Main factors influencing energy efficiency for biofuel production and fatty acid composition in winter oilseed rape

Francis Flénet[1] and André Merrien[2]

The fatty acid composition of rapeseed oil must be monitored, because it determines the possibilities of uses. The oil composition depends on the type of varieties. With the standard type, the oleic and the alpha-linolenic acids range from 60 to 65 % and from 8 to 12% respectively. This standard rapeseed oil can be used for salad dressing, cooking oil, baking oil and for biodiesel. Other types of varieties were developed for specific uses : the oleic type (above 70% of oleic acid) for lubricant, the low alpha-linolenic type (2.5 of alpha-linolenic acid) for frying oil and the erucic type (above 50 % of erucic acid) for lubricant, plastic films and for skin and healthcare products. The composition also depends on environmental factors.

On the other hand, the sustainability of agriculture must be improved, because of the demand of the general public and of the European Union administration. For example, the sustainability of biofuel has been questioned. Hence, sustainable criteria are included in the Directive on energy from renewable sources (European Parliament and European Council). In order to meet these requirements, the environmental management of oilseed crops has been implemented. An interprofessional agreement concerning biodiesel was signed in France in 2007. The objective was to improve the energy and the greenhouse gas balances, the quality of water and biodiversity. The work started in 2008 on energy balance. The other impacts will be investigated from 2009 onwards.

This article presents two examples of studies conducted in order to meet the requirements for fatty acid composition or sustainability: (1) oil with guaranteed fatty acid composition (« fleur de colza »); (2) improvement in the energy efficiency of biodiesel.

1) “Fleur de colza”, a food oil with a guaranteed fatty acid composition

« Fleur de colza » is a rapeseed oil made by LESIEUR with a 9% guaranteed content of alpha-linolenic acid (C18:3), which is a member of essential fatty acids giving clinical benefits in cardiovascular health. In France, the minimum content of 9% was not obtained each year in seeds processed by LESIEUR, despite the use varieties selected for their high level of C18:3 (Table 1). From 2000 to 2003, the % of C18:3 decreased. Hence, the mean C18:3 content was only 8.75 % in 2003.

[1] CETIOM – Avenue Lucien Brétignières – 78850 Thiverval Grignon – FRANCE – flenet@cetiom.fr

[2] CETIOM – 270, avenue de la Pomme de Pin – BP 90635 – Ardon – 45166 Olivet cedex – FRANCE – merrien@cetiom.fr

Table 1 – Alpha linolenic acid (in % of total fatty acids) in seeds[(1)] processed by LESIEUR

	2000	2001	2002	2003
Minimum value	8.82	7.90	8.23	7.96
Maximum value	10,62	10.07	10.00	9.40
Mean value	9.94	9.46	9.21	8.75
Number of samples	221	202	86	85

[(1)] Seeds were produced by varieties selected for their high level of C18:3

The hypothesis that the differences between years in C18:3 resulted from differences in night temperatures during the synthesis of oil was put forward. This hypothesis was supported by previous studies showing that the % of fatty acids were determined within 60 days after flowering (Champolivier, 2006), and showing that during this period the % of C18:3 was negatively correlated with the sum of minimal temperatures (Baux et al, 2007). The objective of the study was to confirm this effect of minimal temperatures, and to investigate the possibility to choose the area of production in order to maximize the % of C18:3.

a. Materials and methods

The % of C18:3 was measured in 20 experiments conducted in France from 2004 to 2008. Most experiments were located in the main regions of rapeseed production in France (Figure 1).

Several varieties were studied in each experiment. AVISO was the only variety studied in all experiments. The % of C18:3 of this variety is one of the highest among the main oilseed rape cultivars grown in France.

The % of C18:3 was also studied on seeds collected from stockpiling agencies.

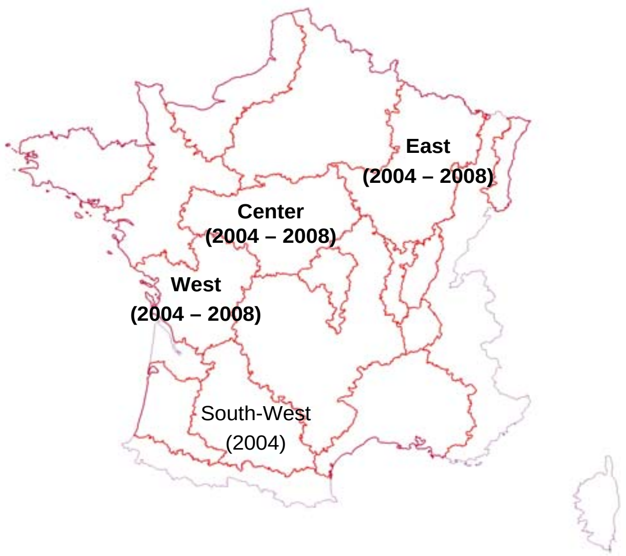

Figure 1 – Regions of France where the experiments were conducted

b. Results and discussion

The % of C18:3 measured on AVISO in the 20 experiments is presented in Figure 2. The seed content in this fatty acid was negatively correlated with the sum of minimal temperatures during the 60 days following the onset of flowering.

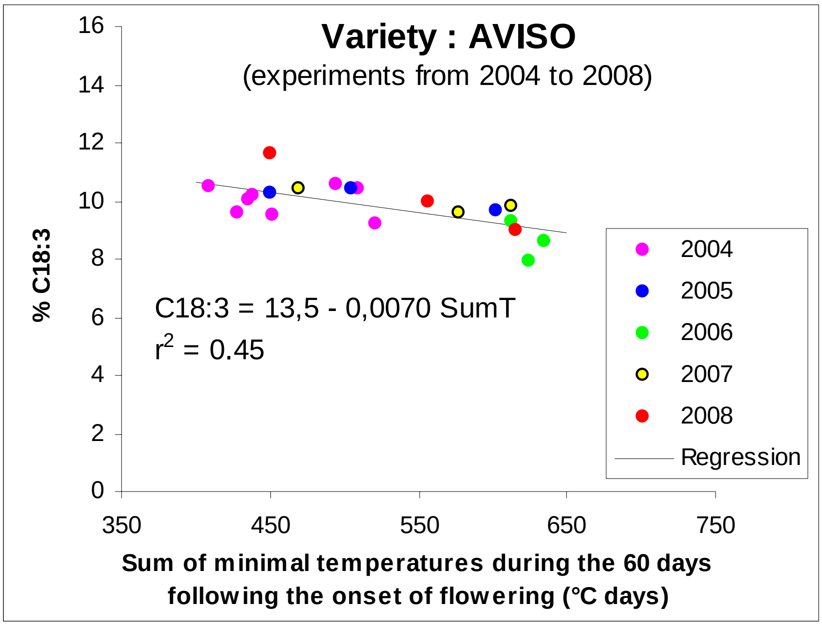

Figure 2 – C18:3 content depending on minimal temperatures after flowering

However, in 2006 the % of C18:3 was higher in the warm region of Western France than in the cooler regions of Eastern or Central France (Table 2). This result could be explained by differences in phenology between regions. In Western France, in 2006 flowering occurred earlier than in Eastern and Central France (Figure 3). Hence, the temperature during the seed filling period was lower in Western France than in the Eastern and Central regions.

Table 2 – Alpha linolenic acid measured in experiments in 2006

Region	Mean % C18:3 across varieties
West	8.6
East	7.6
Center	7.7

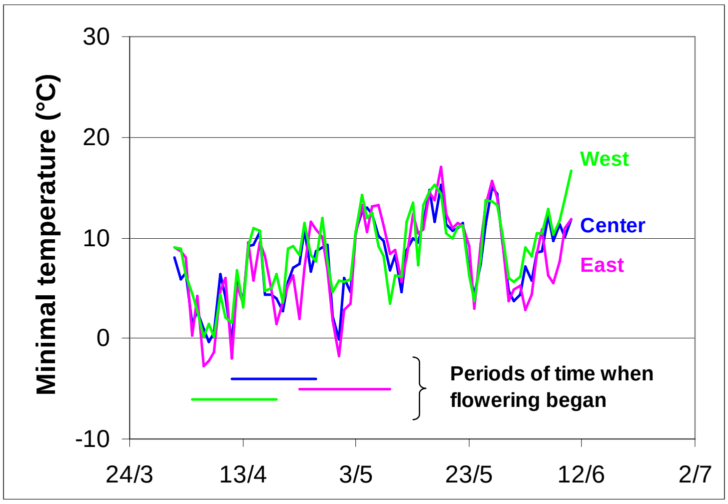

Figure 3 – Minimal temperature in 2006 in France

During the period from 2004 to 2008, there was no consistent effect of the area of production: for instance, the % of C18:3 was the lowest in the warm region of oceanic coast in 2004, but the highest in 2006 (Table 3).

Table 3 – Alpha-linolenic acid measured on seeds from stockpiling agencies (in % of total fatty acids)

Area of production	Year of harvest				
	2004	2005	2006	2007	2008
Oceanic coast of France	7.6	9.1	8.6	10.0	10.8
Central and Western France	8.9	9.6	7.8	9.8	10.9
Eastern France	9.6	8.9	7.7	9.2	10.1

In conclusion, the hypothesis that the differences between years in C18:3 resulted from differences in night temperatures during the synthesis of oil was supported by the negative correlation between the seed content in this fatty acid and the sum of minimal temperatures (see Figure 2). However, the results from stockpiling agencies did not provide clear support for the idea that the area of production may be chosen in order to maximize the % of C18:3 (see Table 3). Simulations of dates of flowering and calculations of night temperature sums are needed to further test this possibility.

2) Improvement in the energy efficiency of biodiesel

The production of biofuels aims to reduce the dependence of transport on fossil energy. The contribution to this objective is evaluated by the energy efficiency, which is the ratio between the energy content of the biofuel and the energy cost for its production. On average, this ratio is 2.87 for oilseed rape biodiesel (Flénet et al., 2007). In 2005 and 2006 in France, a great variability was observed in the energy efficiency between fields. Hence, it may be possible to increase the energy efficiency of biodiesel by improving crop management. In 2008, a survey was conducted in order to confirm the great variability in energy efficiency between fields cultivated in oilseed rape. The objective was also to investigate the factors affecting the energy efficiency.

a. Materials and methods

The energy efficiency was calculated according to life cycle assessment: the energy cost was calculated from « cradle » (manufacture of inputs) to « grave » (fuel depository). The energy cost was allocated between biodiesel and the co-products (cake…) depending on the energy contents. Data were collected from more than 4000 winter oilseed rape fields from all over France, with the help of 44 stockpiling agencies. The main data collected were seed yields and cultural practices.

b. Results and discussion

The energy efficiency was highly variable between fields: values lower than 2.0 or greater than 4.5 were observed (Figure 4). On average, the efficiencies were slightly greater when organic matter was applied than in fields with no application. However, when fields with or without application of organic matter were examined separately, the variability in energy efficiency remained high. This indicated that the application of organic matter could not explain a great part of this variability.

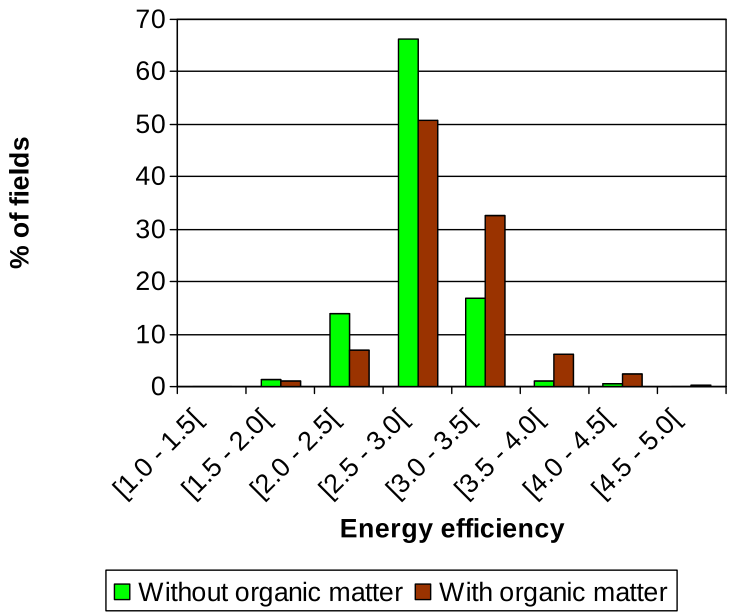

Figure 4 – Distribution of fields in energy efficiency groups

The energy efficiency depends on both seed yield and energy cost of cultural operations, because it is a ratio between the output and the input of energy. However, in a given population of fields the variability in energy efficiency may be more related to one of these two factors (seed yield or energy cost). In the population of fields studied in 2008, seed yield and energy cost of cultural operations were both highly variable (Figure 5). Moreover, the large scattering of values indicated that these two factors had a great effect on the variability in energy efficiency. For instance, the energy efficiency ranged from 2.2 to 4.2 for a given seed yield of 3.5 t/ha which was close to the mean value (data not shown), because of the variability in energy cost. Similarly, the energy efficiency ranged from 1.6 to 3.3 for a given energy cost of 13000 MJ/ha which was close to the mean value (data not shown), because of the variability in seed yield.

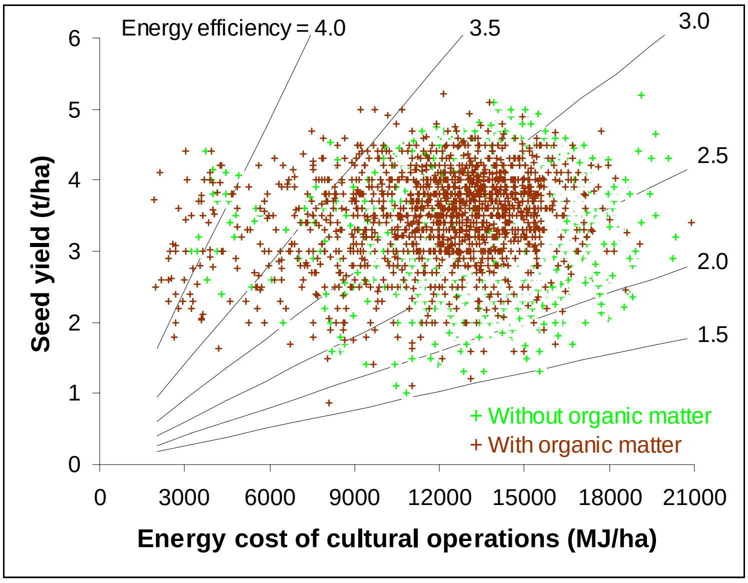

Figure 5 – Energy efficiency of each field depending on seed yield and on energy cost

The energy cost of mineral N fertilizer was highly correlated with the total energy cost, and in most fields this input was the most costly (Figure 6). On the contrary, there were no clear relationships between the energy cost of other inputs and the total energy cost.

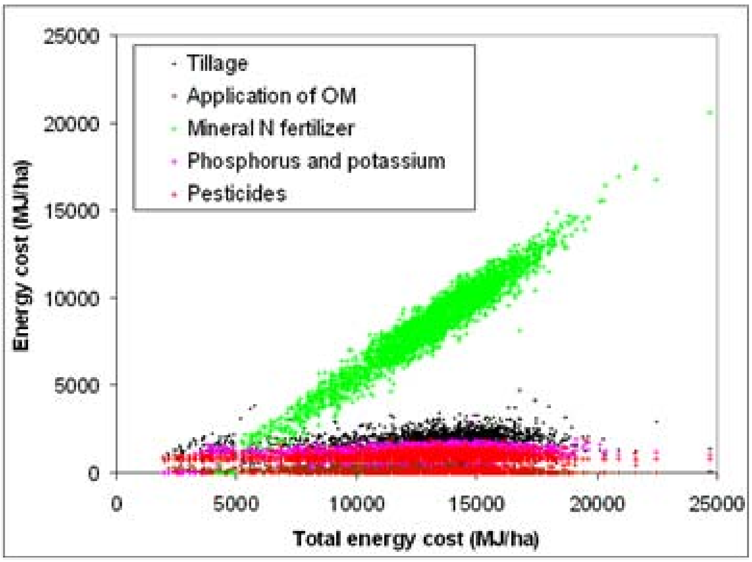

Figure 6 – Energy cost of inputs in each field vs. total energy cost of cultural operations

In conclusion, the great variability in energy efficiency between fields cultivated in winter oilseed rape was confirmed by the results collected in France in 2008. The energy efficiency was affected by both seed yield and energy cost of mineral N fertilizer, suggesting that better cultural practices would reduce this variability, and thus increase the energy efficiency. However, evidence that such improvement is possible is needed.

Conclusion

In this article, two examples of studies conducted in order to meet the requirements for fatty acid composition or sustainability in winter oilseed rape were presented. Specific cultural practices are needed to meet these requirements: specific varieties for oil quality in addition to a possible regional effect, or high yielding and low energy cost practices for energy efficiency. However, no changes in the list of varieties nor in the regions of production have been made in order to improve the oil quality, because 2003 has been the only year with oil quality problems so far. On the contrary, the possibilities to change cultural practices in order to increase the energy efficiency of biodiesel will be investigated from 2009 onwards, with the help of agricultural advisory agencies. The objective is to achieve continual improvements.

References

Baux A., T. Hebeisen, and D. Pellet. 2007. Effects of temperature on low-linolenic rapeseed oil fatty-acid composition. p. 339-342. In: Proc. 12th Int. Rapeseed Congress, Vol. III, Wuhan, China. GCIRC, Paris, France.

Champolivier L. 2006. Le remplissage des graines, étape cruciale pour l'élaboration du rendement et la qualité du colza. Oléoscope 86 : 10-14.

Flénet F., A. Poupart, and D. Wagner. 2007. Rapeseed is an efficient energy crop which can still improve. OCL 14 : 354-359.