena mrkve i proizvodnja iz letnje setve namenjena za upotrebu u svežem stanju, pri čemu su ostvareni prosečni prinosi od 50 i 69 t/ha, uz ukupni energetski input (Total energy input) od 52,45 i 76,44 GJ/ha. Ukupni energetski input za industrijsku preradu sušenjem, bio je 373 GJ/ha. Koren mrkve za svežu upotrebu se određeni period skladišti (prosečno 6 meseci), a zatim pere i pakuje uz ukupni energetski input od 99 GJ/ha. U strukturi ukupnog energetskog bilansa za sušenje korena mrkve, najveći udeo ima potrošnja zemnog gasa i električne energije, što iznosi 74,52 i 19,73%. Prilikom dorade korena mrkve za svežu upotrebu, u strukturi ukupnog energetskog bilansa, najveći udeo ima potrošnja električne energije prilikom skaldištenja, 74,57%. Da bi se ostvarila minimalna vrednost ukupnog energetskog inputa, mrkvu namenjenu za sušenje je potrebno proizvoditi iz prolećne setve, a mrkvu namjenjenu za svežu upotrebu iz letnje setve.

Ključne reči: *energija, mrkva, skladištenje, dorada, sušenje, pranje.*

INTRODUCTION

Interest in carrot production is increasing on the daily basis. Surfaces planted with carrot are constantly increasing. In Serbia, carrot is produced on, in average, 8 000 hectares. In the World the surfaces under carrot are covering 1,100,000 hectares *(Đurovka, 2008)*. There is an increasing demand for this vegetable on the world market. There are the opportunities for the export not only the fresh carrot but also for the processed (dried, frozen,..). There is a great interest in the energy consumption in the carrot open filed production as well as in the area of its processing. The interest increased in last years due to the need of finding the optimal and cheaper solutions for the certain technical problems in the production chain (*Ivanišević i Mitrović, 2012*).

Great number of authors has been dealing with the energy consumption in the field crop. In the case of sugar beet production total energy input was 32.9 GJ/ha *(Ortiz-Canavate and Hernandez, 1999)*. In the case study for Iran (randomly chosen 153 farms for sugar beet production) the energy needed for the sugar beet production was 42 GJ/ha where 57 % of this value was used via direct energy input and the other 43 % were estimated as indirect energy input *(Asgharipour et al., 2012)*.

Irrigation has a significant influence on the energy consumption in the crop production. In the years 2003 / 2004 a case study was carried in Iran. There were 28,400 ha of irrigated land with wheat, barley and corn production and 19,300 ha with the dry farming technology of wheat and barley production. In the case of irrigated land total energy consumption was 51.6 GJ/ha for wheat, 53.5 GJ/ha for barley and 72.7 GJ/ha for corn production *(Safa et al., 2010)*. The same authors stated that without the irrigation the energy consumption in wheat production was 12.5 GJ/ha and in barley 11.9 GJ/ha that is 4.11 and 4.49 times lower than with the irrigation. Similar test were carried in Poland where energy efficiency and profitability were analysed in wheat and barley production *(Gorzelany et al., 2012)*. Profitability of wheat production was 1.49 and of barley 1.53. Energy efficiency of the wheat production was 1.4 and of barley 2.3.

Energy consumption for the carrot fresh consumption was 11.2 GJ/ha, with the energy productivity of 0.45 kg/MJ, energy ratio of 0.778 and the average carrot root yield of 50 t/ha *(Ponjičan, 2009)*. In the structure of total energy consumption, the highest share had the energy input via irrigation, with 30.75 %, then energy used through the fertilizers, 19.37 %, followed by transportation, 11.68 % and plastic packing, 9.88 %.

Beside the energy analysis economical analysis and costs are very interesting for the farmers and producers. In Hungary, costs of technical systems for carrot filed production are 1,500 euro or 3 eurocents/kg carrot *(Magó, 2013)*. This calculation did not include the costs of human labour, fertilizers, pesticides and water for the irrigation.

Concerning everything previously said it is of a great interest to further study the energy consumption structure in carrot fresh production and its processing.

MATERIAL AND METHOD

For determination of the energy consumption and its structure two sites were chosen for the experiment. For the spring seeded carrot experiment was carried in the Despotovo area (Vojvodina, Serbia) and for the summer seeded carrot experiment was carried out in the Gospodjinci and Begeč area (Vojvodina, Serbia). Total energy input in processing of carrot for fresh consumption were determined on the family farm "Family farm of Lazar Djukić" in Gospodjinci while total energy input in carrot drying was determined in the "BAG A. D." plant for drying in Bačko Gradište.

Total energy input for the carrot field production was determined as the sum of the specific energy inputs via human labour, technical systems, equipment and buildings, diesel fuel, gas, electricity, fertilizers, chemicals for plant protection, packing and water for irrigation and washing. Having the all energy inputs on one side and knowing the carrot yield, basic energy parameters of the production system were determined *(Gülistan et al., 2007; Đević and Dimitrijević, 2009; Đević et al., 2010; Safa et al., 2010; Asgharipour et al., 2012;Ponjičan et al., 2013; Bajkin et al., 2014)*:

specific energy input (EI_{sp}):

$$EI_{sp} = \frac{EI}{G}, \text{ (MJ/kg)}, \quad (1)$$

energy ratio (ER):

$$ER = \frac{EV \cdot G}{EI}, \text{ (–)} \quad (2)$$

energy productivity (EP):

$$EP = \frac{G}{EI}, \text{ (kg/MJ)}, \quad (3)$$

where: G – carrot root yield (kg/ha) and EV – energy value of the carrot root (1,73 MJ/kg) (*www.elements4health.com/carrots.html*).

RESULTS AND DISCUSSION

4.1. Energy input in the production of carrot for the fresh consumption

In case of the summer carrot seeding, total energy consumption was 76.4 GJ/ha. The highest energy input of 25.1 GJ/ha, was observed for the irrigation. When water for irrigation is taken into account this value is 31.4 GJ/ha which represents 41.05 % of the total energy input in the production. The values are high due to numerous irrigation cycles (35 times during the production cycle). For the irrigation self propelled sector device was used (Tifon). Since carrot was planted in summer, in order to have a good germination, numerous irrigation cycles were needed. Irrigation was also used as a cooling technique. Some of the energy savings could have been done by using some of the shading techniques (mulching) or drip irrigation systems. Drip irrigation systems are less energy consuming systems, they are more efficient when it comes to the water usage and its efficiency. Due to these reasons drip irrigation systems will have their place in future not only in vegetable production but also in the fruit and crop irrigation (*Ponjičan et al., 2013*).

Specific energy input for the open filed carrot production was 1.529 MJ/kg, energy productivity 0.654 kg/MJ and energy ratio 1.132 which is in accordance with the previous investigations. In the year of 2008, calculated energy ratio in the case of the filed carrot production for the fresh consumption, was 1.204 (*Ponjičan, 2009*). In the case of sugar beet production, with the yield of 60 t/ha, obtained energy ratio was 1.3 (*Ortiz-Cañavate, 1994*).

4.2. Energy input for the carrot production for drying

In the case of the spring seeded carrot for the processing, total energy consumption was 52.45 GJ/ha. The lower value of the energy input is a consequence of the less numerous irrigation cycles. Specific energy input was 0.760 MJ/kg while the energy productivity was 1.316 kg/MJ. Higher value of the energy productivity is due to the higher yield of the carrot root (69 t/ha) and to the lower energy input. Energy ratio was 2.276.

4.3. Energy consumption for the carrot root processing for the fresh consumption

Carrot root processing consists of root storage in the cold storage, washing and packing. For the carrot packing, 10 kg plastic bags were used. Productivity of the washing and packing machine was 20 t for 8 hours. Energy balance was determined for the storage buildings where storing and washing was carried out. The energy consumption was determined based on the construction material used and the adequate energy equivalents for the materials. Period of building exploitation was adopted to be 40 years (*Jovanović, 2005; Ponjičan, 2009*). Energy input for building the storage was 2.6 GJ/ha. Energy built in concrete parts was estimated to be 0.266 GJ/ha, energy built in the steel parts was estimated to be 1.901 GJ/ha and for the panels it was 0.436 MJ/ha. Indirect energy inputs through the built in equipment were 0.520 GJ/ha (20 % of the total energy consumption for the storage building). Energy consumption during the period of keeping was also estimated and presented in the table 1.

Table 1. Total energy input for fresh carrot root storage, cleaning, washing and packing (Ponjičan et al., 2013)

Energy inputs:	MJ/ha	%
LPG (indoor transport) (3x)	1,514	1.52
Electricity (storage)	74,088	74.57
Electricity (washing and packing)	2,772	2.79
Building, refrigerator	2,604	2.62
Building for washing and packing	335	0.34
Equipment/machines	1,560	1.57
Washing water	2,250	2.26
Storage packaging	6,045	6.08
Packaging packing	7,648	7.70
Human labour	536	0.54
Total energy input:	99,351	100.00

Total energy input for the storage, washing and packing of the carrot root was 99.35 GJ/ha. The highest share in this amount had the electricity used during the storage itself. Storage period for the carrot is 6 months and in this period 74.09 GJ/ha of the electricity was used, which represents 74.57 % of the total energy consumption. As for the indirect energy inputs, the highest share was calculated for the packing material (7.7 %). Analysis of the energy consumption in the carrot root processing showed that the specific energy input was 1.987 MJ/kg, energy ratio 0.871 and the energy productivity 0.503 kg/MJ. So, for the carrot filed production and for processing total amount of 175.8 GJ/ha is needed (76.4 GJ/ha for the carrot for fresh consumption and 99.4 GJ/ha for the storage, packing and washing). This value represents the total energy input from the field carrot production up to final product that is consumer ready. Total labour needed was 852.14 h/ha. Total energy productivity was 0.284 kg/MJ while specific energy input was 3.516 MJ/kg. Energy ratio was 0.492. In the case of carrot production for the fresh market with the carrot yield of 50 t/ha, energy productivity for the production, storing, processing and packing was 0.450 kg/MJ *(Ponjičan, 2009).* The same author stated that the total energy input in this case was 111.2 GJ/ha. The difference between the values is due to the favourable production conditions and the fact that carrot was stored in the cold storage without the air conditioning thus having the shorter storage period (4 months).

4.4. Energy consumption in the process of carrot drying

After the field production and harvesting, comes the root drying and packing of the final product. In order to obtain 1 kg of dried carrot 13.5 kg of fresh carrot is needed so from 1 ha, total amount of obtained dry carrot was 5,111 kg. Specific gas consumption was 1.7 m^3/kg. Total energy consumption for the drying and packing of the carrot was 373 GJ/ha. The highest value of the input energy had the natural gas consumption for drying. The value was 277.9 GJ/ha i.e. 74.52 % of the total energy consumption.

Tabela 2. Total energy input for carrot root processing and drying (Bajkin et al., 2014)

Energy inputs:	MJ/ha	%
Diesel fuel (transport)	3,626	0.97
Electricity (processing equipment)	73,600	19.73
Natural gas (drying)	277,921	74.52
LPG (transport)	48	0.01
Equipment and machines	4,929	1.32
Building	1,122	0.30
Washing water	9,200	2.47
Packaging	771	0.21
Human labor	1,747	0.47
Total energy input:	372,965	100.00

On the second place is electricity with the 73.6 GJ/ha (19.73 % of the total energy input). Concerning the indirect energy input, the highest value was calculated for the water consumption, 9200 MJ/ha that is 2.47 % of the total energy consumption. After that, with 4.9 GJ/ha (1.32 %), comes the energy consumed via technical systems and the equipment. Analysis of the energy consumption in the carrot root processing and drying showed that the specific energy input was 5.405 MJ/kg, energy ratio 0.320 and the energy productivity 0.185 kg/MJ. So, for the spring seeded carrot filed production and for drying total amount of 425.4 GJ/ha is needed (52.5 GJ/ha for the carrot for fresh consumption and 373 GJ/ha for drying). This value represents the total energy input from the open filed carrot production up to final product that is consumer ready. Total energy productivity of the carrot filed production was 1.316 kg/MJ while total energy productivity, up to the final product was 0.162 kg/MJ. The tendency of lower energy productivity is due to the higher share of direct energy inputs through natural gas, used for drying. Specific energy input for the filed carrot production was 0.760 MJ/kg, while total specific energy consumption up to the final product was 6.165 MJ/kg. Energy ratio for the filed production was 2.276 while total energy ratio, up to the final product, was 0.280.

4.5. Energy consumption for the carrot processing

For the carrot processing the most energy consuming parts of the process are cooling and storage in the cold storage systems. In order to reduce the energy consumption for the cooling, seeding of carrot should be carried out in summer in order to have harvest in November, for example. Drip irrigation systems can also reduce the energy input in the irrigation and can significantly improve the seed germination which is crucial for the carrot production. For the carrot processing, it is important to establish the production in the early spring when there are favourable conditions for germination and root development and growth. In this case, harvesting comes at the end of summer (September) while there are still high air temperatures. Prior to processing, carrot roots should be with higher dry meter content. Few days are needed for natural drying on the concrete surface. After that comes the rough cleaning, stone separation, washing, inspection, slicing, blanching, transportation, drying and packing. The highest energy input is needed in the carrot drying and packing and this should be carried out while there are still high air temperatures in the open.

CONCLUSION

For the fresh carrot root consumption, carrot should be planted in summer in order to be harvested in the late autumn when energy input in cooling carrot to 1-3 °C could be significantly lowered. The carrot that is meant for the fresh market must have the adequate organoleptic properties.

Carrot for the industrial processing should be produced in the period of year with the favourable production conditions. In this way maximal yield will be obtained as well as the good root quality with the minimal energy inputs. High quantities of the natural gas are used for the carrot drying. The interesting thing, from the economical aspect, would be to replace gas with some other alternative and chipper fuel.

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REFERENCES

Asgharipour M.R, Mondani F, Riahinia S. (2012). Energy use efficiency and economic analysis of sugar beet production system in Iran. Energy, 44, 1078-1084.

Bajkin, A., Ponjičan, O., Radomirović, D., Pavkov, I., Dulić, M. (2014). Energy balance for carrot root production and drying. Journal on Processing and Energy in Agriculture, 18 (2), 59-61.

Đević, M., Dimitrijević, Aleksandra (2009). Analiza potrošnje energije u proizvodnji paradajza na otvorenom polju i u objektima zaštićenog prostora. Savremena poljoprivredna tehnika 35 (3), 169-175.

Đević, M, Dimitrijević, Aleksandra, Mileusnić, Z, Miodragović, R. (2010). Potrošnja energije u proizvodnji paradajza na otvorenom i u objektima zaštićenog prostora različite konstrukcije. Savremena poljoprivredna tehnika, 36 (2), 138-146.

Đurovka, M. (2008). Gajenje povrća na otvorenom polju. Poljoprivredni fakultet, Novi Sad, 251.

Gorzelany, J., Zagula, G., Findura, P., Turan, J. (2012). Assessment of costs and energy consumption in wheat and oat production in a privately owned farm in Podkarpacie Region. Contemporary agricultural engineering, 38 (1), 31-38.

Gülistan, E., Kemal, E., Hilmi, E., Orhan, G. (2007). Energy use and economical analysis of sugar beet production in Tokat province of Turkey. Gaziosmanpasa University, Faculty of Agriculture, Department of Agricultural Economics, Turkey.

Ivanišević, S., Mitrović, D. (2012). Specifičnosti sušenja proizvoda liofilizacijom. Savremena poljoprivredna tehnika, 38 (2), 97-107.

Jovanović, M. (2005). Ekonomska analiza proizvodnje biodizela. Poglavlje u monografiji: Biodizel–alternativno i ekološko tečno gorivo, Poljoprivredni fakultet, Novi Sad, 160-180.

Magó, L. (2013). The significance of post-harvest transportation tasks in the field root vegetable production. The First International Symposium on Agricultural Engineering, 4th-6th October 2013, Belgrade Zemun, Serbia, IV-1–IV-6.

Ortiz-Cañavate, J. (1994). CIGR Handbook of Agricultural Engineering, Volume V Energy and Biomass Engineering, Chapter 2 Energy for Biological Systems, Part 2.1 Energy Analysis and Saving: 13-42.

Ortiz-Cañavate J, Hernanz J.L. 1999. Energy Analysis and Saving in Energy for Biological Systems, In CIGR Handbook 3, 13-37.

Ponjičan, O. (2009). Analiza parametara mašine za formiranje mini gredica pri proizvodnji korenastog povrća. Doktorska disertacija. Univerzitet u Novom Sadu, Poljoprivredni fakultet, Novi Sad, Srbija.

Ponjičan, O., Bajkin, A., Pavkov, I., Dulić, M. (2013). Energetski bilans proizvodnje i dorade mrkve za svežu upotrebu. Savremena poljoprivredna tehnika, 39 (3), 167-176.

Safa, M., Mohtasebi, S., Behroozi, M.L., Ghasemi-Varnamkhasti, M. (2010). Energy consumption in production of grains prevalent in Saveh. African Journal of Agricultural Research, 5 (19), 2637-2646.

www.elements4health.com/carrots.html

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