In Ortega, E. & Ulgiati, S. (editors): Proceedings of IV Biennial International Workshop "Advances in Energy Studies". Unicamp, Campinas, SP, Brazil. June 16-19, 2004. Pages 301-313

ENERGETIC STUDY ABOUT CONVENTIONAL, ORGANIC AND BIODYNAMIC CROPPING SYSTEMS OF SWEET POTATO (*IPOMOEA BATATAS*)

Raquel Fabbri Ramos [1] Maristela Simões do Carmo [2]

[1] Agronomical Engineer, M S. in Energy Applied to Agriculture. Assistant of Directory and Professor at Paula Souza Technological Education Center.

E-mail: raquelfabbri@fca.unesp.br

[2] Professor of the Management and Agro industrial Technology Department of the UNESP – Botucatu – SP – Brazil

ABSTRACT

The sweet potato (*Ipomoea batatas*) is vegetable specie of high rusticity with further climatic adaptation and high capacity of energy production (calorie) in a short period of time. It is the sixtieth vegetable cultivated in Brazil with such social and economic importance. A field trial was carried out at Demétria Farm at Botucatu City, State of São Paulo (Brazil), in the year 2003 to evaluate alternative cropping systems using low inputs, with no economic dependence to the agriculturists and no environmental damage. In this way the crop was submitted to three fertilizations systems: a conventional one in which one it was utilized 1000 kilogram per hectare of the fertilizer NPK 4-14-8 (nitrogen -N, phosphorus-P and potassium-K); an organic and a biodynamic in which it were utilized the organic and biodynamic composts with nitrogen level of 40 kilogram per hectare. There were evaluated and identified energetic sources spent in the three cropping systems. There was calculated the energy balances and also was obtained the energetic efficiency and the energy sources. The main results showed that the organic and biodynamic systems presented better energetic efficiencies and higher energy rates, with less dependence on industrial and more on biological energy, which suggests better social and environmental benefits when compared with the conventional one. The three cropping systems were energetically efficient.

Keywords: Energetic analyses; energy balance; organic and biodynamic cropping systems; sweet potato.

1. INTRODUCTION

Most climatic changes taking place on Earth nowadays have their origin on the way the natural resources are explored especially in the agriculture activities with high levels of mechanization and chemical products which today is predominant. That becomes necessary to research and to search for an energetic efficiency in all agricultural activity steps aiming the sustainability of the planet Earth.

The sweet potato is a plant of high rusticity with easy maintenance, good climatic adaptation, high tolerance to dryness, low crop production cost and has being the sixth most horticultural specie cultivated in Brazil (Silva et al, 2002). It is also one of the highest calorie producers per area (370.00 Kcal/100g on a dry basis, Franco, 1996) and it is a root easy to transport and to storage (Miranda et al, 1987). It is a crop cultivated in the tropic places where live most of the poor people, constituting an excellent human and animal food supply. Also is industrialized as powder, amid and even alcohol (Silva et al, 2002).

Seeking for a better energetic efficiency of the productive process and the less waste of the natural resources it is necessary to have inputs obtained inside the own agriculture organism like the organic compost. To maximize the efficiency of the complex plant-input-environment it is possible to use the properties of the biodynamic preparations elaborated on basis of natural products, under the same procedures used in the homeopathic medicine what means dilution in water agitating them in circular movements (switching from clock wise and anti-clock directions about an hour in a wooden barrel) before its application.

It was evaluated the energetic potential of two alternatives cropping systems of sweet potato (*Ipomoea batatas*) in comparison to a conventional one utilizing this rustic vegetal specie witch has a high energy production per area. The two alternatives systems were carried out with low environmental impact inputs utilizing organic and biodynamic composts and the biodynamic preparation effects.

By conventional cropping it is understood the use of fertilizers and chemical products intensively that are industrialized inputs. The two alternatives cropping systems were organic and biodynamic. The term organic is a reference to the agricultural organism in which exists an interaction in the various productive activities of the property and its etymological origin is the same of the word organization. The biodynamic agriculture which also considers the property as an organism, recommends the soil fertilization and plant nutrition giving priority to the soil vivification by cultivating vegetable species and composting organic residues considering also their interaction with the cosmos. To the biological aspect it is added the dynamic aspect of the organic and mineral substances dissolution prepared considering the calendar and astronomic cycles, which are called the biodynamic preparations in a way to stimulate the involved organism's vital forces. The purpose was to maximize the benefits effects of the composts in the soil; the biodynamic cropping recommends the application of specific preparations during the composting process (Steiner, 2000; Wistinghausen, 1997; Koepf et al, 1986; and, Piamonte, 1996).

The analysis and the energy ratios provided a view of the three systems in a comparative way, introducing an interconnection of the energetic studies with the natural resources ecologic basis involved in the production unit. This association can be considered an alternative to the traditional methods based only on economic calculations. It allows knowing how much energy is necessary to produce another type of energy. By the total energy classified into renewable and non- renewable it is possible to identify the system's dependence, to calculate each one's energetic efficiency and to evaluate the system's highest or lowest environmental sustainability. Thus it's another analysis and management tool available to technicians, agriculturists and the general community.

The inputs identification and energies sources classification in the three systems the research showed the exaggerated usage of fossil energy in the conventional cropping which is most utilized in the developed countries. It became a classic research the Pimentel's study (1973) were he demonstrated that in 1945 more than a half of the energy necessary to produce corn in the USA was spent with fuel for tractors. That was also showed that in 1970 this fossil energy was spent with chemical fertilizer and there was a reduction in the energetic efficiency ratio of the crop that went from 3,71 in 1945 to 2,82 in 1970 (Macedônio, 1987).

Castanho & Chabaribery (1982) established the demand and the twenty one agricultural activities energetic profiles of the state of São Paulo crop production in the years of 1978 and 1979. They also confirmed that 80% of the agricultural energetic consumption had a fossil source, fuel had 38% of participation and there was 36% of the energy lost.

Carmo & Comitre (1991) calculated the energy balance of corn and soil bean crops in the years of 1965 and 1990 in the State of São Paulo and concluded that the fossil energy took the place of the biological energy and the fuel was the most expressive component followed by the fertilizers and soil correctives in the long term. The energy related to the fuel and to the agrochemical utilization results in environmental and social impacts that should be considered. They also confirmed that the energy analyses complements the economic one contributing to the natural resources conservation and in the maintenance of the agro systems in the long term.

To Carmo (1988) in the properties with alternative crop systems (organic and biodynamic) the caloric sources of biological origins were the most important than the fossil's and represented technologies of lower social and environmental impacts.

Many authors (Pinto, 2002) observed the elevated fossil agriculture consumption, which makes evident a high dependence on external energy. To save 50% of the energy spent per unit of area it has to use conservative technologies which must be adapted to the Brazilian social and environmental reality. The author also points that the energy analysis is one of the better agricultural development evaluation method since it allows measuring the level of crop sustainability.

The difference between the cropping systems was the kind and quantity of the fertilizer used in the soil. The N-P-K (conventional) and the organic and the biodynamic composts treatments were compared in relation to energy consumption to this research hypothesis in which these two systems are energetically more efficient than the conventional one. It was taken the quantity of 40 kilogram of nitrogen per hectare to calculate the chemical fertilizer (NPK) and the composts quantities.

2. MATERIAL AND METHODS

2.1. Place and Material

The field trial was carried out in the Brazilian Association of Biodynamic Agriculture (ABD) area called "Fazenda Demétria" (Demeter Farm) at the City of Botucatu (State of São Paulo, Brazil) utilizing the sweet potato specie which branches that came from the Organic Producers Association named Mantiqueira at the City of Gonçalves (State of Minas Gerais, Brazil). That was because of the difficulty to find the branches in the Botucatu's region with the insurance that they were obtained in an organic or in a biodynamic crop. The branches of sweet potato were prepared in a shaded place in a way that each one of them presented ten stems at least and in the sequence they were planted over little soil hills previously prepared in the experimental area.

2.2. Treatments

The treatments consisted in the application of:

a) 1,000 kilogram (kg) per hectare (/ha) of mineral fertilizer N-P-K (4-14-8), totalizing 40 kg of nitrogen (N); 140 kg of phosphorus (P_2O_5) and 80 kg of potassium (K_2O) in the conventional treatment;
b) 2,920 kg/ha of organic compost (dosage sufficient to supply 40 kg of N/ha) in the organic treatment;
c) 2,381 kg/ha of biodynamic compost (dosage sufficient to supply 40kg of N/ha) in the biodynamic treatment;

The conventional crop followed the standard cropping system established by Filgueira (2000). The organic and biodynamic systems followed the same recommendations except the activities banished by the Organic and Biodynamic Rules of Certification (IBD, 2002).

2.3. Compost Preparation

Two composting piles of organic residues had been constituted in the area of the Enterprise “Centroflora do Brasil” in the City of Botucatu (Sao Paulo, Brazil). The residues came from the plants pressed to obtain medical compounds and were disposal in two piles aiming to get two kinds of compost, one organic and another one, biodynamic. The difference between them, like they were made of the same residues, was that in one of the two piles it was added the biodynamic preparations named 502, 503, 504, 505, 506 and 507 as recommended by Wistinghausen (1997) and Koepf et al (1986). Both the piles were frequently watered in a way they had enough moisture for the decomposition and were turned up at every 20 days. The whole decomposition process took two months and it occurred before its utilization. The biodynamic preparations

2.4. Soil preparation and cultivation

The experimental area was delimited and the soil was revolved with a cultivator linked to a Valmet 65 tractor. There were made sulks spaced 40 centimeters were the chemical fertilizer (NPK 4-14-8) and the composts (organic and biodynamic) were put down corresponding to the each treatment. After that there constructed little soil hills manually with shelves in a way they covered the fertilizers and composts. The little soil hills were 40 centimeters of thickness and 30 centimeters high. Later, the sweet potato branches, that were prepared in a shaded place like described in the 2.1 item, were distributed in a transversal direction of the little soil hills in a way the central part could develop roots and the two opposite extremes parts could grow up.

The crop was installed on March first (2003) witch day was favorable to plant root production vegetables according to the Maria e Matthias Thun Biodynamic Agriculture Calendar 2003 year (Thun & Thun, 2003). In the biodynamic treatments there was an afternoon application in the experimental crop soil of the prepared called 500 using 200g of the prepared and 60 liters of water obtained by the liquid agitation in circular movements (switching from clock wise and anti-clock directions for an hour in a wooden barrel).

2.5. Cultural treatments and harvest

The weeds were cut down past 45 to 60 days of the crop installation and they were left on the soil to contribute for its coverage. In the partial of the biodynamic treatments it was done pulverization of the prepared called 501 when the plants were 85 days old, before seven o’clock in the morning of March 22, 2003, a favorable day for roots according to the Maria and Matthias Thun Biodynamic Calendar (Thun & Thun, 2003). Such liquid pulverization was done using 3g of the prepared in 60 liters of water, agitating them in circular movements for an hour before its application. The roots harvest was carried out four months later, with the aid of shelves, and they were weighted (still when they were on the field).

2.6. Energetic Analysis of the organic, conventional and biodynamic crop systems

To do the energetic analysis there were quantified the three crop systems operations and energy inputs and the correspondent tables were elaborated.

Since the experimentation area was less than one hectare the economic scale gains of the data expansion and distortions were not considered and so it was utilized as a model the production costs of institutions that have been working with the sweet potato crop. It was used as models the data of the Technical Support Enterprise and Rural Extension from the District Federal of Brasilia City, Brasil (acronym EMATER- DF), the Agriculture Secretary of the State of Paraná, Brasil (acronym SEAGRI- PR), the Rural Syndicate of the City of Mogi das Cruzes in the State of Sao Paulo, Brasil and the knowledge and common sense in the agricultural practices adapted to each system.

The crop harvest obtained in the three experimental systems was considered too low when compared to the medium national outcome, according to the literature. The crop harvest amount obtained in the conventional system was 5,575 kg/ha (2.31kg of roots/partial treatment); in the biodynamic was 6,975 kg/ha (3.38kg of roots/partial treatment); and in the organic, 8,450 kg/ha (2.79 kg of roots/partial treatment). This low harvest is because of the climatic adaptation factors which usually happens to plants with vegetative reproduction as is the case of the sweet potato and some sweet potato specialists were questioned about this fact and they confirmed it. The branches used in the experiment came from the City of Gonçalves (MG) so it is inferred that for physiological reasons their adaptation to the Botucatu's (SP) conditions could have been quite drastic what significantly affected the productivity, even though all agronomic factors such as watering and fertilization followed the specific prescriptions to the crop. It was suggested researches and comparisons during the cropping cycles to obtain a more complete explanation of the occurrence of this drop in productivity. However this fact didn't affect the main research objective which was the energetic analysis comparison between the three crop systems since the conditions for all the three crops were the same.

The conventional system productivity was calculated taking the average of the State of São Paulo according the Institute of Agricultural Economy's Annual Statistics of 2002 year (State of São Paulo) witch was 14,680 kg/ha for the conventional system (Secretaria da Agricultura e Abastecimento do Estado de São Paulo, 2003). To the correspondents harvests estimative to the organic and to the biodynamic systems were adopted as criteria a relation based in the experiment differences productivity. This way if 14,680 kg/ha corresponds to 2.31 kg of roots per partial experimental area in the conventional crop system so in the organic it presents 21,480 kg/ha and in the biodynamic 17,730 kg/ha, respectively 3.38 and 2.79 kg of roots per partial experimental area which were obtained in the experimental crop.

The energetic analysis was done on the items obtained by Castanho & Chabaribery, 1982:

1. Injected energy in the crop – EI: It is about the input of the direct and indirect energy forms. The constitution of the energies or their sources are: biological (Ebio), witch refers to the human and animal labor and to the seeds and branches; fossil energy (EFos) from petroleum; and, electric energy (EEl), from hydro electrics. The indirect energy (Eind) is relative to the build construction and to the machines and agricultural equipment industry, according the depreciation to these utilities life time. This way, it is presented the equation representing the input energy of the crop:
   $EI = Edir + Eind$ ou $EI = (Ebio + EFos + EEl) + Eind$.
   All factors involved were converted to energetic units using a specialized literature and energetic coefficients already calculated for most of them. However there were difficulties to determine the ones very specific and mostly of indirect energy.

2. Energy Produced by the crop– EP: By photosynthesis the vegetables have the power to capture solar energy and transform it into biological energy called Primary Energy or Eprim, which can be used by animals that also transform it and

constitutes the Secondary Energy or Esec. So, the energy produced in the agriculture is the result of the addition of the primary to the secondary energies witch form the final crop energy usable (EF).

3. Energetic performance rates: it is possible to evaluate how agriculture transforms the external energy into useful energy, establishing the relation EF/EI what is Final Energy Useful divided by the Input of Energy. To evaluate the outcome of the biological process or its energetic transformation efficiency it is established the Eprim / EF relation, witch is Final Energy of Primary Origins divided by Final Energy Usable. The energy balance is given by the difference between the Final Energy Usable (roots)–EF and the Input of Energy – EI. It is possible to quantify and to identify the renewable and non-renewable sources of energy used in the system process decomposing the Injected Energy–EI into biological, fossil and industrial energy and determining the dependence and the sustainability of the system, applying sufficient amount of N.

3. RESULTS AND DISCUSSION

3.1 Quantification charts and the cropping operations technical coefficients

It is possible to have an idea of the operations, labor and energy inputs of the three crop systems in the Tables 1, 2 and 3, which are showed next, with respective technical coefficients of the experiment.

Table 1. Technical coefficients of conventional sweet potato crop in one hectare, Botucatu City (State of São Paulo, Brasil), 2003

Item	Quantity	Unit
Inputs		
Branches	50,000	branch
Fertilizer NPK 04-14-08	1,000	kg
Operations		
Soil cultivation		
Tractor with cultivator e succor	5	H/M
Tractor	5	H/H
Manual construction of little hills of soil	1	H/D
Branches cutting	2	H/D
Manual fertilizer distribution	2	H/D
Manual Plantation	5	H/D
Irrigation by drops (labor)	10	H/D
Cultural treatment (weeding)	5	H/D
Harvest/classification/packing	40	H/D
Others		
Irrigation system's depreciation	120	H

H/D = work of one man in a day; H/H = work of a man in an hour;H/M = one hour of a machine work; H=Hour; kg= kilogram; Branches = sweet potato part to vegetative reproduction. Source: Research data.

Table 2. Technical coefficients of biodynamic sweet potato crop in one hectare, Botucatu City (State of São Paulo, Brasil), 2003

Item	Quantity	Unit
Input		
Branches	50,000	branch
Biodynamic Compost	2,381	kg
Biodynamic Preparation	1	Pack
Operations		
Soil Cultivation		
Tractor with cultivator e succor	6	H/D
Tractor	5	H/M
Tractor's driver labor	5	H/H
Manual Construction of little soil hills	1	H/D
Branches cutting	2	H/D
Manual distribution of the biodynamic compost	4	H/D
Manual plantation	5	H/D
Biodynamic Preparations application	1	H/D
Irrigation by drops (labor)	10	H/D
Cultural treatment (weeding)	5	H/D
Harvest/classification/packing	40	H/D
Others		
Irrigation system's depreciation	120	H

H/D = work of one man in a day; H/H = work of a man in an hour; Branches = sweet potato part to vegetative reproduction. H/M = one hour of a machine work; H=Hour; kg= kilogram; pack= biodynamic preparation quantity. Source: Research data.

With this data it is possible to detect that the three crop systems were different from each other by the fertilizers kind and quantity utilization in relation to the total. There was a difference between the conventional in relation to the organic and biodynamic crop systems which had more utilization of human labor, because of the compost production and pulverization of the biodynamic preparations. Other analyses made with the composts and the sweet potatoes roots showed that the biodynamic crop promoted composts and roots with more nutrients quantity but this is not object of this paper.

It is worth pointing that the experimentation was made on an environmentally stabilized area, with many years of organic and biodynamic cultivation so it was not necessary the practices normally recommended for the crop in the conventional system. It is highlighted thus that the variation between the conventional system and the two others is lower than it actually could be in order to the special field conditions while the usual technical recommendations of the first system would be followed and done with the biocides application and soil chemical fertilization.

Table 3. Technical coefficients of sweet potato organic crop in one hectare, Botucatu City (São Paulo, Brasil), 2003

Item	Quantity	Unit
Inputs		
Branches	50,000	Branches
Organic compost	2,920	kg
Operation		
Compost preparation	6	H/D
Soil preparation		
Tractor with cultivator and succor	5	H/M
Tractor's driver labor	5	H/H
Manual construction of little soil hills	1	H/D
Branches cutting	2	H/D
Manual compost distribution	5	H/D
Manual plantation	5	H/D
Irrigation by drops (labor)	10	H/D
Cultural treatment (weeding)	5	H/D
Harvest/classification/packing	40	H/D
Others		
Irrigation system's depreciation	120	H

H/D = work of one man in a day; H/H = work of a man in an hour;
H/M = one hour of a machine work; H=Hour; kg= kilogram;
Branches = sweet potato part to vegetative reproduction
Source: Research data.

3.2. Energy Analysis

The energetic coefficients obtained in the literature and adapted when necessary are in the Table 4.

There were elaborated charts for the Energy Input of each crop system considering the respective technical coefficients and dismembering the energy into biological, industrial and fossil sources. The final energy was constituted by the calories generated in the total harvest production of sweet potato and it was calculated multiplying the energetic coefficient by the estimated productions of each treatment discounting the 70% of water in the roots (as the moisture average stated at 70% ; Table 5, Graphic 1).

Table 4. Energetic coefficients to calculate the Final Energy Input (EF) in the conventional, biodynamic and organic sweet potato crop systems, Botucatu City (State of São Paulo, Brasil), 2003

Items	Unit	Energetic coefficient	Source
Biological Energy			
Human Labor	Mcal/hd	2.34	6
Organic compost	-	-	4
Biodynamic compost	-	-	4
Branches of sweet potato	-	-	4
Biodynamic preparation	-	-	4
Industrial Energy			
Tractor 50 cv	Mcal/day	10.82	7
Cultivator	Mcal/day	2.55	7
Succor	Mcal/day	2.55	7
Fertilizers NPK 4-14-8	Mcal/t	876.00	3
Fossil Energy			
Fuel (diesel)	Mcal/l	9.025	2
Oil	Mcal/l	9.025	2
Grease	Mcal/kg	9.025	2
Tire	Mcal/kg	20.50	1
Final Energy (EF)			
Sweet potato	Mcal/t	3700	5

Mcal= Megacalorie = 10^{6} calorie; 1 calorie = 4,18 Joule; H/D = work of one man in a day; t=1,000kilogram; branches= sweet potato part to vegetative reproduction
Source: 1- Serra et al. (1979) ; 2- Castanho Filho & Chabaribery (1983); 3- Quevedo (1992);
4- Inexistent data; 5-Franco (1996); 6- Comitre (1993); 7- Carmo & Comitre (1991).

By the data obtained it was possible to verify that the conventional crop system was the one which had the highest quantity of energy input and most of it (66.13%) came from the industrial source. In the other two systems there was comparatively less energy input and also the most of its quantity came from fossil origins, used in the soil mechanical operations (62.19% for both).

The operations were the same in the present experiment for the three crop systems but they corresponded to different percentages when considered the kind (source) of the energy spent in each crop system. However for the conventional crop system, if taken the current crop technical recommendations, the amount of the energy input is underestimated. For the biodynamic system there was a higher input of biological energy related to the labor to obtain and apply the biodynamic preparation (Tables 5 and 6; Figures 1 and 2).

Table 5. Energetic quantification and classification of sweet potato conventional, biodynamic and organic crop systems in one hectare, Botucatu City (State of São Paulo, Brasil), 2003

Energy input (Mcal/ha) Crop System	Conventional	Biodynamic	Organic
Biologic Energy			
Human Labor	152.98	174.04	174.04
Branches	-	-	-
Organic compost	-	-	-
Biodynamic compost	-	-	-
Biodynamic preparation	-	-	-
Total of Biologic Energy	152.98	174.04	174.04
Industrial Energy			
Tractor 50 cv	6.75	6.75	6.75
Cultivator	0.80	0.80	0.80
Succor	0.80	0.80	0.80
Fertilizer (NPK 4-14-8)	876.00	-	-
Total of Industrial Energy	884.35	8.35	8.35
Fossil Energy			
Fuel (diesel)	282.03	282.03	282.03
Oil	5.42	5.42	5.42
Grease	5.42	5.42	5.42
Tire	7.18	7.18	7.18
Total of Fossil Energy	300.05	300.05	300.05
Total of Energy Input (EI)	1,337.38	482.44	482.44
Final Energy (EF)	23,276.7	28,116.3	34,062.20

Mcal = Megacalorie = 10^6 calorie e 1 calorie = 4,18 Joule; branches= sweet potato part to vegetative reproduction
Source: Research result.

Table 6. Energy input sources percentages (%) in the conventional, biodynamic and organic crop systems of sweet potato in one hectare, Botucatu City (State of São Paulo, Brasil), 2003

Sources of Energy	Conventional crop	Biodynamic crop	Organic crop
Biological	11.44	36.08	36.08
Industrial	66.13	1.73	1.73
Fossil	22.43	62.19	62.19

Source: Research results.

The energy input in the organic and biodynamic crop systems could be higher but it was difficulty to define the energetic coefficients of the various organic composts materials like the plant residues and the biodynamic preparation.

For the energetic efficiency comparative evaluation of the three crop systems, there were calculated the relations between the final energy (EF) obtained by the crop harvest and the energy input (EI). The three crop systems energy balance was obtained subtracting the energy spent in the crop cultivation or the energy input (EI) from the energy produced by the crop harvest or final energy (EF; Table 7 and Figures 3 and 4).

Table 7. Energetic efficiency indicators of the conventional, biodynamic and organic sweet potato crop systems in one hectare, Botucatu City (State of São Paulo, Brasil), 2003

Crop systems	Conventional	Biodynamic	Organic
EF/EI	17.40	58.28	70.60
Energy balance (Mcal/ha) EF-EI	21,939.32	27,633.86	33,579.76

Mcal= Mega calorie = 10^6 calorie and 1 calorie = 4,18 Joule.
EF = final energy obtained by the crop harvest; EI = energy spent in the crop cultivation or the energy input. Source: Research data.

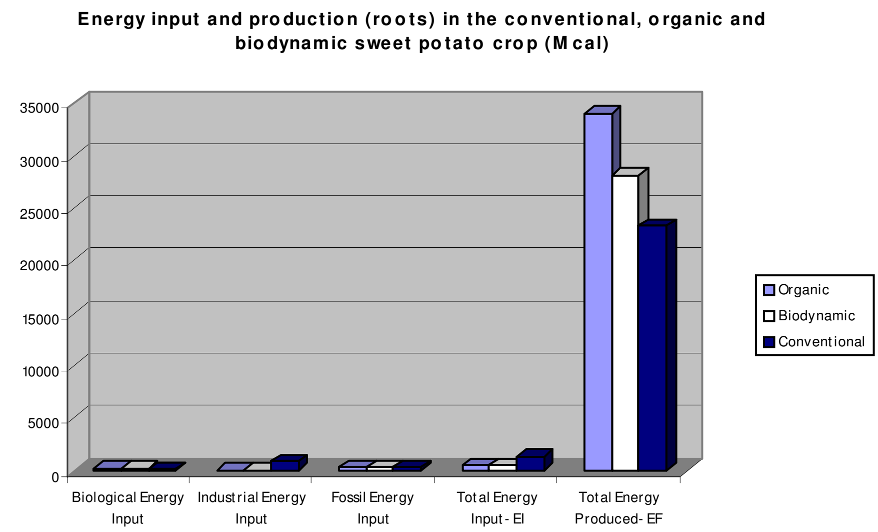


Figure 1. Energy input and production (roots) in the conventional organic and biodynamic sweet potato crop systems, Botucatu City (State of São Paulo, Brasil), 2003.
Source: Research data

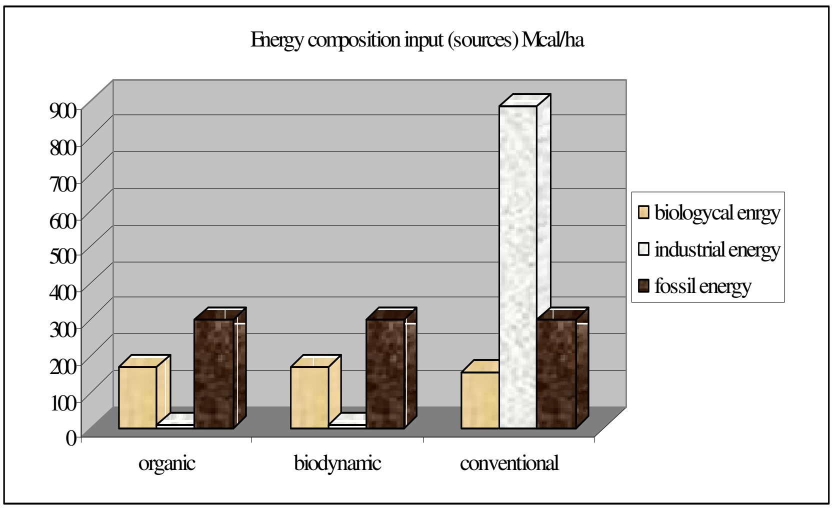
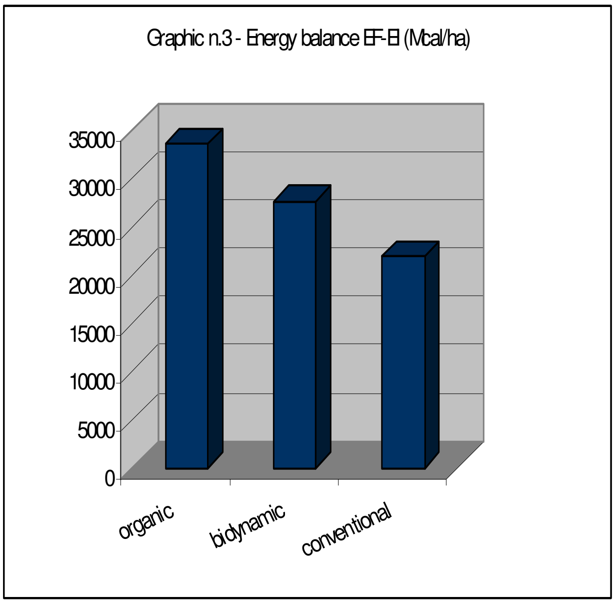
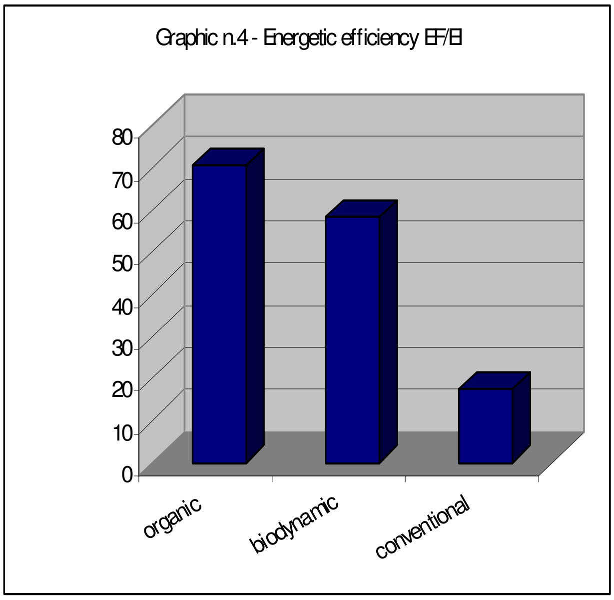


Figure 2. Energy input composition (sources) in the organic, biodynamic and conventional sweet potato crop systems, Botucatu City (State of São Paulo, Brasil), 2003.

Source: Research data





Figures 3 and 4. Energetic efficiency of the conventional, organic and biodynamic sweet potato crop systems, Botucatu City (State of São Paulo, Brasil), 2003

EF = final energy obtained by the crop harvest; EI = energy spent in the crop cultivation or the energy input. Energy balance (Mcal/ha) = EF-EI; Energy efficiency = EF/EI
Source: Research data.

These results showed that the organic system was the most energetically efficient system, followed by the biodynamic one. The conventional system although with the worst performance also was efficient by the energetic point of view. The two systems considered not conventional, organic and biodynamic, were more efficient twice in terms of energetic relation and presented higher energy balances when compared to the conventional one. However, it is necessary to highlight that is was not possible to calculate the energy incorporated in the organic and biodynamic composts since there were not energetic coefficients, what may be super estimating such results.

4. CONCLUSIONS

The conventional crop system had a higher input of industrial energy source. In the other two crop systems the highest quantity of energy input came from the fossil energy (as the conventional one) and the total energy input was the lowest. The organic crop system was the most energetically efficient considering the relation between the produced energy (by the roots harvest) and the total energy input of the system, followed by the biodynamic and by the conventional crop systems. The same sequence was obtained for the energy balance of the three systems.

Considering desirable to develop and environmental sustainable agriculture what means better utilization of the human labor (biological energy), which promotes the field employment and is the proper to the familiar agriculturists, the research points to the organic followed by the biodynamic crop systems.

The sweet potato vegetable specie proved to be an appropriated crop to integrate the organic and biodynamic systems and to achieve the goals mentioned, since it has a good nutritional quality, rusticity and easiness to be cultivated with the necessity of low energetic inputs and with an excellent energy production per area.

In summary, it is concluded that:

- The research pointed the organic and the biodynamic sweet potato crop systems to have the best energetic efficiencies and to have the highest energy balance per area in relation to the conventional one.
- The organic and biodynamic sweet potato crop systems have the best environmental sustainability because they have less dependence on industrial energy and more on the biological energy. Moreover they also contribute to the social sustainability providing the increase of work offers in the field.

References

[1] CARMO, M. S. do Balanço energético em sistemas de produção na agricultura alternativa. São Paulo: Instituto de Economia Agrícola da Secretaria de Agricultura e Abastecimento de São Paulo, 1988. 96 p. Mimeografado (Relatório Final - Bolsa de Pesquisa CNPq).

[2] CARMO, M. S. do; COMITRE, V. Evolução do balanço energético nas culturas de soja e milho no Estado de São Paulo. In: CONGRESSO BRASILEIRO DE ECONOMIA E SOCIOLOGIA RURAL Anais. Campinas: SOBER, 1991. p 131-149.

[3] COMITRE, V. Avaliação Energética e Aspectos Econômicos da *Filière* Soja na Região de Ribeirão Preto-SP. 152 f. Dissertação, (Mestrado) Faculdade de Engenharia Agrícola, UNICAMP, Campinas, 1993.

[4] CASTANHO FILHO, E. P.; CHABARIBERY, D. Perfil energético da agricultura paulista. São Paulo: Secretaria da Agricultura, 1982. 55 p. (Série relatório de pesquisa, 9-82).

[5] FILGUEIRA, F. A. R. Novo Manual de Horticultura. Viçosa: Editora Universidade Federal de Viçosa, 2000, 402 p.

[6] FRANCO, G. Tabela de Composição Química de Alimentos. 9ª ed. São Paulo: Atheneu, 1996. 307 p.

[7] IBD- Associação de Certificação Instituto Biodinâmico. Diretrizes para o padrão de qualidade orgânica. 12 ed. Botucatu: IBD, 2002. 75 p.

[8] KOEPF, H. H. ; PETTERSSON, B. D.; SCHUMANN, W. Agricultura biodinâmica. São Paulo: Nobel, 1986. 316 p.

[9] MACEDÔNIO, A.C. A análise ecológica-energética aplicada à agricultura. Curitiba: Secretaria de Agricultura e Abastecimento, 1987. 30 p. Mimeografado.

[10] MIRANDA, J. E. C. de et al Cultivo de batata-doce. EMBRAPA. Instruções Técnicas do CNPH, no 7, Brasília, 1987. 8 p.

[11] PIAMONTE, R. P. Rendimento, qualidade e conservação pós-colheita de cenoura (Daucus carota L) sob adubações mineral, orgânica e biodinâmica. 54 f. Disssertação, (Mestrado em Agronomia-Horticultura) Faculdade de Ciências Agronômicas, Universidade Estadual Paulista, Botucatu, 1996.

[12] PIMENTEL, D. et al. Food production and the energy crisis. Science, n. 182, p. 443-449, 1973.

[13] PINTO, M. S. V. Análise econômica e energética de sistema agroflorestal para implantação na terra indígena Araribá – Município de Avaí – SP. 136 f. Dissertação (Mestrado em Agronomia - Energia na Agricultura) - Faculdade de Ciências Agronômicas, Universidade Estadual Paulista, Botucatu, 2002.

[14] RAMOS, F. R. 2004. "Productive, economical and energetic comparisons between the conventional, organic and biodynamic cropping systems of sweet potato (Ipomoea batatas)". Master of Science Program Dissertation at UNESP, Botucatu, State of São Paulo, Brazil.

[15] SECRETARIA DA AGRICUTURA E ABASTECIMENTO DO ESTADO DE SÃO PAULO, Informações Estatísticas da Agricultura, Anuário IEA 2002, São Paulo: IEA, v.14, n.1, p.1-316, 2003.

[16] SERRA, G. E. et alii. Avaliação da Energia Investida na Fase Agrícola de Algumas Culturas. Secretaria de Tecnologia Industrial. Ministério da Indústria e Comércio. São Paulo, set. 1979. 86p.

[17] SILVA, J. B. C. da; LOPES, C. A.; MAGALHÃES, J.S. Cultura da batata-doce, p. 448-504. In: Cereda, M. P. (coord) Agricultura: Tuberosas Amiláceas Latino Americanas. São Paulo: Fundação Cargill, 2002. 540 p.

[18] STEINER, R. Fundamentos da agricultura biodinâmica: vida nova para a terra. 2. ed.- São Paulo: Antroposófica, 2000. 235 p.

[19] THUN, M.; THUN, M.K. Calendário agrícola 2003. Botucatu: Associação Brasileira de Agricultura biodinâmica. 2003. 29 p.

[20] WISTINGHAUSEN, C. von; et al. Manual para uso dos preparados biodinâmicos. Caderno de trabalho n.2. Botucatu: Associação Brasileira de Agricultura Biodinâmica. 2 ed., 1997. 77 p.