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REVIEW

Research progress and strategies for multifunctional rapeseed: A case study of China

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Abstract

Rapeseed (*Brassica napus*), is an important source of edible oil, animal fodder, vegetables, condiments and biodiesel, and plays a significant role in securing edible oil production worldwide. However, in countries with comparatively low levels of agricultural mechanization, such as China, increasing costs of labor and agricultural inputs are decreasing rapeseed profitability, and hence the area of rapeseed under cultivation. If the value of rapeseed crops is not further increased, the rapeseed growing area will continue to decrease, potentially jeopardizing oil production. Therefore, full exploitation of the existing and potential value of rapeseed is desirable. Different rapeseed products are already utilized in different ways, with more applications currently underutilized. As well as oil extraction from the seeds, the shoot and leaves can be used as vegetables, the roots to absorb soil cadmium for pollution remediation, the flowers for sightseeing and as a source of nectar, the pollen for extracting flavonoids and useful amino acids, the seeds/seed meal for extracting isthiocyanates and other important sulforaphane compounds, the straw and seed meal for fodder, and immature whole plants for green manure. This review summarizes recent research on ways to explore the potential holistic value of rapeseed, by taking the example of multifunctionality of rapeseed in China.

Keywords: multifunctional rapeseed, sightseeing rapeseed, remediation of cadmium pollution, rapeseed oil, fodder, vegetables

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1. Introduction

Oilseed rape is the general name for *Brassica* oil crops, and includes *Brassica napus* (rapeseed), *B. rapa* (turnip rape) and *B. juncea* (Indian mustard). Oilseed rape is the second-highest yielding oil crop worldwide (http://www.ers.

usda.gov/data-products/oil-crops-yearbook.aspx). Oilseed rape accounted for 14% of world major oil crop production, and ranked in the top fourteen European agricultural commodities in 2014 (http://www.fao.org/). The latest data from French market analyst agency "Strategie Grains" shows that the global rapeseed yield is expected to reach 70 million tonnes in 2014–2015, a yield increase of 0.4% compared to the previous year. More than 85% of rapeseed oil is produced in the 27 countries in the European Union. The European Economic Community (EEC) ranks first globally for total rapeseed yield (26%), followed by China (20.2%), India (11.3%), Canada (9.3%) and Japan (6.6%) (http://www.indexmundi.com/agriculture/?commodity=rapeseed-oil). In 2011, the major usages of rape oil were for food (67%), biofuels (27%) and oleochemicals (3%) (http://www.cyberlipid.org/index.htm). With increasing global population size, the demand for vegetable oil and feedstock for biofuel as well as seed meal (which contains 35 to 40% protein) for fodder is also increasing. According to the Canola Council of Canada, the demand for global canola oil is estimated to reach 250 million tonnes by 2025, an increase of 67% or 100 million tonnes from current market demand (http://www.canolacouncil.org/). To meet this market demand, many countries will need to either increase the cultivated area of rapeseed or enhance the rapeseed yield per unit area.

However, in countries with low levels of rapeseed mechanization, the comparative benefit to farmers of growing rapeseed has decreased, negatively affecting farmer perceptions of this crop and shrinking the cultivated area of rapeseed. In the present situation, the usage of rapeseed only for oil is unlikely to change the trend of decreasing cultivated area. Only by developing the value of rapeseed products across different markets, increasing the product value and the usage of raw materials, can farmers gain more net profit, thereby improving growers' enthusiasm and boosting market vitality. Therefore, this review focuses primarily on the development of multifunctionality in rapeseed crops, using the case of China to provide an important reference for innovation of the canola industry.

2. Edible oil

The major use of rapeseed is as edible oil. Edible oilseed rape (with low seed glucosinolates and erucic acid) is referred to as canola, and canola oil has distinct advantages over other rapeseed oil types. Firstly, canola oil contains only 7% saturated fatty acids on average, which is the lowest of the commonly consumed oils: corn oil has 13% saturated fat, olive oil and soybean oil have 15%, palm oil has 51% and sunflower oil has 12%; animal oils like lard contain 43% (http://www.canolacouncil.org/media/514518/dietary_fat_english.pdf). The major unsaturated fats in canola oil are oleic acid (C18:1) at 61%, linoleic acid (C18: 2) at 21% and alpha-linoleic acid (C18:3) at 11% ("Comparison of Dietary Fats Chart", Canola Council of Canada, Retrieved 2008-09-03, http://www.canolacouncil.org/media/514518/dietary_fat_english.pdf). These unsaturated fats can reduce both total cholesterol and 'bad' cholesterol (low-density lipoprotein (LDL)) without changing the amount of 'good' cholesterol (high-density lipoprotein (HDL)), helping to prevent cardiovascular diseases (Palomaki *et al.* 2010; Iggman *et al.* 2011; Baxheinrich *et al.* 2012). High oleic acid, low alpha-linoleic acid (HOLL) canola cultivars have also been released and could produce oil suitable for deep-frying and long-term storage, due to their high stability (Przybylski *et al.* 2013). HOLL canola is already well established in many countries. For example, in Canada, HOLL canola varieties currently account for approximately 15% of the canola acreage (http://www.grdc.com.au/Research-and-Development/GRDC-Update-Papers/2010/09).

In China, rapeseed oil, as the largest source of vegetable oil, accounts for 45–50% of national oil production. Currently, the cultivated rapeseed area in China is around 1.35 billion ha, producing 12–13 million tons of seeds, 7–8 million tons of seed meal, and about 4.5–5 million tons of oil. However, the supply of rapeseed oil still cannot meet the demands of the edible oil market. The self-sufficiency rate in China for rapeseed oil is less than 40% (Yin and Wang 2012), much lower than grain self-sufficiency (95%) (http://english.agri.gov.cn/overview/201301/t20130128_10644.htm). Moreover, the cultivated rapeseed area in China is still shrinking, which is due to several reasons. Firstly, rapeseed profits have been declining recently due to large increases in the cost of planting rapeseed, including labor, pesticides, herbicides and fertilizers. Because of China's urbanization, large numbers of farmers have been moving to the big cities looking for jobs, causing severe labor shortages in rural areas and hence increasing the labor costs. However, the price of canola oil has not increased correspondingly and has remained steady at 4.6 to 5.4 CNY (Chinese Yuan) per kilogram (kg). If canola seeds are priced at 5.4 CNY kg^{-1} and each ha produces 1 875 kg, the gross profit per ha is 10 125 CNY. The average labor cost is approximately 6 300 to 7 650 CNY ha^{-1} (Table 1), and the average cost of seeds, fertilizers and pesticides per ha is approximately 2 700 CNY, meaning the net profit per ha is around –225 to 1 125 CNY ha^{-1}. For most farm families who only have 30–45 ha of land, the profit from planting rapeseed for one year is much lower than a year's wage working in the big cities. Secondly, the level of mechanization in rapeseed cultivation in China is very low: there is a shortage of adapted cultivars with suitable traits for mechanized production, as well as a shortage of good quality, affordable equipment. Fortunately, the technology and equipment needed for mechanization of