EFFECT OF FEEDING CANOLA QUALITY RAPeseed Mustard MEAL ON ANIMAL PRODUCTION - A REVIEW

Tilling Tayo, Narayan Dutta and K. Sharma

Centre for Advanced Faculty Training in Animal Nutrition
Indian Veterinary Research Institute, Izatnagar- 243 122, India

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ABSTRACT

Rapeseed mustard cake (RMC) can be readily used as a protein supplement in ruminants’ diet due to its availability and being cheaper than common oil cakes. The use of RMC as protein supplement to ruminant diet is constrained due to its higher level of glucosinolates that have variable adverse effect on palatability, intake, nutrient utilization, thyroid hormone status and overall performance of the animals. Though, the glucosinolates present in RMC are biologically inactive; but they are hydrolyzed by endogenous enzyme, myrosinase (thioglucosidase, E.C 3.2.3.1) to yield active metabolites viz. thiocyanate, iso thiocyanate, oxazolidone-2-thiones and nitrile compounds, which may be toxic to the animals. Thiocyanate gets absorbed into blood and secreted into the milk which may have detrimental health hazards to consumer. Improved varieties of rapeseed mustard cultivar (canola quality) which is low in both erucic acid and glucosinolates can replace conventional cakes like soybean meal/groundnut cake as a protein source in the diet of ruminants without affecting growth and lactation performance.

Key words: Canola meal, Glucosinolates, Nutrient utilization, Growth, Thiocyanate, Milk.

The new improved varieties of rapeseed mustard cultivar which is low in both erucic acid (<2%) and glucosinolates (<30µmolg⁻¹) are commonly known as canola and meals obtained is known as canola meal to distinguish from the traditional rapeseed meal containing high glucosinolates (Sanchez and Claypool, 1983). Rapeseed/canola (Brassica napus L. and B. campestris L.) oil is among the three most important edible oils in world after soybean and palm, and has the annual growth rate of the 10 major edible oils (Downey, 1990). World production of canola meal in 2007-08 was 27.59 million metric tons, India rank 4th (11%) after the European Union with (38%), China (24%), and Canada (18%) in canola production in world (CRB, 2008). The canola meal is gradually replacing the traditional costlier meals like soybean meal or groundnut cake without affecting the health and production of ruminants (Ravichandiran et al., 2008).

Chemical Composition: The chemical composition of canola meal (CM) is affected by environmental factor during the growing season (Bell, 1993) and size of the seed (Jensen et al., 1995b). Nutritional value of canola meal depends mainly on the glucosinolates level, fiber, oil and protein contents. The amount and kind of hulls present in CM also have significant effects on the nutrient compositions of CM (Bell, 1993). Canola contains 10.5 to 17% hull, depending on the size of the seed (Jensen et al., 1995b), with smaller seeds having a higher proportion. In addition, canola seed is much more difficult to dehull than soybean seed, so hull removal is not currently used to increase protein content. Canola seed also contains a higher proportion of oil (H“42%) than soybean (H“18%) and, therefore, its extraction further concentrates the hull and other fibre components. After solvent extraction of the oil, the hull comprises between 19.6 and 30.4% of the meal (Jensen et al., 1995b).

Canola is crushed to yield approximately 42% oil and 58% meal (Unger, 1990). The hull represent about 16% of the seed weight and about 30% of meal weight, hull is largely fibre and all of it

1ICAR, KAB-II, New Delhi.
remain in the meal after oil extraction, (Bell ,1993). It has been reported that canola meal contains 38.3% CP, 21.5% neutral detergent fiber (NDF), 17.5% acid detergent fiber (ADF), 12% CF, 3.6% ether extract (EE), 0.6% Ca, 1.0% P and 0.9% sulphur (S) (Bell and Keith, 1991). However, crude protein content of CM varies between 34 - 38% depending on the varieties of canola (Bell, 1993). Clandinin and Robblee (1983) reported higher protein content (38 - 39%) of rapeseed meal in *Brassica napus* than *Brassica campestris* (35%), whereas the commercial rapeseed meal (with unknown or mixed genetic origin) contains on an average 36 - 37% crude protein. Similarly, Durrani and Khalil (1990) reported crude protein value of 41.5 and 37.6% for *B. juncea* and for *B. napus*, respectively.

Canola meal has a good balance of amino acids. It is slightly lower in arginine, isoleucine, leucine, lysine, phenylalanine and tryptophan than soybean meal (SBM), but it is enriched in methionine, cystine, threonine and valine (NRC, 1994). However, the seed contains higher levels of amino acids, expressed as a proportion of the protein, than the meal (Lee et al., 1995), indicating that commercial processing is reducing amino acid content.

Canola meal has a higher concentration of fibre relative to soybean meal and it is attributed by the thick coat and size of the seed (Jensen et al., 1995b). According to Newkirk et al., (1997) ADF and NDF of *B. napus*, *B. rapa*, *B. juncea* and Soybean were found to be 20.6, 13.2, 12.8, 6.7 and 25.7, 19.6, 21.1, 9.1%, respectively, which contributes the most to its lower metabolizable energy. However, an another report indicated that CM contains between 15.0 and 28.6% insoluble fibre, and between 2.0 and 12.6% soluble fibre (Jensen et al., 1995b). The high fibre content is contributed by the hull and oil content of the seed. Canola seed is small (H"2mm diameter) in comparison to soybean seed (H"5 mm diameter) and therefore, has a higher surface area and as a result, proportionately more hulled, as a percentage of the seed (Jensen et al., 1995b).

**Nutrient Digestibility**

DM disappearance was substantially less for CM than SBM, despite similar CP disappearance. These results are consistent with the higher fiber content of CM and its lower overall digestibility. Laarveld *et al.*, (1981a) fed high glucosinolates (HG) rapeseed meal (Midas) and low glucosinolates (LG) rapeseed meal (Tower) to milch cows up to 18.9% of the diet by replacing SBM and found that apparent digestibility of crude protein was significantly (P<0.01) reduced, although fibre and fat digestibilities were not significantly different among diets. Protein and energy digestibilities were significantly (P<0.01) higher for ewes fed with 23.1% rapeseed meal diet than ewes fed with 37.8% rapeseed meal or 18.1% soybean meal diets (Devlin *et al.*, 1984). Zinn (1993) reported total tract digestibility of N 88.0, 91.3, and 94.8% in CM-40, CM-46 and SBM, respectively. Conversely, Khorasani *et al.*, (1994) reported total tract digestibility of protein from CM and SBM to be 73.1 vs. 83.5% following 24 hr rumen incubation. Soybean meal had the highest whole tract digestibility of DM, NDF and CP at all rumen retention times compared to CM. This was attributed to the large hull fraction (30%) associated with CM, that is poorly digested by all types of animals (Bell, 1984; Khorasani *et al.*, 1994).

**Anti-Nutritional Factor in Rapeseed-Mustard Cake**

Most Indian rapeseed-mustard varieties show high glucosinolates level in the range of 150-240µmol/g oil free meal (TERI, 2003), which is almost 10 times higher than the amount present in canola varieties. Glucosinolates are a group of sulphur containing compounds present in the vegetative tissue and seeds of *Brassica* family. Till date more than 90 different type of glucosinolates have been reported, however, they can be classified into three main classes (Sorenson, 1991):

1. Aliphatic/Alkenyl- glucosinolates derived from L-methionine.
2. Aromatic glucosinolates derived from L-phenylalanine and tyrosine.
3. Indolyl glucosinolates derived from L-tryptophan.

All major groups of glucosinolates present in prominent varieties of *Brassica* are...
Glucosinolates are a class of secondary plant compounds generally found in plants of the Brassica species (Kjaer and Skrydstrup, 1987). GLS are thioglucosides where a molecule of glucose is combined with a sulphur derivative and they can be divided up into alkenyl-GLS or indolyl-GLS on the basis of their side chain constituted by alkyl, alcenyl, hydroxy-alcenyl, aryl, indolyl, sulfinyl, and sulfonylurea or thio residues. Due to different side chains, over 100 plant GLS have been identified, out of which seven to ten are relevant for RSM. The three principal GLS in RSM are gluconapine, glucobrassicanapine and progoitrin. The dominant GLS of *B. napus* are progoitrin and gluconapine, whereas in *B. campestris* the dominant GLS are gluconapine and glucobrassicanapine (Henkel and Mosenthin, 1989). Quantitatively, *B. napus* varieties were found to contain double the amount of total GLS found in *B. campestris* (Appelquist and Ohlhon, 1972; Blair and Scougal, 1975).

Glucosinolates as such are considered to be non toxic. It is, rather, their hydrolytic products, which are associated with diverse antinutritional effects (Tapper and Terry, 1973; Benn, 1977). Hydrolysis of GLS occurs by the enzyme, myrosinase (thioglucosidase, E.C 3.2.3.1). Myrosinase activity has also been observed in gastrointestinal bacteria of several animal species and poultry (Marangos and Hill, 1974; Bougon et al., 1988). Upon hydrolysis of GLS by myrosinase at neutral pH and sufficient moisture, glucose and sulfate are split off and free (aglucone) goitrogenic compounds *i.e.* thiocyanates, isothiocyanates, oxazolidine-2-thiones (goitrin) and nitriles evolve (Tyagi and Singhal, 1993).

**Thiocyanates** These are degradation products from indolyl-3-methylglucosinolates or other indolyl glucosinolates found in plants of Brassica species. The presence of thiocyanate in milk from cows fed either high or low GLS-RMC focuses attention on indolyl glucosinolates, which occur at about the same concentration in both high and low glucosinolate-RMC. McGregor (1978) reported that Indolyl glucosinolates occur in significant quantities in RSM and yield thiocyanate on hydrolysis. Hence, nearly one-half of the glucosinolates present in the RSM are precursors of thiocyanate.

**Isothiocyanates** - Glucosinolates are hydrolyzed to isothiocyanates in the gut and produces powerful antithyroid effects (Emanuelson et al., 1993). Thiocyanate may also arise from isothiocyanates (Van Etten, 1969).

**Oxazolidine-2-thiones** - These are cyclic compounds closely related to isothiocyanates. A glucosinolate, progoitrin (2-hydroxy, 3-butenyl-glucosinolate) yields these compounds by enzymatic hydrolysis and also called as Goitrins due to their strong goitrogenic effects (Kjaer, 1960).

**Nitriles** - Under some hydrolysis conditions, such as low pH, nitriles are produced from GLS (Larsen, 1981), which may be more toxic than the usual products although the thyroid is not the primary organ affected (Van Etten, 1969). However, Fenwick et al., (1983) reported that the most important of these degraded products are the thiocyanate and oxazolidine-2-thiones because of their interactions with the thyroid gland, which in turn cause strong metabolic disturbances.

**Effect on Voluntary Feed Intake**

Rapeseed mustard oil cakes are utilized for livestock feeding but their use is restricted due to presence of glucosinolates. However, the effect of RMC supplementation in the ration of ruminants has been reported to be variable probably due to variations in the glucosinolates content of various cultivars and their dietary levels. It has been reported that rapeseed mustard on chewing produce pungent flavour and hot test due to glucosinolates metabolites that reduce its palatability (Hill, 1991). Glucosinolates cause pungent odour due to the formation of volatile and pungent compounds after...
Table 1: Erucic acid and glucosinolates present in different Brassica species.

<table>
<thead>
<tr>
<th>Varieties</th>
<th>Erucic acid in oil (%)</th>
<th>Glucosinolates (µmol/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Indian varieties</td>
<td>40-50</td>
<td>100-300</td>
</tr>
<tr>
<td>2. Canola varieties</td>
<td>&lt;2</td>
<td>30 (Downey, 1990b)</td>
</tr>
<tr>
<td>3. Developed Indian varieties</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. TERI- Uttam</td>
<td>[TERI (00) R 9903]</td>
<td>12-20 (ICAR, 2002)</td>
</tr>
<tr>
<td>b. TERI-Unnat</td>
<td>1-2</td>
<td>90-95 (TERI, 2003)</td>
</tr>
<tr>
<td>c. TERI- Uttam</td>
<td>0-2</td>
<td>10-25 (TERI, 2003)</td>
</tr>
</tbody>
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their hydrolysis (Papas et al., 1979) which may contribute to lowered feed intake when glucosinolate containing RMC is included in the ration of ruminants (Tyagi, 1991).

The calves given concentrates containing high glucosinolates rapeseed meal recorded lower intake relative to other calves given soybean meal, sunflower meal or linseed meal (Schingoethe et al., 1974; Olsson, 1978; Papas et al., 1979; Vincent et al., 1990a). The feed intake reported to be higher for low-glucosinolate containing rapeseed mustard concentrate (Schingoethe et al., 1974). Similarly, Sharma et al. (2007) and Ravichandran et al. (2008) reported 22% higher concentrate intake in low-glucosinolates-RMC as compared to high glucosinolates-RMC fed calves, this resulted 14% higher total DMI in low-glucosinolates-RMC fed calves. Feeding CM to lactating dairy cows up to 20-30% can be recommended with no risk of feed refusal (Song and Kennelly, 1989; Mawson et al., 1993).

Effects of Glucosinolates Metabolites on Biological System

The major ill effects of metabolites of GLS in ruminants are altered activity of the thyroid (Hill, 1991), liver necrosis and kidney lesions (Panter and James, 1990). The histological study of the thyroid of rats given milk of cows that were fed with rapeseed meal diets, has shown feature characteristics of goiter (Iwarsson, et al., 1973). Excessive dietary GLS levels can result in increased thiocyanate and reduced iodine levels in milk (Hill, 1991), increased liver weight in cattle (Gutzwiler, 1996), increased weight of the thyroid, internal organs (kidneys and liver) and/or reduced serum T$_3$ and T$_4$ concentrations in pigs (Etienne and Dourmad, 1994). In ruminants it is unlikely that substances other than glucosinolates also contribute to observed ill effects of rapeseed meal (Hill, 1991; Emanuelson, 1994).

Thyroid Activity

The antithyroidic properties of GLS metabolites occur by two mechanisms; firstly competition between thiocyanate and iodine which limits the iodine transfer to the thyroid gland and secondly in the case of goitrin, increased iodine transfer but inhibition of synthesis and release of T$_3$ and T$_4$ (Etienne and Dourmad, 1994).

Thiocyanate may decrease the trapping of iodides and the accumulation of iodine ions in the follicular cells of thyroid gland (Ruckebush et al., 1991) leads to inhibition of iodine uptake by the thyroid gland. Isothiocyanate is also converted to thiocyanate (Van Etten, 1969) and produces same effects. Goitrin causes hyperplasia and hypertrophy of thyroid gland by inhibiting the incorporation of iodine in to precursors of thyroxine and by interfering with thyroxine secretion (Kjaer, 1960). Goitrin has been shown to hinder the iodide oxidation, resulting in its decreased availability for organification (binding) to the aromatic ring of tyrosine, which serves as the basic structural nucleus for thyroxine formation (Bergner and Schmidt, 1972). However, its anti-thyroid effect is not corrected by adding iodine to the diet (Panter and James, 1990). Most of the other metabolites of glucosinolates have been also frequently reported to be implicated in the anti-thyroidal activity, differing only in the degree of severity and mode of action (Bell, 1984). Throckmorton et al. (1981) noted goiter and altered serum thyroid hormones in newborn lambs from ewes fed raw meadowfoam meal (LG variety). White et al. (1983) also noted thyroid changes in rabbits and goat kids fed milk from goats that were given raw meadowfoam meal.

Liver and kidney

The nitrile compound formed from the glucosinolates of meadowfoam and rapeseed meal are toxic, causing poor growth, bile duct hyperplasia, liver necrosis and megalocytosis of tubular epithelium in the kidney of animals (Paik et al., 1980). Rapeseed meal diet (Tower variety) fed to calves resulted in significant (P<0.05) increase of liver weight than
those fed on soybean meal diet (Papas et al., 1979). Growing pigs fed diets containing rapeseed meal of high (137 µmol/g) and low (5 µmol/g) glucosinolates varieties, liver weight increased significantly (P<0.05) for each µmol increase in glucosinolates content of the diet, confirming that the level of glucosinolates present in the diet is of much greater consequence to both performance and physiological well being of the growing pigs (Davis et al., 1990). Liver hypertrophy was noticed in pigs fed with diet containing expeller extracted 00-rapeseed meal (Bourdon and Aumaitre, 1990).

**Blood Parameters**

Iwarrson (1973) found no effect on blood parameters due to feeding of HG-RSM at 1, 4.2 and 8.05% of the ration in milch cows. However, Laarveld and Christensen (1976) fed rapeseed meal in complete feeds to milch cows and reported that haemoglobin and RBC count tended (P<0.01) to be lower for cows fed rapeseed meal than soybean meal. Tyagi and Singhal (1993) fed 3 diets viz, control diet with GNC, mustard cake (MC) and rapeseed cake (RSC) to calves and found that average T₃ and T₄ concentrations of plasma in GNC, MC and RSC fed groups were 0.39, 0.30 and 0.39 ng/ml and 51.44, 47.11 and 40.29 ng/ml, respectively. Average thiocyanate concentrations of plasma in corresponding groups were 0, 8.90 and 7.92 µg/ml, respectively. Higher plasma thiocyanate content in MC fed group than in RSC fed group may be attributed to the higher glucosinolates content in MC diet (1.72%) than in RSC diet (1.40%). Significantly lower (P<0.05) concentration of T₃ in MC fed group than in other groups may be attributed to the higher plasma thiocyanate content, which acts as iodine binder. Cow fed tower RSM showed a lower erythrocytes and higher leucocytes count than the control SBM (Papas et al., 1978). Similar trend was observed by Laarveld and Chistensen (1976), although the mechanisms involved are not understood. Thyrotoxicosis increase RBC and Hb, and decrease WBC. A deficiency of thyroxin shown to increase RBC but no effect on other blood parameter was reported. Spiegel et al. (1993) studied the serum metabolites and enzyme activities in swine fed diet containing 15 % RSM replaced for SBM with or without thyroxine added to the diet. Concentrations of glucose, protein, albumin and urea nitrogen did not differ significantly among groups, however, thiocyanate level was significantly (P<0.05) higher in animals fed RSM than control. Activities of SGOT, LDH were similar in all the experimental groups, while SGPT activity was lower in RSM fed groups relative to control. Similarly, Ravichandiran et al. (2008) reported that various blood parameters did not differ significantly between high and low GLS diets fed to calves except Hb, serum urea and T₄.

**Milk Yield and Composition**

Incorporating CM at 12% of concentrate of dairy cows grazing on pasture resulted in equivalent milk production than those supplemented with 0.9% urea in concentrate (about 27 kg d⁻¹) and the fat content was equal (39 g/kg) between two groups, however, CM supplementation increased milk protein and lactose in comparison to urea based diets and the cereal by product control (Tesfa et al., 1995). Song and Kennelly (1989) incorporated 10% CM; barley silage supplemented with urea or ammoniated barley silage into mixed rations for late lactation cows and observed no effect on milk yield and composition. Canola meal supplementation with barley or corn resulted in a higher milk fat percentage without an effect on the rest of the milk composition parameters (Khorasani et al., 1994).

Iodine content of milk reduced, while thiocyanate concentration was found to be increased in milk (10 to 35 µmolL⁻¹) when cows fed with rapeseed meal diets (Papas et al., 1979; Laarveld et al., 1981a). Similarly, thiocyanate excretion in the milk increased from 24-38µg/ml when HG-RMC was fed to crossbred cows (Palanivel, 2008). Pailan and Singhal (1998) reported that the iodine content of goat milk was significantly reduced by 2.54% (240-186µgL⁻¹) as a result of feeding RMC glucosinolates in the diet. The reduction of iodine content in milk may be attributed to the inhibition of iodine passage in the milk by thiocyanate ions, resulting from the hydrolysis of the glucosinolates (Papas et al., 1979).

The elimination of plant toxicants via milk by lactating animals is considered a minor route of excretion and beneficial to them. Many natural plant toxicants like pyrrolizidine and piperidine alkaloids, tremetol, thiocyanate, etc., are known to be present in milk from lactating animals grazing plants containing them (Panter and James, 1990). The consumption of the milk from the poisoned animals
can induce poisoning in humans or in suckling animals. Thiocyanate is a normal component of the milk in low amounts and participates in the lactoperoxidase system, an unspecific antimicrobial in the milk (Reiter, 1985). Thiocyanate was reported to be present in readily determined quantities in cow milk with the range of 3.2 to 4.6 ppm (Bjorck, et. al., 1979) and the concentration was consistently and significantly increased by feeding rapeseed meal diets. Iwarsson (1973) measured milk thiocyanate concentrations of 26 and 57 µmolL⁻¹ when cows were fed SBM and HG-RSM at 4.5% of the diet, respectively. The smallest increase (13 µmolL⁻¹) in milk thiocyanate (Vincent and Hill, 1988) was associated with the minimum daily intake of glucosinolates (3.9 mmol) and the largest increase (135.2 µmolL⁻¹) in milk thiocyanate (Laarveld et al., 1981a) corresponded to the maximum glucosinolates intake (314.2 mmol) in the diet. The milk thiocyanate levels in cows and buffaloes fed MOC diets for 21 days were 8.21 and 8.94 ppm, respectively. The corresponding values for GNC-fed cows and buffaloes were 3.82 and 5.09 ppm, respectively (Sharma and Pailan, 2004).

**Milk Quality**

The organoleptic tests of milk from milch cows fed with three diets consisting of control, diet with medium level of 00-RSM (1.2 kg DM/day) and with high level of 00-RSM (2.5 kg DM d⁻¹) did not reveal any significant score differences (Emanuelson, et al., 1993). When low-glucosinolates-RSM introduced as sole protein supplement in the concentrate mixture for milch cows, until the level of rapeseed glucosinolates breakdown products in milk are 0.1 µmolL⁻¹ oxazolidine-2-thiones, 10 µmolL⁻¹ nitriles and 100 µmolL⁻¹ thiocyanate, no evidence has been found to indicate the negative influence of glucosinolates breakdown products on the sensory properties of milk or threat for consumers (Panter and James, 1990).

**CONCLUSION**

Feeding of rapeseed mustard cake from traditional genotypes (high-glucosinolates-RMC) significantly reduces the palatability of concentrate, growth rate, milk yield in dairy animals and adversely affects thyroid hormones. The metabolites of glucosinolates have been also commonly reported to be concerned in the anti thyroidal activity. However, canola quality RMC had low glucosinolates, had no effect on thyroid. Canola quality RMC as a protein source can be used as complete replacement of conventional cakes like soybean meal/groundnut cake in the diet of growing and lactating dairy animals without affecting growth and lactation performance.

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