

total crude protein and oil are greater between grades. Conkerton *et al.* (1978) found that certain peanut genotypes have more methionine than other similar genotypes. These reports indicate that peanut geneticists may be able to produce cultivars with high levels of lysine and methionine and a more favorable balance of amino acids for swine. Although raw peanuts have been shown to contain a trypsin inhibitor, Balogum and Koch (1979) indicated that heating at 120°C for 1 hr was of no benefit to the pig. Twenty percent raw or cooked peanuts replaced an equal quantity of maize and soybean meal in the diet without modifying pig performance. If higher dietary levels of peanuts had been used, thus increasing the total trypsin inhibitor content of the diet, proper heating might have proven beneficial.

Although soft fat has been observed commonly when full-fat peanuts constitute a significant portion of growing-finishing swine diets, local quality requirements and relative cost of peanuts, cereal grains, soybean meal, and other feed ingredients will determine the use of full-fat peanuts in swine diets.

RAPSEED MEAL (CANOLA MEAL)

Rapeseed meal is a by-product of the production of vegetable oil from rapeseed (also called canola rape, colza, or raps). In the Cruciferae or mustard family, many species of the genus *Brassica* are known; however, two of these species *B. napus* L. and *B. campestris* L. are most commonly grown. Because of its adaptation to the temperate and subtropical zones, rapeseed is produced as a winter or cool season crop in Europe, Asia, and the Western Hemisphere. Its production in many of these areas is of great importance since rapeseed and sunflower are the only edible oil crops that can be produced effectively in the colder areas of these regions. Detailed information on rapeseed meal for livestock has been reviewed elsewhere (Downey 1965; Bell and Belzile 1965; Bowland 1965; Wetter 1965; Josefsson 1972; Bowland 1975; Fenwick and Curtis 1980; Clandinin 1981).

Eighty percent of the world's annual production of some 10.6 million metric tons (FAO 1980) is produced in Asia and Europe. Within the Western Hemisphere, it is an important crop only in Canada and Chile.

Rapeseed contain about 40–50% oil by weight, which may be removed by expeller, solvent extraction, or a combination of both techniques. The oil has a history of industrial use as a special lubricant, but until recently it contained a high level of glycerides derived from erucic acid. This is nutritionally undesirable, but plant breeders have been successful in developing low glucosinolate rapeseed cultivars. Seed, oil, and meal derived from these cultivars have come to be known as canola seed, canola oil, and canola meal to distinguish them from high glucosinolate cultivars grown extensively in other parts of the world (Clandinin 1981).

Meals produced after removal of the oil may contain 32–44% crude protein with the majority containing 35–37% protein. Average analysis values of 40.5, 1.1, and 0.3% for crude protein, fat, and fiber can be expected from a typical solvent-extracted meal. The amino acid pattern (Table 15.17) of the rapeseed protein is similar to that of other vegetable protein meals, with rapeseed meal containing more methionine and less lysine than soybean meal. However, the

Ref. Bond, W. C. and J. H. Warner. 1984. Swine Production and Nutrition. The AVI Publishing Company, Inc., Westport, Connecticut, USA. 731P.

TABLE 15.17. Amino Acid Composition of 'Tower' and 'Candle' Rapeseed Meal and Soybean Meal

Amino acid	Soybean meal, %	'Tower' meal, %	'Candle' meal, %
Aspartic acid	4.44	2.65	2.91
Threonine	1.78	1.51	1.77
Serine	2.39	1.60	1.81
Glutamic acid	6.20	5.11	4.99
Proline	2.52	2.13	2.31
Glycine	1.78	1.67	1.76
Alanine	1.82	1.57	1.65
Cystine	0.74	0.51	0.64
Valine	1.74	1.53	1.62
Methionine	0.83	0.67	0.94
Methionine + cystine	1.57	1.18	1.58
Isoleucine	1.74	1.25	1.32
Leucine	3.15	2.39	2.54
Tyrosine	1.64	1.03	1.16
Phenylalanine	2.27	1.45	1.55
Lysine	2.74	1.90	2.13
Histidine	1.17	1.00	0.99
Tryptophan	0.60	0.48	0.50
Arginine	3.36	2.16	2.22
Crude protein	49.7	43.2	41.4

Source: Bell et al. 1981.

processing method can greatly influence the availability of these amino acids and thus the nutritive value of the meal. The high heat of processing by the expeller method probably is associated with poor amino acid availability; however, a combination expeller-solvent extraction, which is conducted at a lower temperature, produces a higher quality meal.

Although the amino acid composition and availability of quality rapeseed meal would indicate that it is an excellent protein supplement for swine, it has been recognized for some years that there are limits to the amount of the older varieties which can be added to swine diets without serious effects on growth and reproduction.

For young weanling or pre-weanling pigs from 3 weeks of age, levels of rapeseed meal of not more than 4-5% of the total diet should be fed. Higher levels of the meal may reduce palatability and consumption and therefore have adverse effects on the growth rate of the pig. When growth depression occurs on higher levels of rapeseed meal, it does not affect feed utilization and cannot be corrected by lysine supplementation, but usually is associated with reduced feed intake.

Similar, though less severe, adverse effects of high levels of rapeseed meal have been observed with growing-finishing pigs (Devilat 1965). Replacement of 25% of the protein supplement of the diet with rapeseed meal does not significantly affect feed intake, rate of gain, or feed efficiency, but when higher levels are utilized both rate of gain and feed efficiency are depressed.

As the result of many investigations which have been carried out on problems

associated with the consumption of rapeseed meal, it is clear that the detrimental effects of high levels of conventional rapeseed meal are due to the presence of up to 8% glucosinolates in the meal depending on variety. Glucosinolate breakdown products, isothiocyanates and oxalaldimethione, have been shown to exert a goitrogenic effect on nonruminant animals, causing histological changes of the thyroid. Lower levels of these toxic substances consumed by pigs in diets containing rapeseed meal cause limited thyroid hypertrophy; higher levels that are commonly supplied by 10–12% meal cause a marked hypertrophy and an increase in cellular components.

In recent years, perhaps the greatest factor in the increased production and use of rapeseed meal for animal feed has been the development of low (or zero) glucosinolate cultivars (Clandinin and Robblee 1978). Two cultivars commonly grown today, 'Tower' (in Canada) and 'Erglu' (in Europe), and other recently developed varieties, are so-called *double zero* varieties, possessing low levels of both erucic acid and glucosinolates. To distinguish rapeseed meal derived from low erucic acid, low-glucosinolate cultivars of *B. campestris* or *B. napus* from conventional rapeseed meal, the term *canola meal* has been created.

One of the main factors that tends to limit the feeding value of rapeseed meal for pigs is its relatively low digestible energy (DE) or metabolizable energy (ME) values. Rapeseed meal has lower DE and ME values than soybean meal and the high fiber content of rapeseed meal has been suggested as an important reason for the lower energy values. Plant breeders have successfully developed varieties with thinner, less fibrous seed coats. The introduction of yellow seed varieties, such as 'Candle,' achieve both a 4% reduction of fiber content and a zero level of erucic acid and glucosinolates; such seeds have been termed *triple zero* varieties. To distinguish these new varieties in subsequent discussions in this chapter, the term *canola meal* will be used for double zero rapeseed meal and low-fiber canola meal for double zero varieties with low fiber content ('Candle').

All swine experiments that have compared canola rapeseed meal ('Tower') with regular rapeseed meal have demonstrated the superiority of the double zero meal as a protein source for pigs (McCuaing and Bell 1976; Moody *et al.* 1976; Castell 1977; McKinnon and Bowland 1977; Bowland 1975A,B,C). Canola meals are finding increased acceptance as protein sources in swine diets and are being used as a replacement for soybean meal. Some studies have shown that 'Tower' canola meal may totally (Bowland 1975) or partially (Omole and Bowland 1974; Grandhi *et al.* 1976A,B, 1977; McKinnon and Bowland 1977; Narendran *et al.* 1981) replace soybean meal in starting, growing, and finishing pig diets without adverse effects on performance, while other studies have shown that complete (McKinnon and Bowland 1977; Aherne and Lewis 1978; Singam and Lawrence 1979) or partial substitution (Kennelly *et al.* 1978) of soybean meal with canola meal ('Tower' and 'Erglu') adversely affects pig performance.

Although most studies (Bowland 1975A,B; McKinnon and Bowland 1977; Aherne and Lewis 1978) have not shown any adverse effects of partial or complete replacement of soybean meal by canola meal during the finishing period, complete or partial replacement of soybean meal with canola meal during the starting or growing period has resulted in depressed pig performance (Castell 1977; Moody *et al.* 1976; Grandhi *et al.* 1976A,B; McKinnon and Bowland 1977; Aherne and Lewis 1978; Singam and Lawrence 1979). Castell (1977) added 7.5%

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24

Rapeseed Meal (Canola Meal)

461

'Tower' canola meal to the diets of pigs in the starter period, and 12.5% during the growing period, resulting in a significant decrease in growth rate and feed conversion efficiency. Moody *et al.* (1976) and Grandhi *et al.* (1976A,B) also observed a reduction in performance of growing pigs fed on diets in which some or all of the soybean meal in the diet was replaced by 'Tower' canola meal, but the differences were not significant. In studies by McKinnon and Bowland (1977), complete substitution of soybean meal with 'Tower' canola meal resulted in reduced feed intake during the starting phase as well as significantly lower daily gain and feed conversion efficiency during the growing phase. Aherne and Lewis (1978) not only showed a reduced pig performance during the growing phase when 'Tower' canola meal completely replaced soybean meal, but also demonstrated reduced feed conversion efficiency when only 50% of the soybean meal was replaced by canola meal (Table 15.18). Although Singam and Lawrence (1979) were unable to show any difference between 'Tower' and 'Erglu' canola meal, both were shown to be inferior to soybean meal when used as the only supplemental protein source to barley-based diets.

Although studies of the amino acid levels and availability (Cho and Bagley 1972) of rapeseed meal suggest that lysine is potentially first limiting, the addition of lysine to canola meal-supplemented diets has been shown to have no influence on feed intake, daily gain, or feed efficiency. Moody *et al.* (1976) added 0.125 or 0.250% lysine to diets based on maize and canola meal for young pigs and

TABLE 15.18. Performance of Growing and Finishing Pigs Fed Diets Containing Soybean Meal (SBM) or Two Levels of 'Tower' Canola Meal (CM)

Source/Criteria	Diets		
	SBM	SMB/CM	CM
McKinnon and Bowland 1977			
Growing period (20-43 kg)			
Av daily feed, kg	1.67	1.68	1.63
Av daily gain, kg	0.64 ^a	0.63 ^a	0.55 ^b
Feed/gain ratio	2.63 ^c	2.67 ^c	2.96 ^b
Finishing period (43-85 kg)			
Av daily feed, kg	2.36	2.25	2.24
Av daily gain, kg	0.62	0.58	0.58
Feed/gain ratio	3.80	3.87	3.87
Aherne and Lewis 1978			
Growing period (20-60 kg)			
Av daily feed, kg	2.05	2.15	2.19
Av daily gain, kg	0.73 ^a	0.71 ^{a,b}	0.67 ^b
Feed/gain ratio	2.80	3.05 ^b	3.27 ^b
Finishing period (60-100 kg)			
Av daily feed, kg	3.33	3.28	3.26
Av daily gain, kg	0.79	0.76	0.75
Feed/gain ratio	4.17	4.32	4.33

^{a,b,c}Numbers in same line with different superscripts are significantly different.

observed no significant improvement in pig performance. Similar studies with growing and finishing pigs reported by Aherne and Lewis (1978) also failed to show any effect of the addition of 0.065% lysine HCl (0.05% lysine) to a barley-wheat based diet supplemented with canola meal. Experimental evidence available to date would suggest that a response is more likely to be obtained from supplemental methionine than from lysine (Bell 1975).

It is possible that the reduced performance observed when canola meal replaces soybean meal may be a reflection of its glucosinolate level. Although pigs fed low-glucosinolate cultivars (canola meal) have shown less thyroid dysfunction than those fed regular cultivars with high-glucosinolate as demonstrated by tetraiodothyronine ('T-4') levels in young pigs (Bowland 1975A), these and other studies (Bowland 1975A; Grandhi *et al.* 1976; Aherne and Lewis 1978; Ochetim *et al.* 1980A,B) have shown histological changes of the thyroid and lowered 'T-3' and 'T-4' levels when pigs were fed canola meal as a complete or partial replacement for soybean meal. These results suggest that although impaired thyroid function is less severe than with conventional, high-glucosinolate rapeseed meal, levels of glucosinolate (approximately 0.98 mg/g) in 'Tower' canola meal were sufficiently high to cause some impairment in thyroid hormone synthesis and thus in pig performance.

Canola meal ('Tower') contains a substantially higher crude fiber level than soybean meal (13 vs. 6%) and this has been suggested as contributing to the lower performance observed when canola meal is fed as the sole protein supplement in diets of young pigs (Castell 1977; Aherne *et al.* 1977A,B). The limitations imposed by the high fiber levels of rapeseed meal led to the development by plant breeders of a yellow-coated cultivar ('Candle') that is low in glucosinolate and also contains about 4% less fiber. Although Bell *et al.* (1981) reported a DE value of 3370 kcal/kg that is slightly greater than those obtained by May and Bell (1971) and Saben *et al.* (1971) of 3280 and 3210 kcal/kg, respectively, for conventional rapeseed meal. Muztar *et al.* (1978) have shown with chickens that 'Tower' and 'Candle' rapeseed meals do not differ significantly in apparent or true ME. Feeding trials with pigs have also failed to demonstrate any improvement in pig performance when canola meals prepared from 'Candle' and 'Tower' varieties are compared (Bell *et al.* 1981; Kennelly *et al.* 1978).

In studies to measure the effect of steam pelleting of the diet on the performance of growing-finishing pigs fed 'Tower' and 'Candle' rapeseed meal, or soybean meal, Narendran *et al.* (1979) reported that the performance of pigs fed soybean meal was superior to that of pigs fed either 15% 'Tower' or 15% 'Candle' rapeseed meal. Pigs fed 'Tower' rapeseed meal had a lower average daily gain and back fat thickness and pigs fed Candle rapeseed meal had a lower average daily gain and feed intake and higher feed-to-gain ratio compared to pigs fed soybean meal. Steam pelleting of the maize-soybean meal and maize-soybean meal-rapeseed meal diets improved average daily gain, feed intake, and feed-to-gain ratio of the pigs, with the effects being greatest for the rapeseed meal diets. A similar improvement due to steam pelleting was also reported by Grandhi *et al.* (1979).

Several Canadian and Chilean experiments with gilts and sows fed high glucosinolate (10-11 mg/g) rapeseed meal have demonstrated that conception and litter size may be reduced when rapeseed meal constitutes more than 6-8% of

24

Rapeseed Meal (Canola Meal)

463

the diet of pregnant gilts and sows (Manns and Bowland 1963; Bell and Belzile 1965; Schuld and Bowland 1968; Esnaola and Ochoa 1970; Devilat and Skoknic 1971; Bowland and Hardin 1973). Gilts fed high levels (10–12%) of high glucosinolate rapeseed meal have been shown to require more estrous cycles for conception, to farrow lighter and smaller litters, and to wean fewer and lighter pigs than similar animals fed diets not containing this meal. These reports indicated that not only is maturation of the ovaries delayed but also lactation is depressed when high glucosinolate rapeseed meal supplies a major portion of the diet (Manns and Bowland 1963; Esnaola and Ochoa 1970). Devilat and Skoknic (1971) showed very severe effects on the number of pigs born alive and their survival when feeding 12% rapeseed meal and a marginal iodine level to gilts during gestation and lactation. A report by Saben and Bowland (1971) using rapeseed meal with a somewhat lower glucosinolate level (5 mg/g) suggested that a dietary rapeseed meal level of 8% may be satisfactory, but there was still a trend toward smaller litters for gilts and sows fed diets containing this level of rapeseed meal. Later studies (Bowland and Hardin 1973) indicated that up to 6% rapeseed meal with no more than 5 mg/g of glucosinolate can be fed throughout three reproductive cycles without any reduction in sow performance. As a consequence of the detrimental effects observed in some experiments with high glucosinolate rapeseed meal, it is recommended that not more than 3% conventional rapeseed meal should be used in diets of breeding swine during pregestation, gestation, and lactation.

Recently (Flipot and Dufour 1977; Lewis *et al.* 1978), studies with rapeseed meal from low glucosinolate cultivars of rapeseed have indicated that 'Tower' rapeseed meal (containing 0.98 mg/g glucosinolates) may be used as a partial or complete replacement for soybean meal in the diets of pregnant and lactating swine for at least two reproductive cycles with no apparent reduction in sow reproductive performance. Flipot and Dufour (1977) studied the reproductive traits of 64 gilts fed diets containing 0 or 10% canola meal ('Tower' rapeseed meal) when they were diagnosed as pregnant. No significant differences in litter size and weight at birth and at weaning were reported between gilts fed 0 to 10% canola meal. The first postpartum estrus observed after weaning at 28 days and the ovulation rates at first estrus were similar for the two groups. Thyroid weight was not affected by the treatment.

Lewis *et al.* (1978) fed low glucosinolate rapeseed meal (derived from the cultivar 'Tower') to replace 50 or 100% of the soybean meal in diets for 72 gilts from 20-kg liveweight through two gestation and lactation periods. The gilts were fed diets containing 17% protein from 20 to 60 kg and diets containing 15% protein from 60 kg until the end of the second lactation. All of the gilts successfully completed one reproductive cycle and 51 animals completed two. Treatments had no significant effect on litter size or weight at birth or weaning, sow weight changes in gestation or lactation, or gestation length in either the first or second parity.

Based on these studies, it appears that rapeseed meal produced from the new cultivars with low glucosinolate content (less than 1 mg/g), such as 'Tower,' 'Erglu,' and 'Candle,' can be used to supply all of the supplemental protein for gilts and sows during pregestation, gestation, and lactation without any detrimental effects on reproductive performance.