ENERGY EFFICIENCY ANALYSIS OF AGARICUS BISPORUS MUSHROOM PRODUCE IN FELDIOARA-BRASOV

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Abstract: *The purpose of this research was to assessment of the nature energy and specifically to measure and benchmark the effi- ciency for Agaricus Bisporus mushroom production in Feldioara, Brasov county. The data used in this study were collected poersonaly from October 2011 to November 2012 in the mushrooms farm KADNA BIONATURA one of the important mushroom producer in the area. In the investigated farm, the average and total energy were calculated, during both summer and winter season, considering the financial implications. Electricity and fossil fuel were found to be used in excess in mushroom production farm. The conclusion is that the total energy consumption can be reduced with 8% for mushroom production especialy by improving the thermal insulation of the building and use of heat recuperators.*
Keywords: *Agaricus Bisporus, Energy Equivalents Used, Energy Equivalent, Technical Efficiency*

1. INTRODUCTION

Currently, champignons are grown in 80 countries of the world. At present, of all the diversity of mushroom realm, more than 14 species are cultivated on a commercial scale. Production of mushroom has already crossed 7 million metric tons annually in the world and is expected to reach 10 million metric tons in the next 10 years [10]. The leading position in the global production belongs to white button mushroom (champignon); its annual volumes exceed 1.5 million tons. The champignon is followed by such wood-attacking fungi as Siitake (527,000 tons) and oyster mushroom (250,000 tons). Besides the mentioned species, the following are also grown on a commercial scale: volvariella volvacea (200,000 tons), Jew's-ear fungus (120,000 tons), velvet foot (105,000 tons), nameko (30,000 tons), Coprinus comatus, honey fungus and stropharia rugoso-annulata (10,000 tons each). Torq, black truffle, agrocybe, and some other species are grown in insignificant volumes. Presently, the scientific research work is underway to introduce new prospective species of edible fungi into cultivation. White button mushroom (Agaricus Bisporus) cultivation began in France two hundred years ago and has developed into a thriving industry not only in Europe, but world over [19]. Greenhouse production is one of the most intensive parts of the world agricultural production. It is intensive in the sense of yield and annual production, but also in sense of the energy consumption, investments and costs [22]. Efficient use of resources is one of the major assets of ecoefficient and sustainable production, in agriculture [4]. Efficient use of energy is one of the principal requirements of sustainable agriculture. The shares of greenhouse crops production were as follows: vegetables 59.3%, flowers 39.81%, fruits 0.54% and mushroom 0.35% [16].
Energy use in agriculture has been increasing in response to increasing population, limited supply of arable land, and a desire for higher standards of living.
Continuous demand in increasing food production resulted in intensive use of chemical fertilizers, pesticides, agricultural machinery and other natural resources. The development of energy efficient agricultural systems with a low input of energy compared to the output of products should therefore help to reduce the emissions of greenhouse gasses in agricultural production [3]. Energy use is one of the key indicators for developing more sustainable agricultural practices. Renewable energy sources coming from agricultural crops could play an important role to supply the energy requirement and in terms of environmental effects [19], [20].
The study was conducted from October 2011 to November 2012 in the mushrooms farm KADNA BIONATURA of Fledioara village, Brasov County. Farm has 4 spaces for mushrooms production, with area of 150 square meters, equipped with 4 rows of shelves with 4 levels. Developed culture surface is 256 sqm / room, respective 1024 sqm / farm.
The selection of button mushroom growing rooms was based on random sampling method.

2. AGARICUS BISPORUS (CHAMPIGNON) MUSHROOM PRODUCING

Mushroom culture is a cyclical process and involves several different operations, each of which must be carefully performed. The white button mushroom is more acceptable to the consumer and fetches higher prices. For its successful and profitable cultivation, careful attention must be paid [10].

Producing Champignon mushroom needs cool weather condition in temperatures ranged of 16.5-18.5°C or 18.5-21°C [11], [12], [24].

Most of farmers in Romania grown in winter but many important farmers work throughout the year, also in summer. These farmers have to create cool condition in their rooms in summer but would sell their product more expensive than winter growers. During the crop cycle, mushrooms are harvested in a series of breaks or flushes that occur at approximately 7 or 8 day intervals with hand carefully. After two flushes, mushroom production declines rapidly so that each successive flush produces fewer mushrooms. Usualy, romanian farmers harvest only 3 flushes to obtine an 35-36% productivity. In recent years large number of commercial units has been built to increase production, but a few effective unorganized were closed.

3. ENERGY EQUIVALENTS USED

The amounts of inputs (Champignon mushroom compost, electricity, human power, machinery, water and chemicals) used in the production of button mushroom were specified in order to calculate the energy equivalences in the study. The energy coefficients of inputs are the energy used from primary production to the end user. The energy equivalent of water input means indirect energy of irrigation consist of the energy consumed for manufacturing the materials for the dams, canals, pipes, pumps, and equipment as well as the energy for constructing the works and building the on-farm irrigation systems [19], [22]. The energy equivalent of human power is the muscle power used in growing room operations [22]. Transporting machines and other machines used by farmers is also calculate.

Chemicals energy equivalents include the energy consumption for producing, packing and distributing the materials and they are given on an active ingredient basis. Also in button mushroom production chemicals only contains insecticides (Dinilin, Mirage, Formalin), that used to control insects. The units in Table 1 were used to find the amount of inputs.

Table 1: Energy equivalents for different inputs in agricultural production

Inputs	Unit	Energy equivalent (MJ/Unit)	Reference
Human power	h	1.96	Mohammadi et al., 2008
Machinery	h	62.7	Mandal et al., 2002
Diesel fuel	l	47.8	Kitani, 1999
Electricity	kWh	11.93	Qasemi-Kordkheili et al., 2013
Chemicals	kg	101.2	Erdal et al., 2007
Water	m_3	1.02	Khan et al., 2009

3.1. Button mushroom energy equivalent

Button mushroom contains 87.5-89.5% moisture and 12.5-10.5% dry matter [18]. Energy equivalent of 100 gr button mushroom dry matters is 1.55 MJ [2], so button mushroom energy equivalent is calculated as 1.6275 MJ/kg.

3.2. Button mushroom compost

Producing button mushroom compost is a separated procedure and has different formulas with different inputs in each country. In Romania there is no compost plant, it is imported from other European countries (Hungary, Nedreland, Italy).

From the specifications of suppliers, mushroom compost contains mainly wheat straw as dead organic matter and Farmyard manure about 310 kg and 320 kg per 1 ton respectively. Wheat seed, urea (46% N) and water are other inputs. Other input quantities for producing 1 ton button mushroom compost and their energy equivalents are given in Table 2.

Table 2: Energy equivalents and quantity of inputs for producing 1 ton button mushroom compost

Inputs (unit)	Energy equivalent (MJ Unit-1)	Quantity per 1 ton compost	Total energy equivalent (MJ)
Human power (h)	1.96	6.20	12.15
Diesel fuel (l)	47.80	14.20	678.76
Machinery (h)	62.70	6.00	376.20
Electricity (kWh)	11.93	209.50	2499.34
Wheat straw (kg)	12.50	360.00	4500.00
Farmyard manure (kg)	0.30	280.00	84.00
Urea (46% N) (kg)	78.10	10.00	781.00
Wheat seed (kg)	25.00	24.00	600.00
Water (m3)	1.02	8.00	8.16
Total			9539.61

Energy equivalent estimated for producing 1ton mushroom compost in Hungary is about 9540 (MJton-1). The amounts of inputs were calculated per hectare and then, these input data were multiplied with the coefficient of energy equivalent. The energy equivalences of unit inputs are given in megajoule (MJ) unit. The total input equivalent can be calculated by adding up the energy equivalences of all inputs in Mega Joule (MJ).

3.3. Data envelopment analysis

A non-parametric method of DEA was employed to evaluate the technical, pure technical and scale efficiencies of individual farmers. So, the energy consumed from different energy sources including: human power, machinery, chemicals, water, electricity and button mushroom compost, were defined as input variables; while, the button mushroom yield was the single output variable; also each farmer called a Decision Making Unit (DMU).
In DEA, an inefficient DMU can be made efficient either by reducing the input levels while holding the outputs constant (input oriented); or symmetrically, by increasing the output levels while holding the inputs constant (output oriented) [14]. The choice between input and output orientation depends on the unique characteristics of the set of DMUs under study. In this study the input oriented approach was deemed to be more appropriate because there is only one output while multiple inputs are used; also as a recommendation, input conservation for given outputs seems to be a more reasonable logic [6], [19], so the button mushroom production yield is hold fixed and the quantity of source wise energy inputs were reduced.

3.4. Technical efficiency

The technical efficiency (TE) can be expressed generally by the ratio of sum of the weighted outputs to sum of the weighted inputs. The value of technical efficiency varies between zero and one; where a value of one implies that the DMU is a best performer located on the production frontier and has no reduction potential. Any value of TE lower than one indicates that the DMU uses inputs inefficiently [14]. Using standard
notations, the technical efficiency can be expressed mathematically as following relationship

$$TE_j = \frac{u_1 y_{1j} + u_2 y_{2j} + \cdots + u_n y_{nj}}{v_1 x_{1j} + v_2 x_{2j} + \cdots + v_m x_{mj}} = \frac{\sum_{r=1}^{m} u_r y_{rj}}{\sum_{s=1}^{m} u_s y_{sj}}$$

(1)

Where, u_r, is the weight (energy coefficient) given to output n; y_r, is the amount of output n; v_s, is the weight (energy coefficient) given to input n; x_s, is the amount of input n; r, is number of outputs ($r = 1, 2, ..., n$); s, is number of inputs ($s = 1, 2, ..., m$) and j, represents jth of DMUs ($j = 1, 2, . . ., k$). To solve Equation (1), Linear Program (LP) was used, which developed by Charnes

$$Maximize \ \theta = \sum_{r=1}^{n} u_r y_r$$

(2)

$$Subjected \ to \ \sum_{r=1}^{n} u_r y_r$$

(3)

$$\sum_{s=1}^{m} v_s x_{sj} = 1$$

(4)

$$u_r \geq 0, \qquad v_s \geq 0, \qquad and \ (i \ and \ j = 1,2,3, \dots k)$$

(5)

Where, θ is the technical efficiency and i represent ith DMU, it will be fixed in Equations (2) and (4) while j increases in Equation (3). The above model is a linear programming model and is popularly known as the CRS DAE model which assumes that there is no significant relationship between the scale of operations and efficiency [19]. So the large producers are just as efficient as small ones in converting inputs to output.

3.5. Pure technical efficiency

Pure technical efficiency is another model in DEA that introduced by Banker et al. in 1984. This model called VRS and calculates the technical efficiency of DMUs under variable return to scale conditions. Pure technical efficiency could separate both technical and scale efficiencies. The main advantage of this model is that scale inefficient farms are only compared to efficient farms of a similar size [1]. It can be expressed by Dual Linear Program (DLP) as follows [14]:

$$Maximize \ z = uy_i - u_i$$

(6)

$$Subjected \ to \ vx_i = 1$$

(7)

$$-vX + uY - u_0 e \leq 0$$

(8)

$$v \geq 0, \qquad u \geq 0, \qquad and \ u_0 \ free \ in \ sing$$

(9)

Where, z and u_0 are scalar and free in sign. U and v are output and inputs weight matrixes, and Y and X are corresponding output and input matrixes, respectively. The letters x_i and y_i refer to the inputs and output of ith DMU.

3.6. Scale efficiency

Scale efficiency shows the effect of DMU size on efficiency of system. Simply, it indicates that some part of inefficiency refers to inappropriate size of DMU, and if DMU moved toward the best size the overall efficiency (technical) can be improved at the same level of technologies (inputs) [15] The relationship among the scale efficiency, technical efficiency and pure technical efficiency can be expressed as [19]:

$$Scale \ efficiency = \frac{Technical \ efficiency}{Pure \ technical \ efficiency}$$

(10)

In the analysis of efficient and inefficient DMUs the energy saving target ratio (ESTR) index can be used which represents the inefficiency level for each DMUs with respect to energy use. The formula is as follow [9]:

$$ESTR_j = \frac{(Energy \ Saving \ Target)_j}{(Actual \ Energy \ Input)_j}$$

(11)

Where energy saving target is the total reducing amount of input that could be saved without decreasing output level and j represents jth DMU. The minimal value of energy saving target is zero, so the value of ESTR will be between zero and unity. A zero ESTR value indicates the DMU on the frontier such as efficient ones; on the other hand for inefficient DMUs, the value of ESTR is larger than zero, means that energy could be saved. A higher ESTR value implies higher energy inefficiency and a higher energy saving amount [9]. In order to calculate the efficiencies of farmers and discriminate between efficient and inefficient ones, the Microsoft Excel spread sheet and Frontier Analyst software were used.

4. EFFICIENCY OF GROWING ROOMS

Results obtained by application of the inputorientated DEA are illustrated in Table 3. The mean radial technical efficiencies of the samples under CRS and VRS assumptions are 0.82and 0.97 respectively. This implies first, that on average, growing rooms could reduce their inputs by 18% (3%) and still maintains the same output level, and second, that there is considerable variation in the performance of growing rooms. Increasing the technical efficiency of a growing room actually means less input usage, lower production costs and, ultimately, higher profits, which is the driving force for producers motivation to adopt new techniques.

Table 3: Energy equivalents and quantity of inputs for producing 7.5 ton button mushroom

Equipments/items	Power Kw	Hours	People	Total KW	Tot hours	L diesel	Total energy equivalent (MJ)	Percentage (%)
Total	388.58	1311	60	2479	1484	46	34680	100 %
Energy equivalent (MJ/Unit)				11.93	1.96	47.8	Total 20 t compost	Total/1 t mushrooms
Total energy equivalent (MJ)				29573	2908	2198	34680.48	4624.06
Unit price (Euro)				0.12 €	1.20€	1.27 €	Total 20 t compost	Total/1 t mushrooms
Value (Euro)				293 €	1780€	58.55 €	2132 €	266.54 €

5. CONCLUSION

Due of the variable weather condition in Romania, especial in Brasov county, the energy consumption is determined especial by the temperature differences between winter and summer (-28 ºC + 36 ºC). Cold weather require high consumption for heating and in the warm season, major consumption is given by the plant cooling water.

The comparative analysis performed in the period 2010-2012, shows that energy consumption is the main HVAC (Heating system + Ciller + fans).
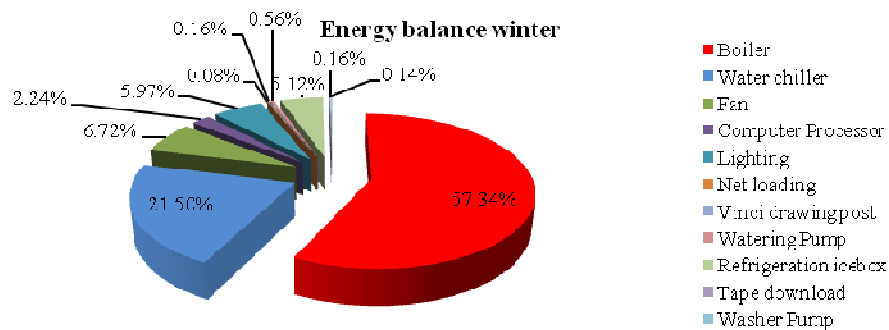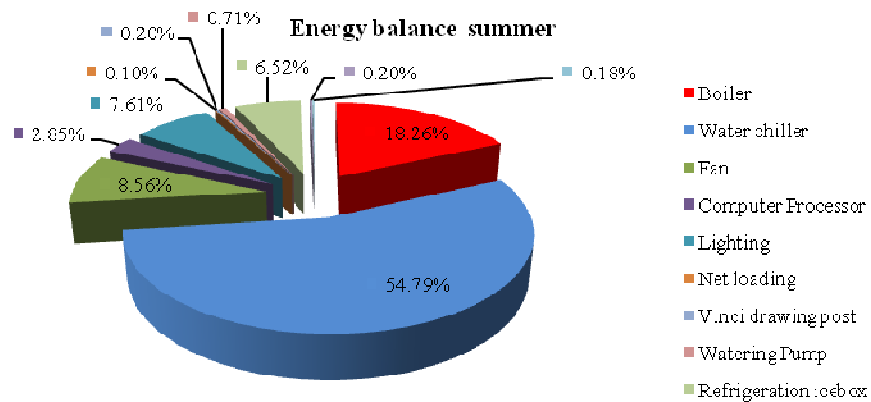

Figure 1: Energy balance for winter season

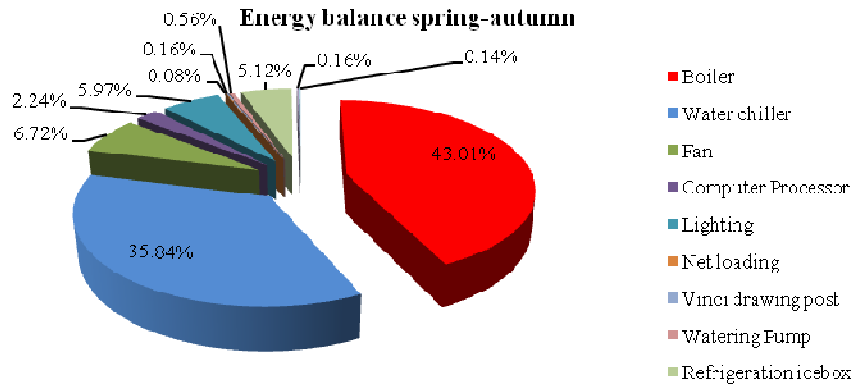**Figure 2:** Energy balance for summer season

Figure 3: Energy balance for spring-autumn seasons

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