RESEARCH ON ROMANIA'S OIL SEEDS BIODIESEL PRODUCTION POTENTIAL

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Abstract. *Romania has a high potential for producing biodiesel from rape, sunflower and soybean seeds. In the period 2006-2010, Romania cultivated 1,296 thousand ha in average, per year, with these oil crops and produced 6,748.5 thousand tons solid biomass, of which 44 % from sunflower, 20 % from rape and 36 % from soybean. Energy production estimate/year, based on seeds biomass, was 110,518.58 GJ, of which 54.2 % from sunflower, 20.5 % from rape and 25.2 % from soy bean. Annual biodiesel production was estimated at 277,631.5 thousand liters, of which 63.5 % from rape biomass, 33.5 % from sunflower biomass and 2.9 % from soybean biomass. In conclusion, Romania is able to reach its target of 20 % biofuel blend with classic fuels by the year 2020 according to the EU provisions.*

Key words: biodiesel, biomass, oil crops, Romania, energetic efficiency

1. Introduction

"Biofuels represent substitutes for petrol and diesel and promptly available on a large scale for ordinary vehicles"(EU Renewable Energy Directive 2009/28/EC).
Their use had the advantage to emit less than 35-40 % green house gases than the fossil fuel, with a positive impact on environment sustainability and to diminish fuel import decreasing the degree of energy dependence of a country.
The main biofuels are bioethanol and biodiesel. Despite that biofuels have advantages, the big disadvantages are related to land and food diversion to fuel and in addition increased pollution of the air and soil (Pimentel *et al*, 2005). Biodiesel is poorer in Carbon than diesel (-8.98 %) and Hydrogen (-0.79%), but it contains 10 % Oxygen, stimulating the burning process in the engine (Burnete *et al*., 2011).
For this reason, biofuels are used in some proportions with the classic fuels without imposing a change of the engines. Sunflower biodiesel but also rape and soy bean seeds, in general oilseed crops could offer an alternative to fossil diesel (Madyira *et al*, 2012).
Because biofuel could be produced of cereals, oil crops and other resources, one of the main aspects which has to be taken into consideration is the cultivated area

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with energetic crops and biomass production which should not affect the amount needed to cover human food and animal feedstuff consumption.
Biodiesel production depends on crop type, cultivar, cropping technology, plat protection measures (Adamiak *et al*, 2009), cultivated area, biomass production/ha (Adamovics *et al*, 2009), conversion efficiency into biofuel given by output/input ratio (Rathke *et al*, 2009).
Economic aspects regarding oil seed production, oil extraction, biodiesel processing have also o be taken into account (Jaeger *et al*, 2008).
Biodiesel represents 75 % of biofuels produced in Europe. The EU is the top producing area with a market share of 65 % in the world biodiesel production (Biofuel production.www.biofuelstp.eu/fuel production.html).
The EU is focused on the security of energy supply based mainly on biodiesel production. Till 2020, the EU member states have to carry out at least 10 % share of renewable energy in the total transport consumption of essence and diesel (Biofuels. Agriculture and Rural Development, www.ec.europa.eu/agriculture).
As an EU member state since 2007, Romania became a REFEP member in 2008, aligning its legislation and measures to the EU Regulations to stimulate biofuel production, mainly biodiesel in order to reach its target of 10 % biofuels in 2020, estimated at 514 thousand tep (thousand tons of oil equivalent), while gasoline will account for 5,139 thousand tep (EuroStat, 2011).
This will contribute to the sustainable development and less energy import. During the period 2006-2010, the energetic consumption decreased by 12 %, accounting for 34,817 thousand tep in 2010, of which 78.77% was assured by domestic primary energy production and the difference of 21.23 % by import. However, the increased biofuel production had diminished import by 37 %, assuring 78.8 % energetic independence of the country (Romania's Statistical Yearbook, 2011).
Biofuels could be obtained by biomass conversion into energy as long as at world level it s a huge variety and amount of resources for producing biomass (Green Media, 2006, Biomass-Precious energy and heat source).
In Europe, biodiesel is the mainly produced from sunflower and rape seeds In the EU, 84 % biodiesel is produced from rape oil, 13 % from sunflower oil and 3 % of soy bean oil.
In Romania, there are some research results, mainly during the last decade, regarding biofuel production reflecting the production capacity in the energy sector (Burnete *et al*, 2011, Chintoanu *et al*, 2008, Oancea, E., 2010, Popescu Agatha, 2010).
In this context, the paper aimed to estimate Romania's annula energy potential in terms of solid biomass production and biodiesel production, taking into consideration cultivated area and production of oil crops, energy content by crop and biomass conversion rate into biodiesel. The analysis was carried out for the

period 2006-2010 and was based on the data provided by Romania's Statistical Yearbook, 2011.

2. Materials and Methods

In order to set up this paper and estimate Romania's potential for producing biodiesel, the following indicators were used: biomass production estimate, energy production estimate from total biomass provided by oil crops, biodiesel production estimate and cake and glycerin byproducts production estimate.

In this purpose, the following data were collected from Romania's Statistical Yearbook, 2011: arable land, cultivated area, total area cultivated with oil crops, cultivated area for sunflower, rape and soybean, seed yield/ha by crop, seed production by crop, for the period 2006-2010.
In the study, it was calculated the average for each indicator mentioned above for the period of fie years.
The calculations were based on the following formulas:

Biomass production estimate:

$$BQ_T = \sum_{i=1}^{n} (Q_i + q_i) = \sum_{i=1}^{n} (Q_i + Q_i * \alpha_i) = \sum_{i=1}^{n} Q_i (1 + \alpha_i),$$ where:

Q_T = total biomass production, Q_i= main biomass production for i energetic crop= seed production, i=1,2,3…,n energetic crops; q_i = secondary biomass production for i energetical crop= specific secondary production for each crop; α_i= conversion coefficient of main production into secondary production for the i energetic crop.
The values considered for α_i were the following ones:1.65 for sunflower, 1.5 for rape and 2 for soy bean based on the main production/secondary production ratio (Balteanu, G, 2005).

Energy production estimate:

$$EPE_T = \sum_{i=1}^{n} (E_i + e_i) = \sum_{i=1}^{n} (Q_i * \beta_i) + (q_i * b_i) = \sum_{i=1}^{n} Q_i (\beta_i + \alpha_i * b_i),$$ where:

E_T=total energy production from solid biomass coming from oil crops; E_i=energy production resulted from main biomass production for i oil crop, where i=1,2,3,...,n; e_i= energy production resulted from secondary biomass production for i oil crop; β_i= energy content in terms of GJ/ton in the main biomass for i oil

crop; b_i= energy content in terms of GJ/ton in the secondary biomass for i oil crop.

In the calculus, β_i and b_i had the following values: for sunflower: β_i= 24 GJ/ton and b_i=17.85 GJ/ton; for rape: β_i= 23 GJ/ton and b_i=12.5 GJ/ton; for soybean: β_i= 16.6 GJ/ton and b_i=9 GJ/ton (Oancea, E., 2010).

Biodiesel production estimate:

$BDE= (Q_i - Q_i * \% C)* CC$, where:

BD= biodisel production; Q_i= main biomass production (seeds); % C = percentage of seeds destined to human and animal consumption; CC= concersion coeffient of solid biomass into biodiesel.

In the calculus, only the main biomass production (seeds) was taken into account, of which the following percentage was considered available to be transformed into biodiesel: 90 % of rape main biomass, 20 % of sunflower main biomass and 6 % of soy bean main biomass (Oancea, E., 2010).

Aso, it wsa taken into consideration biodiesel rate of oil seeds, as follows: 17 % (0.170) for soy bean biomass, 41.5 % (0,415) for sun flower and 36 % (0.360) for rape (Oancea, E., 2010).

Cake production estimation:

$CPET= \sum_{i=1}^{n} (Q_i * \beta_i * \gamma_i)$, where: CPET= cake production; γ_i= cake rate of processed main biomass (seeds) into biodiesel. The ocnsidered value for γ_i was the following one: 58.4 % for sun flower seeds, 60 % for rape seeds and 82.5 % for soy bean seeds.

Glycerine production estimation:

$GPE= (\sum_{i=1}^{n} Q_i)* \delta$, where: GPE= glycerine production estimate; δ=glycerin rate from seed production destined to produce biodiesel. The δ value taken into consideration was 42 kg/ton seeds.

3.Results and Discussions

Romania is among the largest countries in Europe coming on the 7th position I the EU with 283,391 square km surface. It has a huge potential for crop production

with 9,405 thousand ha arable area, representing 64.26 % of agricultural land, 14,635.5 thousand ha (Statistical Yearbook, EuroStat, 2011).
Due to its favorable soil and climate conditions and geographical position in the Central-Eastern Europe, its long tradition in crop and animal farming, it has a high potential for producing biomass both of vegetal and animal origin.
The capacity for producing biomass varies from a region to another. The plains could provide about 9-12 t/ha/year, while the mountains and the hilly areas mainly from the Southern Romania could produce 14-18 t/ha/year. In the Eastern part of the country, more precisely in Dobrudja, in te North –Eastern Romania and along the Danube River, the biomass production is lower, just 4-8 t/ha/year. A high biomass potential is in Tulcea area, accounting for 30-40 t/ha/year. The highest biomass amount is offered by the plains situated in the Southern, Western and North Eastern Romania.
The main resource of agricultural biomass of vegetal origin is represented by cereals: wheat and maize, which could be used for producing bioethanol and oil plants such as: sunflower, rape and soy bean for producing biodiesel.
At present, Romania produces only biodiesel as the EU is mainly focused on this biofuel production (EuroStat, 2011).
The cultivated area recorded a slight decline from 7,884 thousand ha in 2006 to 7,807.4 thousand ha in 2010. Its share in the arable land represented 83.01 % in 2010 and 83.14 % in 2006, reflecting that there is still about 17 % uncultivated arable land, representing about 1,598 thousand ha (Table 1).

Table 1. Arable and cultivated area, Romania, 2006-2010 (thousand ha)

Year	Agricultural land	Arable land	Cultivated area	Share of cultivated area in the arable land (%)
2006	14,731.0	9,434.6	7,884.0	83.56
2007	14,709.3	9,423.3	7,777.2	82.53
2008	14,702.3	9,415.1	7,798.1	82.82
2009	14,684.9	9,422.5	7,884.1	83.67
2010	14,635.5	9,405.0	7,807.4	83.01
2010/2006 %	99.35	99.68	99.02	-

Source: Romania's Statistical Yearbook, 2011, Own calculations.

The cultivated area with oil crops accounted for 1,409.7 thousand ha in 2010, being by 8.63 % higher than in the year 2006.
Three oil crops are the most important ones for producing biodiesel: sunflower, rape and soy bean. Their surface accounted for 1,292.3 thousand ha in 2006 with a share of 99.59 % in the oil crops cultivated area and for 1,392 thousand ha in 2010 with a share of 98.74 %.

In 2006, the share of these 3 crops in the oil crops cultivated area was the following one: 76.4 % sunflower, 14.7 % soybean and 8.5 % rape. In 2010, sunflower was cultivated on 56.1 % land, rape on 38.1 % and soy bean on 4.5 % land with oil crops.
Therefore, sunflower remains on the 1st position with 790.8 thousand ha despite that its share decreased in oil crops area. Sunflower is a very important crop for producing oil both for domestic and EU market.

Table 2. Oil crops cultivated area, Romania, 2006-2010 (thousand ha)

Years	Oil crops cultivated area, of which:	Sunflower		Rape		Soy bean	
		Thou ha	%	Thou ha	%	Thou ha	%
2006	1,297.6	991.4	76.4	110.1	8.5	190.8	14.7
2007	1,340.4	835.9	62.4	364.9	27.2	133.2	9.9
2008	1,239.4	813.9	65.7	365.0	29.4	49.9	3.9
2009	1,253.8	766.1	61.1	419.9	33.5	48.8	3.8
2010	1,409.7	790.8	56.1	537.3	38.1	63.9	4.5
2010/2006 %	108.63	79.76	-	488.01	-	33.49	-

Source: Romania's Statistical Yearbook, 2011, Own calculations.

Rape cultivated area increased 4.88 times in 2010 accounting for 537.3 thousand ha due to its high importance in producing biodiesel.
Soy bean cultivated land deeply decreased by 66.5 %, accounting just for 63.9 thousand ha in 2010. This happened because of the prohibition regarding the use of genetic modified soybean imposed by the EU.
The oil seeds average production varied from a crop to another during the peiod 2006-2010. Also, it varied according to climate conditions, mainly the drought of the year 2007 deeply affected production performance per surface unit in case of all the studied crops. The yield calculated as an average during the five year period was 1,743 kg/ha soy bean seeds, 1,507 kg/ha and 1,332 kg/ha sunflower seeds. Sunflower produced 1,597 kg seeds/ha in 201, by 3.70 % more than in 2006. Rape seed yield accounted for 1,755 kg/ha in 2010, being by 10.4 % higher than in 2006. Soy bean yield was 2,345 kg/ha in 2010 by 29.7 % higher than in 2006 (Table 3).

Table 3. Oil seeds yield by crop, Romania, 2006-2010 (kg/ha)

Year	Sunflower seeds yield	Rape seeds yield	Soy bean seeds yield
2006	1,540	1,590	1,807
2007	654	991	1,021
2008	1,437	1,844	1,817
2009	1,433	1,357	1,726
2010	1,597	1,755	2,345
2010/2006 %	103.7	110.4	129.7

Source: Romania's Statistical Yearbook, 2011, Own calculations.

Oil seed production increased by 15.97 % from 2,050.1 thousand tons in 2006 to 2,377.7 thousand tons in 2010. The lowest level, 1,046.6 thousand tons was recorded in 2007, the year with the terrible drought.

In 2006, the share of oil crops in the total oil seed production was the following one: 74.4 % sun flower, 8.5 % rape and 1.6 % soy bean, all these three crops contributing by 99.8 % to oil seed production.

In 2010, their weight in oil seed production was: 53.1 % sun flower, 39.7 % rape and 6.3 % soy bean, all together representing 99.07 % of production. Therefore, the change of the cultivated area and yield had a direct influence on the oil seed total production (Table 4).

Table 4. Oil seed production by crop, Romania, 2006-2010 (thousand tons)

Year	Oil seed production	Sunflower seeds	Rape seeds	Soy bean seeds	Production of the 3 crops
2006	2,050.1	1,526.2	175.1	344.9	2,046.2
2007	1,046.6	546.9	361.5	136.1	1,044.5
2008	1,942.3	1,169.9	673.0	90.6	1,933.5
2009	1,764.0	1,098.0	569.6	84.3	1,751.9
2010	2,377.7	1,262.9	943.0	149.9	2,355.8
2010/2006 %	115.97	82.74	538.5	43.46	11.5.13
Average 2006-2010	1,836.14	1,120.8	544.4	805.8	1,826.4

Source: Romania's Statistical Yearbook, 2011, Own calculations.

Sunflower seeds production decreased by 17.26 % from 1,526.2 thousand tons in 2006 to 1,262.9 thousand tons in 2010, while rape seed production increased 5.38 times from 175.1 thousand ton sin 2006 to 943 thousand tons in 2010. Soy bean seed production registered a deep reduction, accounting for 56.54 % from 344.9 thousand ton sin 2006 to 149.9 thousand tons in 2010.

Estimation of solid biomass production from oil crops. Taking into account the primary and secondary production and the conversion coefficient into biomass for the 3 oil crops, the biomass production was estimated for the minimum, maximum and average seed production in the period 2006-2010.

Romania's biomass production was 6,748.5 thousand tons in average, ranking between a minimum level of 2,139.9 thousand tons and 7,436.6 maximum level.
The average biomass production estimate accounted for 2,970.1 thousand tons for sunflower, 1,361 thousand tons for rape and 2,417.4 thousand tons for soy bean. Based on the minimum and maximum production, the ranking of the crops w as: sunflower, rape and soy bean.
In case of sunflower, the solid biomass production is mainly produced by secondary production (62.26 %) and seed production contributed by 37.74 %. In case of rape, seed production could contribute by 40 % to biomass production and the secondary production by 60 %. In case of soy bean, seeds could contribute by 33.34 % and the secondary production by 66.66 % to the solid biomass production (Table 5).
Energy production estimate from solid biomass produced by oil crops. During the analyzed period, Romania's average energy production was estimate at 11,518.5 thousand GJ, while the minimum potential accounted for 39,460.02 thousand GJ and the maximum potential accounted for 132,883.46 thousand GJ (Table 6).

Table 5. Biomass production estimate for oil crops destined to produce biodiesl, Romania, 2006-2010 (thousand tons)

Oil crop	Specification	Minimum Biomass production	Maximum Biomass production	Average Biomass production
Sunflower	Primary production	546.9	1,526.2	1,120.8
	Secondary production	902.4	2,518.2	1,849.3
	Total biomass production	1,449.3	4,044.4	2,970.1
Rape	Primary production	175.1	943.0	544.4
	Secondary production	262.6	1,414.5	816.6
	Total biomass production	437.7	2,357.5	1,361.0
Soy bean	Primary production	84.3	344.9	805.8
	Secondary production	168.6	689.8	1,611.6
	Total biomass production	252.9	1,034.7	2,417.4
TOTAL SOLID BIOMASS PRODUCTION ESTIMATE		2,139.9	7,436.6	6,748.5

Source : Own calculations

Table 6. Energy production estimate from solid biomass produced by oil crops, Romania, 2006-2010(thousand GJ)

Oil crop	Energy production estimate from:	Minimum energy production	Maximum energy production	Average energy production
Sunflower	Main biomass production	13,125.60	36,628.80	26,899.20
	Secondary biomass production	16,107.84	44,949.87	33,010.00
	Total energy production	29,233.44	81,578.67	59,909.20
Rape	Main biomass production	4,027.30	21,689.00	12,521.20
	Secondary biomass production	3,282.50	17,681.25	10,207.50
	Total energy production	7,309.80	39,370.25	22,728.70
Soy bean	Main biomass production	1,399.38	5,725.34	13,376.28
	Secondary biomass production	1,517.40	6,208.20	14,504.40
	Total energy production	2,916.78	11,933.54	27,880.68
TOTAL ENERGY PRODUCTION ESTIMATE		39,460.02	132,882.46	110,518.58

Source: Own calculations

The contribution of each oil crop to the energy production potential was determined by the amount of solid biomass estimated for the whole plant by crop and the energetic value of each plant in terms of GJ/ton.

The contribution of each oil crop to the total energy production estimated as average for the period 2006-2010 was the following one: sunflower 54.20 %, soy bean 25.24 % and rape 20.56 %.

Table 7. Contribution of each oil crop to energy production estimate from solid biomass, Romania, 2006-2010 (%)

Oil crop	Minimum energy production	Maximum energy production	Average energy production
Sunflower	74.08	61.39	54.20
Rape	18.52	29.62	20.56
Soy bean	7.40	8.99	25.24
Total	100.00	100.00	100.00

Source: Own calculations

Romania's biodiesel production estimate. Substracting the need of seeds for human food and animal feedstuff consumption, it remained 90 % of rape biomass, 20 % of sunflower biomass and 6 % soybean biomass to be used for estimating biodiesel production. Taking into account the seed conversion rate into biodiesel: 41.5 % for sunflower, 36 % for rape and 17 % for soy bean, the biodiesel production estimate in the period 2006-2010 was 277,631.5 thousand liters in average, 437,723.9 thousand liters as maximum performance and 102,975.3 thousand liters as minimum level (Table 8).

Table 8. Biodiesel production estimate/year from biomass produced from oil crops, Romania, 2006-2010 (thousand liters)

Oil crop	Specification	MU	Minimum biodiesel production	Maximum biodiesel production	Average biodiesel production
Sunflower	Biomass production (20% of seed production)	Tons	109,380	305,240	224,160
	Estimated biodiesel production	Thousand liters	45,392.7	126,674.6	93,026.4
Rape	Biomass production (90% of seed production)	Tons	157,590	848,700	489,960
	Estimated biodiesel production	Thousand liters	56,732.4	305,532	176,385.6
Soy bean	Biomass production (6% of seed production)	Tons	5,060	20,690	48,350
	Estimated biodiesel production	Thousand liters	8,602.2	3,517.3	8,219.5
BIODIESEL PRODUCTION ESTIMATE/YEAR		Thousand liters	102,975.3	435,723.9	277,631.5

Source: Own calculations

The contribution of each crop to the average biodiesel production estimate was: 63.53 % from rape, 33.50 % sun flower and 2.97 % soy bean. Therefore, the most suitable oil crops for producing biodiesel in Romania are rape and sunflower, rape contribution to biofuel production being double compared to sunflower contribution.

Table 9. Contribution of oil crops to biodiesel production estimate, Romania, 2006-2010 (%)

Oil crop	Minimum biodiesel production	Maximum biodiesel production	Average biodiesel production
Sunflower	44.08	29.07	33.50
Rape	55.09	70.12	63.53
Soy bean	0.83	0.81	2.97
Total	100.00	100.00	100.00

Source: Own calculations

Cake production resulted from biodiesel production process accounted for 464,774.15 tons/year, while ***glycerin production*** accounted for 32,023.7 thousand tons (Table 10).

Table 10. Cake and Glycerin production estimate, resulting from biodiesel production process, Romania, 2006-2010

Product	Oil crop	MU	Minimum production	Maximum production	Average production
Cake	Sunflower	Tons	63,877.9	178,341.9	130,909.4
	Rape	Tons	8,835.6	509,220	293,976
	Soy bean	Tons	4,174.5	17,069.25	39,888.75
	Total cake	Tons	76,888	704,631.15	464,774.15
Glycerin	Sun flower + rape+ soy bean	Thousand Tons	11,425.2	49,334.5	32,023.5

Source:Own calculations.

Conclusions

(1)Romania has a high potential for producing biofuels in general, but mainly for biodiesel, because of the important surface cultivated with oil crops, the possibility to extend this surface in the uncultivated areas and biomass production potential.
(2)The main crops suitable to produce biodiesel are sunflower, rape and soy bean.
(3)In the period 2006-2010, the average cultivated area with these three crops per year was 1,296.4 thousand ha. In 2010, the share of oil crops in the cultivated area was 56.1 % for sunflower, 38.1 % for rape and 4.5 % for soy bean.
(4)The average seed production per year was 1,332 kg/ha for sunflower, 1,1507 kg/ha for rape and 1,743 kg/ha for soy bean.
(5)Biomass production estimated in average per year was 2,970.1 thousand tons for sunflower, 1,361 thousand tons for rape and 2,417,4 thousand tons for soy bean, totalizing 6,748.5 thousand tons/year.
(6)In average, energy production estimate based on the total solid biomass production estimate, was 110,518.58 thousand GJ, of which 54.20 % from sunflower, 20.56 % from ape and 25.24 % from soy bean.
(7)Biodiesel production was estimated at 277,631.5 thousand liters in average fr the whole studied period. The contribution of the oil crops to biodiesel production estimate was: 63.53 % from rape, 33.50 % from sunflower and 2.97 % from soybean.
(8)From biodiesel production processing, it also resulted 464,774 tons cakes and 32,024 thousand tons glycerin as byproducts.
(9)Based on this analysis, the final conclusion is that Romania is able to reach the target percentage of biofuels grace of its biomass production potential represented by oil seeds and also by other sources.

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