Quality of rapeseed oil for non-food (bioenergy), and human and animal nutrition*

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ABSTRACT

Rapeseed has the potential to deliver high quality oil for non-food, and human and animal nutrition. Rapeseed oil contains low levels of saturated fatty acids, large percentage of oleic acid and an optimal n-6/n-3 ratio of poly-unsaturated fatty acids, which has been associated to a reduced risk of cardiovascular diseases. Rapeseed oil contains also lipid soluble vitamins, carotenoids, phytoesterols, and a number of phenolic compounds, which, if unaltered by processing, can act as antioxidants. Genetic factors, environmental conditions during the growth of the crop, storage conditions, and processing can influence to a large extent the quality of the oil obtained from rapeseed. In contrast to processing techniques based upon exhaustive heating, mild processing techniques that include optimized enzyme inactivation allow obtaining high quality oil rich in antioxidants and free from unwanted flavours, odours and colour, at the same time as preserving the quality of the seed meal. The high quality oil and seed meal obtained with milder processing techniques may thus compensate for slightly reduced oil yields.

KEYWORDS: rapeseed, oil, processing, nutrition, biodiesel

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The potential of oilseed rape for delivering high quality products

Rapeseed (*B. napus* L. and *B. rapa* L.) has a large potential in human and animal nutrition due to the high quality oil, protein and dietary fibre (DF) contained in its seeds. In average, seeds of rapeseed contain (in % of dry matter (DM)): oil (40-48%), protein (18-23%), dietary fibres (22-28%) and a range of low molecular weight compounds (10-15%) (Figure 1; (1)).

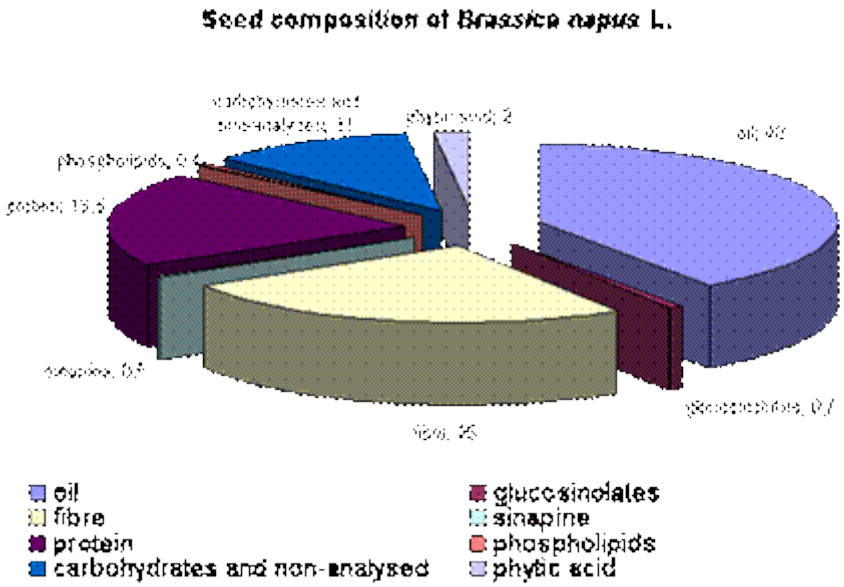

Figure 1. Chemical composition of seeds of rapeseed (*B. napus* L.).

The chemical composition, and especially the structure (constitution) and stereochemistry (configuration), of the individual components of rapeseed sets the potential and limitations for food, feed and non-food uses. The presence of specific low molecular weight compounds – especially antioxidants, phenolics, sinapoyl derivatives as sinapine and glucosinolates – is the main factor influencing the quality of the products obtained from rapeseed – oil, lipids, rapeseed meal/press cake, protein and fibre products. These low molecular weight compounds can thus limit the applicability of rapeseed products in human and animal diets (2,3) . The use of processing techniques specifically tailored for rapeseed can assist in overcoming some of the problems caused by these low molecular weight compounds, ensuring the quality of the final products (see below).

Factors influencing the quality of rapeseed oil

The quality of the seed and the structure/properties of its native constituents are decisive for ensuring the quality of the final products obtained from rapeseed. Genetic factors (type of cultivar), environmental conditions during the growth of the crop and storage conditions, can have large effects on the quality of the seed, which will, in turn, set the limitations for the quality of the products obtained upon processing.

The fatty acid composition of rapeseed oil is determined by genetic factors and thus depends upon cultivar type (Table 1).

Table 1. Fatty acid composition of oil from different rapeseed (*B. napus* L. *B. rapa* L., and *B. juncea* L. Czern) cultivars. Legend: C18:1 (oleic acid); C18:2 (linoleic acid); C18:3 (linolenic acid); C22:1 (erucic acid); saturated (saturated fatty acids).

	Double low *B. napus*rapeseed	Double low *B. rapa*rapeseed	HEAR (high erucic acid)	"Canola quality" *B. juncea*
C18:1 (n-9)	59-65	56-64	13-15	62.9
C18:2 (n-6)	19-26	19-22	11-14	16.8
C18:3 (n-3)	8-9	10-13	8-9	11.1
C22:1 (n-9)	0.1-0.6	0.5-1.5	45-53	0.1
Saturated	5-8	5-7	5-6	6.7

A survey conducted by the Canadian Grain Commission has shown that climatic conditions play a major role in the total oil content, chlorophyll content and free fatty acid (FFA) profile of seeds of *B. napus* L. and *B. juncea* L. cultivars. Frost and/or cool and wet climatic conditions during the growth season generally lead to high oil content in seeds. Oil content in seeds is decisive for the economy of the crop, with 1% higher oil content in seeds meaning up to 11000 $/day higher profit margin in Canada (4) . However, frost and/or cool and wet climatic conditions also induce higher chlorophyll content due to frost damage or insufficient ripening of the seeds. The content of chlorophyll in seeds and oil has to be quantitatively and qualitatively assessed, since the profile of chlorophyll and its derivatives is different between, e.g. immature seeds and frost-damaged immature seeds. FFA profile is also influenced by weather; hot and dry climatic conditions appear to increase the level of FFA, although climate x cultivar interactions exist (4) . Maximum level of FFA in seeds should be kept below 1%.

Conditions during post-harvest storage can also influence the quality of rapeseed. Damage can be caused by humidity, initiated germination – and thereby enzyme production – high temperature, insects and pesticides and this can result in oil rancidity, changed FFA profile and unwanted colours and odours of the products. Moisture of the seed should be kept at 7% in order to avoid off-taste in the oil and de-oiled meal caused by metabolic or autolysis process (5,6) .

Influence of processing on the quality of rapeseed oil

Processing plays an important role for the final quality of the oil and the remaining seed meal. Control of the processing conditions – especially temperature, moisture and time of processing – is thus critical for ensuring that the quality of the oil and the seed meal are preserved throughout the process. Special care should be taken in avoiding glucosinolate

degradation, as this will result in a range of lipophilic products – e.g. isothiocyanates and nitriles – that can negatively affect oil quality. Analysis of the raw material, processing and end products –oil and de-oiled seed meal – can assist in adjusting the processing parameters in order to obtain the best possible quality of products.

The processing of rapeseed requires an initial heat treatment targeted to the inactivation of enzymes – e.g. myrosinase, lipases and lipoxygenases. High temperatures allow for increasing oil yield; however, excessive heat treatment may induce oxidation processes that result in the formation of dark coloured compounds that are released into the oil and the de-oiled meal decreasing their quality. Oil refining may thus be required in order to remove oxidation products and obtain acceptable oil quality. Chlorophyll and FFA present in the seeds also influence the quality of the oil, by e.g. affecting oxidation stability, colour, odour and taste. Chlorophyll can be removed with the use of bleaching clays during processing; although high levels of chlorophyll require extra bleaching, which results in lower oil extraction. Removal of FFA, phospholipids/glycolipids is partly possible by degumming; off-taste and off-odours are removed by desodorization.

Mild processing procedures that include optimized enzyme inactivation – e.g. "cold"-pressing – allow obtaining high quality oil rich in antioxidants and free from unwanted flavours, odours and colour, at the same time as preserving the quality of the pressed-cake (2) . The high quality oil and seed meal obtained with milder processing techniques may thus compensate for slightly reduced oil yields.

Independently of the type of processing, the quality of the raw material and the optimization of the storage conditions are key factors for the production of high quality oil.

Rapeseed oil for human consumption

The oil from double-low rapeseed varieties is generally of high quality, with the FA profile of lipids (including phospho- and glycolipids) being optimal for nutritional purposes (Figure 2). Rapeseed oil contains low levels of saturated FA (SFA), large percentage of oleic acid (> 60%) and an optimal n-6/n-3 ratio of poly-unsaturated FA (PUFA) (Figure 2; (7)).

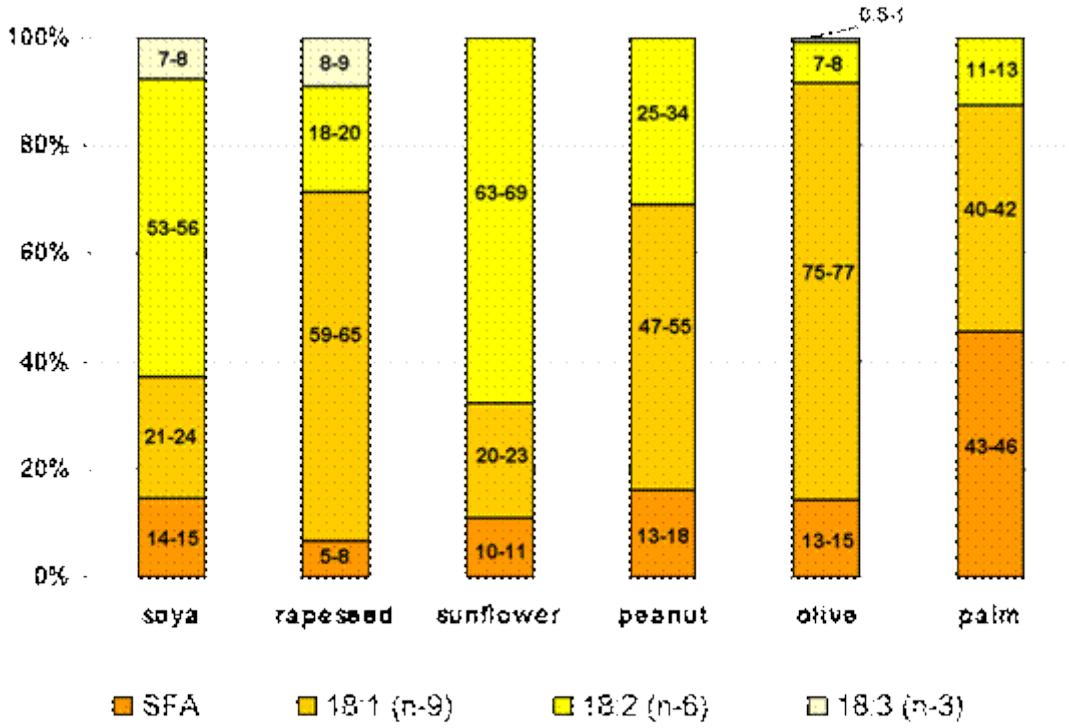

Figure 2. Content of saturated (SFA) and unsaturated FA of different edible oils. Oleic acid is a 18:1 (n-9) mono-unsaturated FA (MUFA) whilst linoleic and alphalinolenic acids are, respectively, 18:2 (n-6) and 18:3 (n-3) poly-unsaturated FAs (PUFAs).

FAs in general, and PUFAs in particular, are subject to a complex metabolism in humans, which results in the formation of a number of intermediate long-chain (LC) PUFAs that can cause a range of positive and negative effects on human health. Alphalinolenic acid (ALA) and the n-3 LCPUFAs formed upon its metabolism reduce the risk of cardiovascular diseases, whilst the LCPUFAs originated from linoleic acid (LA) act as vaso-constrictors and are pro-inflammatory. ALA appears to act by both direct and indirect mechanisms: it has a protective function in itself but also acts through the n-3 LCPUFAs formed in its metabolism, which counteract the cascade of formation of n-6 LCPUFAs. Other reported benefits of ALA and LCPUFAs for human health are decreased risk of dementia, reduced susceptibility to epilepsy and prevention of certain neuronal disorders, such as depression (8,9) .

Rapeseed oil contains an optimal n-6/n-3 PUFA ratio (Figure 2), which makes it suitable for its use in animal and human diets as a balanced source of essential FA for protective functions. The French National Programme on Nutrition and Health (PNNS) has recommended the consumption of vegetable oils rich in n-3 PUFA, such as canola oil. More specifically, the recommended levels in human diets of n-3 PUFA are set to ca. 0.8 %, whereas for n-6 PUFAs the recommended levels are set to ca. 4% of the total energy supply. Simple nutritional modifications – such as the introduction of one to three spoons of rapeseed oil daily in the diet – are an easy way to increase ALA intake, which will result in n-3 protection via the plasma increase of both ALA and n-3 LCPUFAs.

Properly produced and processed rapeseed oil (see above) has also antioxidant effect due to its high content of lipid soluble vitamins (tocopherols), carotenoids, phytoesterols, and a number of phenolic compounds.

Rapeseed oil for animal consumption

In studies on the effects of different vegetable and fish oils on the growth and development of mink, (10) and (9) reported "cold"-pressed rapeseed oil to rank first in promoting mink kit growth (expressed as kit weight 42 days after birth). "Cold"-pressed rapeseed oil contained a more balanced ratio of essential n-6/n-3 PUFAs than sunflower, soybean and fish oils and a higher amount of antioxidants – especially carotenoids – than "hot"-pressed rapeseed oil.

Rapeseed oil for non-food purposes – biodiesel

The increasing demand of liquid fuels for transportation and the negative environmental effects of the use of fossil fuels during the past century have increased the interest in the development of renewable and cheap liquid fuel alternatives. Biodiesel, which is produced from vegetable oil through transesterification, has ca. 90% of the energy potential of fossil-based diesel and provides a number of environmental benefits (11) .

The EU is currently the global leader in biodiesel production, with rapeseed (*B. napus*) being the major feedstock. The EU Directive 2003/30/EC "Promotion of the use of biofuels or other renewable fuels for transport" set out national targets for biofuel to 5.75% of the complete fuel consumption in the EU by 2010(12) . This is expected to result in an increased demand for biodiesel, which, in the case of the EU will be mainly covered by rapeseed oil (11) .

With respect to conventional fossil-based diesel, biodiesel from rapeseed oil shows advantages in the hydrocarbon, carbon monoxide and particulate matter emissions, although some studies indicate that ultra fine particle emissions are high (13) .

CONCLUSION

Native rapeseed oil, as present in the seed, has optimal characteristics for its use as high quality oil for food, feed and non-food purposes. Genetic factors, and environmental, storage and processing conditions, have a large influence on the yield and quality of the oil obtained from rapeseed. Control of these factors is thus necessary in order to guarantee the production of the highest possible quality oil from a given rapeseed variety, whether it will be used for non-food (biodiesel) or nutritional purposes (vegetable oil for human consumption).

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