The advancement of double-low rapeseed meal used as a protein feedstuff in pig and poultry diets

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Abstract

The article reviews the nutritional characteristics and the potential factors that negatively affect the extensive use of double-low rapeseed meals (DLRM) as a protein source in animal diets, and discusses the feasibility to improve the feeding values of DLRM-containing diets by dietary enzyme supplements and/or hull removal treatment by processing techniques. Overall, crude protein content of DLRM is comparable with soybean meal. Also, DLRM has a well balanced amino acid profile and, consequently, a diet with more balanced amino acid profile can be obtained by the combination use of DLRM with soybean meal. Similar even better performance was observed in pigs fed conventional level of DLRM diets (⩽ 6% and 10% of diet for the growing and finishing phase, respectively). However, the unrestricted use of DLRM in rapid growth animals was limited by low available energy resulting from the high content of fibres. Hull removal could reduce the content of insoluble fibres like lignin, and thus improve the digestible energy and crude protein levels, whereas the total non-starch polysaccharides remained same as that in not dehulled DLRM. Decreased weight gain was evidenced in pigs receiving diets incorporated with 10~15% of dehulled DLRM, and in broiler chickens receiving diets incorporated with 21% of dehulled DLRM. Enzyme supplementation could result in improved performance and increase the inclusion levels of DLRM to 10~15% in pigs and 20~23.5% in broilers. It would appear that enhanced nutritional values and, consequently, increased inclusion levels of DLRM in animal diets could be achieved by the combination use of enzyme supplements with hull removal of DLRM by processing techniques.

Key words: Double-low rapeseed meal, hull removal, enzyme supplementation

Introduction

Double-low rapeseed (referred to as a rapeseed cultivar that contains less than 2% erucic acid in its oil and less than 30 μmol/g of glucosinolates in its defatted meal), more commonly known as canola, is second only to soybean as the most important source of vegetable oil in the world. After oil extraction, the remaining part of the seed is known as canola meal (CM) or Doule-low rapeseed meal (DLRM). The high levels of protein and the good balance of essential amino acids make the meal especially valuable as a protein supplement in feed rations for livestock. Despite its benefits, the inclusion levels of CM in monogastric animals is still limited, which is mainly caused by the high levels of fibres (Bell, 1993). Hull removal of canola and the supplementation of enzyme in CM-containing diets are shown to be potential methods to improve the nutritive value of CM. The goal of this paper is to review the nutritional characteristics and the potential factors that negatively affect the extensive use of CM as a protein source in animal diets, and discuss the feasibility to improve the feeding values of CM-containing diets by dietary enzyme supplements and/or hull removal treatment by processing techniques.

The chemical components of CM and its use in animal feed

CM is lower in crude protein than soybean meal (NRC, 1998; Table 1). CM contains approximately 36 percent crude protein compared to 44 percent crude protein for soybean meal. Interestingly, Chinese DLRM has higher protein content than CM and is comparable with soybean meal. Both CM and Chinese DLRM have approximately twice content of calcium and phosphorus than soybean meal. However, the content of fibers such as NDF and ADF is higher in CM than in soybean meal, which was considered to be the major factor resulting in a low digestible energy of CM. Remarkably, Chinese DLRM has much higher fiber content than CM and soybean meal. Research conducted at Huazhong Agricultural University revealed that the much higher fibre content of Chinese DLRM compared to CM was caused by over-heat treatment (Peng, 2000). In particularly, the increase of cell wall protein content in the over-heat treated samples were responsible the large enhancement of dietary fibre. Subsequently, Chen et al. (2003, 2006) investigated the processing on the quality of Chinese DLRM with the focus on the NDF content. The research found that the increment of NDF always occurred in the stages of cooking/conditioning, pressing, dissolventing where heat treatment was adopted (Table 2). In these stages, considerable amount of protein turned to products of maillard reaction. Therefore, to control the quality of rapeseed meals and cakes, NDF content has been regarded as a valid indicator in the current rapeseed-processing conditions in China.

Maybe, just because the difference in nutritive profiles between CM and Chinese DLRM, varied inclusion levels of these two types of meals was proposed in monogastric animal feeds. Thacker (1990) concluded that CM might replace 50% of the protein source in grower and finisher diets without any possible detrimental effect on production. Brand et al. (2001) reported that there was no effect on production performance of pigs receiving diets with solvent-extracted CM up to 24%, and no effect with expeller-extracted CM up to 29.2%. These inclusion rates are much higher than inclusion levels of 12% in diets of growing pigs and 18% in diets of finishing pigs proposed by the Canola Council of Canada (1989). It may be concluded that the meal processed from recently released canola cultivars, which contain lower levels of anti-nutritional factors (Mailer & Colton 1995), are more acceptable for growing finishing pigs and may be included at higher levels. In contrast, the research conducted in China found that the appropriate addition levels of Chinese DLRM were ≤6% in the growing phase and ≤10% in the finishing phase, respectively (Peng et al., 1995). The digestibility and metabolism trial conducted by Peng (2000) provide further evidence for the quality difference between CM and Chinese DLRM. TMEn for three Chinese DLRM samples in SCWL cockerels was 6088-6095 KJ/kg, significantly lower than 8327 KJ/kg for commercial CM. Apparent total-tract digestibility and true ileal digestibility of crude protein in pigs were 67.05-70.12% and 53.44-63.65%, respectively, for three Chinese DLRM samples, substantially lower than 73.61% and 68.95%, respectively, for commercial CM. Notably, a better performance could be obtained when DLRM containing diet for pigs were formulated based on the digestible lysine levels (Peng et al., 1999). This could be explained by the low availability of lysine in Chinese DLRM, whereas sulfur amino acids are particularly higher in canola than in soybean meal and, consequently, a diet with more balanced amino acid profile could be obtained when CM and soybean meal are in combination use.

Table 1. Nutrient Analysis of CM Compared to Soybean Meal (%)

Nutrient	Soybean Meal[1]	CM[1]	Chinese DLRM[2]
CP	43.8	35.6	42.5
NDF	13.3	21.2	45.0
ADF	9.4	17.2	30.9
Calcium	0.32	0.63	0.75
Phosphorus	0.65	1.01	1.03

[1]Data adapted from "Nutrient Requirements of Swine", 10th Ed. (1998).
[2]Data adapted from "Evaluation and Improvement of Quality of Chinese Double Low Rapeseed Meal", Peng (2000).

Table 2. NDF content and fraction of protein contained in NDF in samples from different processing stage (% dry matter, fat free)[1]

Processing stage	Sample type	Low-temperature-press		Prepress-extraction		Hydraulic-press	
		Mean	Range	Mean	Range	Mean	Range
Raw material	Seed	32.8 (6.3)	30.5~34.2 (5.7~7.3)	34.0 (6.4)	32.8~35.6 (5.5~7.8)	34.5 (5.8)	33.0~35.4 (5.1~7.3)
Flaking	Precooked seed	-	-	32.1 (6.2)	30.0~33.1 (5.3~8.1)	-	-
Cooking/conditioning	Cooked seed	-	-	33.1 (12.8)	31.0~34.5 (9.7~15.8)	46.3 (31.7)	39.4~54.2 (27.2~34.5)
Expelling	Prepressing cake	30.5 (6.0)	28.7~31.4 (5.4~6.7)	31.3 (12.7)	29.1~33.6 (8.7~15.4)	55.8 (45.1)	48.9~59.8 (37.6~47.4)
Dissolventing	Meal	-	-	37.8 (19.1)	33.8~45.6 (15.8~24.8)	-	-

[1]Data adapted from "Evaluation of quality characters, quality influencing factors and processing technics of Chinese Rapeseed cake and meal", Cheng (2003).

The routinely use of CM in poultry diets can be ascribed to two aspects: first, the amino acid pattern resembles that of the ideal protein proposed for poultry (Baker and Chung, 1992), and second, CM has high contents of arginine and sulfur amino acid, which is particularly deficiency in conventional corn-soya diet. Liu et al. (2004) indicated that the appropriate inclusion levels of Chinese DLRM in broiler chickens, expressed as the percentage of DLRM protein to total dietary protein derived from soybean meal and Chinese DLRM, were 37.5%-50% for 0-21 days of age and 50%-62.5% for 21-42 days of age. In laying hen diet, inclusion of 15-20% of diet was considered to be allowable considering that these inclusion levels could not result in negative effect on egg production or feed efficiency (Trappett, 2001; Roth-Maler,1999). However, the inclusion level of CM in brown egg-hen was recommended to be 3-5% of diet, due to the presence of considerable amount of choline and sinapine, which was the precursor of trimethylamine. It has been well established that feedstuffs rich in trimethylamine could result in fishy smell eggs (Butler et., 1982).

Effect of hull removal on the nutritional values of CM

Canola hull constitutes about 16%-19% of the seed and about 25%-30% of the meal (Bell, 1993), the hull fraction has a very low digestibility. Therefore, hull removal was considered to be one option available to improve the digestibility of energy in CM. Zuprizal et al.(1992) reported that hull removal could reduce crude fibre from 13.3% of meal to 6.6% (DM basis) and increase protein digestibility from 70.5 to 76.7% in 6 week broilers, and average amino acid digestibilities from 80.8 to 85.2% in ISA Brown roosters (Zuprizal et al. 1991). It was shown in pig trials that partial dehulling increased the digestible energy (DE) content from 12.2 to 13.3 MJ kg DM^{-1}, respectively, and the level of crude protein (CP) from 40.6 to 43.8% in regular and partially dehulled CM samples, respectively (de Lange et al., 1998). However, hull removal did not influence apparent ileal CP or AA digestibilities, except for threonine which was slightly increased.

Kracht et al. (1999) compared the influence of graded rapeseed meal levels (7%, 14%, 21%) from hulled and dehulled rapeseed on growth performance and found that the in the average of the three levels the weight gain of broilers fed dehulled rapeseed meal diets rose about 53 g (=3.5%) compared with that fed hulled rapeseed meal diets although at a substitution level of 21% the growth decreased. In contrast, Campbell et al. (1995) using dehulled CM to replace hulled CM incorporated into broilers' or laying hens' diets didn't result in increased growth rate or improved laying performance. However, broilers responded to lysine supplementation in the dehulled meal treatments which corroborates the amino acid analysis data for the respective. Remarkably, hens fed dehulled CMs tended to show a reduced egg production rate. This effect may have been due to a relatively high glucosinolate content in the dehulled meal samples (Campbell et al., 1995).

In contrast to poultry, study reports about the growth response of pigs to dehulled CM inclusion were relatively scarce. Bell (1993) compared the effect of dehulled CM to replace for hulled CM in growing and finishing pig diets and observed no improvement in feed efficiency. Similarly, Patience and Gillis (1996) reported that pigs receiving diets containing 15% (growing phase, 24 - 56 kg) or 10% (finishing phase, 71 - 100 kg) dehulled CM had a similar growth rate and feed efficiency compared to those receiving hulled CM diet. The modest response may be explained by the following aspects: the reduction in dietary fibre following hull removal was mainly reflected by a decrease in insoluble fibre, lignin in particular, but total non-starch polysaccharides (NSP) still accounts for some 17.8-21.4%, as near as making no difference from that present in hulled CM (16-22%) (Campbell et al., 1995); at the same time, hull removal may cause an increased level of soluble fibre and worse viscosity problem for that a majority of soluble fibre is present in cotyledon of CM (Peng, 2001). In conclusion, the moderate levels at which CM is used in pig diets, combined with the modest improvement in pig performance, make the economics of dehulling questionable.

Potential benefits of enzyme supplementation in CM diet

It was reported that the levels of starch, free sugars and soluble NSP in CM is about 150 g/kg, which should contribute to considerable digestible energy (Slominski and Campbell, 1990). Unfortunately, it appears that these carbohydrates are encapsulated by cell walls and that their actual contribution to digestible energy is modest (Bell, 1993). Enzyme supplementation is thus considered as a potential means of improving the nutrient digestibility and ME of CM. More than 15 years ago, a number of studies had been conducted to investigate the response of broilers to enzyme supplementation in CM diet. Most feeding trials have indicated that enzyme supplementation of CM with carbohydrase and protease preparations does not produce a statistically significant improvement in broiler chick performance (Simbaya et al. 1996; Alloui et al. 1994; Sosulski et al., 1990), although results to the contrary exist (Ward et al. 1991; Bedford and Morgan, 1995). These results demonstrated the difficulty to find appropriate enzymes to match the specific substrate present in CM, for that CM as a protein source has only a small amount of inclusion in animal diet. In the latest decade, Canadian University of Manitoba undertook a series of studies to select enzymes effective in improving canola by in vitro and in vivo methods. Slominski and his co-workers recently demonstrated both an improved broiler performance and an increased nutrient utilization as a result of enhanced depolymerization of cell wall polysaccharides by multicarbohydrase supplementation in CM diets (Meng and Slominski, 2005). In addition, phytase supplementation of CM-based rations (500 g kg^{-1}) was shown to improve phosphorus and calcium retention in broilers aged 7-14 days (Ward *et al.* 1991). The best response of chicks to phytase supplementation was found when phytase was fed in combination with protease (Guenter et al., 1998).

In China, Peng and her co-workers have been taking up researches on canola feeding value and its improvement in the last 15 years. The appropriate inclusion levels of Chinese DLRM in pig diets were determined to be 6-10% (Peng et al., 1995; 1999), substantially lower than the proposed levels of CM (12-18%) by Canola Council of Canada (1989). A comprehensive evaluation of Chinese DLRM nutrient profiles revealed that it was the much higher fibre content that makes Chinese DLRM superior to CM regarding their feeding values (Peng, 2000). Peng (2000) confirmed that Chinese DLRM has similar fibre component compared to CM. The fibre components of CM include lignin with associated polyphenols (8%), cellulose (4-6%) and non-cellulosic polysaccharides (13-16%) which consists of arabinose (33%), xylose (13%), mannose (3%), rhamnose (2%), fucose (2%), uronic acids (30%), galactose (13%) and glucose (5%) (Slominski and Campbell, 1990). The high content of arabinose and xylose in DLRM indicated the presence of considerable amount of arabinoxylans (Slominski and Campbell, 1990). In this regard, xylan-related substrates may play a major role in negatively affecting the nutritional values of DLRM (Fang et al., 2006). Furthermore, previous evidence has demonstrated the effectiveness of xylanase supplementation in improving the growth performance of broilers (Bedford and Morgan, 1995) fed DLRM inclusion diets. Therefore, Peng and her co-workers conducted a series of researches to select xylanase-based enzymes targeting Chinese DLRM by in vivo and in vitro methods. The two Master's Degree thesis in Huazhong Agricultural University provide a comprehensive demonstration about the selection of enzymes and the efficacy of selected enzymes in improving Chinese DLRM (Tang, 2003; Fang, 2005). Recent trials show that the inclusion levels of Chinese DLRM can be enhanced from the conventional 6-10% in pigs and 10-15% in broilers to 10-15% in pigs (Tang, 2006) and 20~23.5％ in broilers (Fang, 2005), respectively, by selected enzyme supplementation.

Summary

The low digestible energy is the major restriction to the expanded use of CM in rapidly growing animals. High content of fibre, cell wall protein in particular, was the main difference in nutrient profiles between CM and Chinese DLRM. Hull removal can be effective in enhancing digestible energy and crude protein contents, but should be cautioned taking into account its economics. Alternatively, enzyme supplementation is considered to have substantial potential to improve CM or Chinese DLRM.

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