**Quality of rapeseed meal for animal nutrition and as a source of value-added products –**

**glucosinolates, protein and fibres\***

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**ABSTRACT**

Rapeseed (*B. napus* L. and *B. rapa* L.) has a great potential for delivering high quality products suited for human and animal nutrition. However, this very potential can be limited by the presence of specific low molecular weight compounds, especially glucosinolates and glucosinolate derived products. Rapeseed protein has a high biological value (BV) due to its nearly optimal amino acid composition; however, the digestibility of the meal is relatively low, since the proteins are more or less strongly bound to dietary fibres. Processing has, however, a marked influence on the quality of the seed meal: suboptimal and too high temperature processing can result in decreased protein availability and formation of unwanted colours, taste, odours and flavours. Optimised mild processing techniques can solve some of these problems and decrease the risk of rancidity and formation of glucosinolate degradation products, which allow maintaining the BV of the protein in the meal as defined by the amino acid composition. The BV will otherwise also reflect the effects of antinutrients on enzymes of xenobiotic metabolism, which is used to evaluate the effects and acceptable levels of glucosinolates and glucosinolate derived products in the diets. Based on comprehensive trials with concentration dependent effects of these compounds, it gives the basis for the preliminary recommendations, that rapeseed can be included in the animal feed to an extent that ensures total glucosinolate level to be below 1-1.5 mmol per kg of diet. This level can be considered safe for most monogastrics, although it can be subject to variations depending on structural types of glucosinolates and degradation products. Ruminants can accept much higher levels in their feed when or if we neglect transfer of products to the animal products as meat and milk.

**KEYWORDS:** rapeseed, protein, processing, animal nutrition, glucosinolates

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**The potential of rapeseed for delivering high quality products**

Rapeseed (*B. napus* L. and *B. rapa* L.) has a great potential for delivering high quality products suited for human and animal nutrition due to the biochemical composition of the seed’s oil, protein and dietary fibre (DF) (1). Rapeseed protein has a high nutritive value compared to other vegetable proteins due to its high biological value (BV) based upon its nearly optimal amino acid composition – i.e. a well balanced content of lysine, threonine, tryptophan and sulphur containing amino acids (1) , which are the first limiting amino acids for monogastrics and humans when using especially cereal-based diets. Rapeseed meal, press cake or expeller have however, relatively low digestibility, due to the fact that its protein is more or less strongly bound or associated to membranes and DF (2,3) . DF and DF associated compounds are well-known for their health promoting effects. If isolated by suitable methods, rapeseed DFs (such as betaglycans), could thus be used as ingredients in food and non-food products (emulsifiers) and as probiotics (4) . DF in the seed meal can nevertheless reduce the BV of the animal diet, especially in the case of monogastrics (3) . Rapeseed also contains carotenoids, tocopherols, phytosterols, water soluble vitamins (B and C) and phenolics –flavonoids, anthocyanins, lignans, lignins, and characteristic for Brassica are the sinapoyl derivatives (as e.g. sinapine the seeds); if preserved by processing, all these components can act as antioxidants.

The potential of rapeseed for delivering high quality products is however limited by the presence of specific low molecular weight (LMW) compounds – especially glucosinolates, and glucosinolate derived products –, which can negatively affect the quality of the final products (5-9) . Some of these LMW compounds can, as a result of suboptimal seed quality, storage and processing, give unwanted odour, colour and taste of oil, protein and DF products, and even act as antinutrients with specific effects on BV, xenobiotic metabolising enzymes and internal organs (5-9) when the seed meal is used in animal diets. Selection of the appropriate cultivars, optimization of the seed storage conditions, and utilization of suitable processing techniques can assist in overcoming the problems caused by LMW compounds, and allow obtaining products of the highest possible quality (10,12) .

**Factors influencing the quality of rapeseed meal**

The initial quality of the seed is decisive for ensuring the quality of the final products obtained from rapeseed. Genetic factors (type of cultivar; (7,12) ), environmental conditions during crop growth, and storage conditions can have pronounced effects on the quality of the seed. Avoiding heat and insect damage as well as keeping moisture to a maximum of 7% can contribute to maintain seed quality during storage (13) .

The quality of the seed meal is especially influenced by the processing conditions. A certain level of heating during processing is needed for ensuring inactivation of enzymes, such as myrosinase, lipase and lipoxygenase, so as to avoid the formation of nutritionally unwanted compounds during oil extraction and use of the de-oiled meal. Heating also allows increasing oil yield, thus raising the economic return of the processing. Nevertheless, excessive heating can result in glucosinolate degradation, decreased available lysine (1), decreased protein solubility and reduced protein utilisation in monogastric diets (Table 1). This decrease in protein quality is partly due to the reaction of glucosinolate degradation products with lysine and cysteine residues in proteins as well as to effects on DF and their associated components.

**Table 1.** Effect of type and temperature of extraction on protein solubility, glucosinolate content and protein utilisation. Legend: extr.: hexane extraction; press: pressing; 4-HyGB: 4-Hydroxyglucobrassicin; TD: true protein digestibility; BV: biological value; NPU: net protein utilisation.

|  |  |  |  |
| --- | --- | --- | --- |
|   | **Protein solubility in KOH (%)** | **Glucosinolate content (umol/g)** | **Protein utilisation****(rat trials)** |
| **4-Hy GB** | **Total** | **TD%** | **BV%** | **NPU%** |
| **1. DK-extr.** | 74.4 | 1.7 | 10.0 | 90.6 | 85.6 | 77.6 |
| **2. DK-press (cold)** | 74.9 | 2.5 | 16.4 | 89.1 | 78.4 | 69.9 |
| **3. DK-press (heat)** | 32.5 | 0.1 | 4.5 | 80.7 | 72.6 | 58.6 |
| **4. G-extr. (heat)** | 49.7 | 0.3 | 7.2 | 87.3 | 79.8 | 69.7 |
| **5. G-press** | 68.3 | 1.3 | 15.4 | 86.3 | 81.0 | 70.2 |
| **6. P-extr (heat)** | 55.7 | 0.3 | 9.8 | 88.7 | 78.7 | 69.8 |
| **7.Ch.-extr (heat)** | 44.6 | 0.3 | 35.6 | 83.5 | 57.0 | 47.6 |

The presence of glucosinolate degradation products can also result in unwanted colour (7), odour and taste, as well as antinutritional and toxic effects when using the seed meal in animal diets. New processing techniques, such as “cold”-pressing, need also to be optimised including the heating, to ensure enzyme inactivation for decreased risk of rancidity and formation of glucosinolate degradation products, but at the same time using a processing gentle enough to avoid severe protein damage, which allow maintaining lysine availability and protein utilisation (Table 1). Analytical control of the raw material, processing steps and end products –oil and de-oiled seed meal – is necessary for guaranteeing the quality of the products obtained by processing.

**Rapeseed meal in animal diets - recommendations**

In general, feed is subject to a number of demands in order to be suitable for a given animal. Feed should be palatable and provide nutrients and energy in adequate content and availability. Adverse constituents should be minimized below acceptable dietary threshold levels and dietary energy, protein, fat and micronutrients should be optimized. An optimal diet thus contributes to animal health, increased performance – optimal daily milk yield per cow and daily weight gain per pig, with a low feed: gain ratio – and good product quality – measured in high sensory properties and concentration of essential nutrients in animal products (14) . Requirements to the feed are different according to the type and developmental stage of the animal. For example, pigs need particularly enough available lysine, whilst ruminants need enough protected protein in order to achieve a high level of rumen-bypass protein (14) As mentioned above, processing plays an important role in the final quality of the seed meal, especially the protein. Weak toasting results in preserved lysine in the meal, which is recommendable for pigs; however, rapeseed meal resulting from this treatment does not contain sufficient rumen-bypass protein, which makes it suboptimal for ruminants. Processing should thus be adapted to the final use of the meal (5-11, 14).

Monogastrics tend to accept low inclusion levels of rapeseed in their diets, due to the detrimental effects caused by glucosinolates and their degradation products (5-9, 14). This is especially the case of goitrin ((5S)-5-vinyloxazolidine-2-thione) – the degradation product of progoitrin ((2*R*)- 2-hydroxybut-3-enylglucosinolate) – and thiocyanate ions (SCN-) – formed upon the degradation of indol-3-ylmethylglucosinolates (15) . Goitrin inhibits the enzymes involved in thyroxine synthesis (T3 and T4 in the thyroid gland) and its effects are irreversible. The effects caused by SCN- are a result of the inhibition of the uptake of iodine into the thyroid gland, thus its effect can be partly counteracted by adding iodine to the diet (14-16) . Feed intake depression and effects on internal organs such as enlarged thyroids have been observed in rats, pigs and mink as a consequence of the presence of excessive glucosinolate concentration in the diet (5, 6, 9, 14) . Regardless of the species, young animals are more sensitive to glucosinolates than older animals. Ruminants are generally less susceptible to glucosinolates in their diets and thus accept higher levels of rapeseed feed than monogastrics (5,17) ; mink and fish diets need to have low levels of glucosinolates/glucosinolate derived products (9) .

In general, glucosinolate levels below 1-1.5 mmol per kg of diet can be considered safe for most monogastrics (5,8,9) , although this can be subject to variation depending on structural types of glucosinolates and degradation products (Table 2).

**Table 2.**Effects of different levels of inclusion of rapeseed feed in the diets.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|   | **Level 1**\*\* | **Level 2**# | **Level 3**´´ | **Level 4**¤ |
| **Diets**(µmol glucosinolates/g DM) | 0.5 | 2.5 | 12.5 | As level 2 but with active myrosinase added |
| **Feed** with 20% rapeseed meal (µmol/g rapeseed meal) | 2.5 | 12.5 | 62.5 |
| **Seed** before de-oiling (µmol/g seed, depend on oil and water content) | 1-2 | 6-8 | 30-40 |

\*\*generally safe; # minor nutritional problems (depending on glucosinolate type); ´´nutritional problems; ¤generally some nutritional problems.

The glucosinolate content of rapeseed based feed determines the maximum inclusion level of rapeseed meal in the diet: rapeseed based feed with low glucosinolate content could thus be included in the diet in higher amounts (Table 2). Data in Table 2 are based upon the assumption that glucosinolate degradation products (formed, e.g. during processing) are not present in appreciable amounts in the meal. However, this has to be documented by the appropriate analytical methods in order to discard negative effects of the meal. Non-enzymatic degradation of glucosinolates, mainly to nitriles, can occur in the stomach of monogastrics due to the acidic and reducing conditions and the presence of iron in the form of Fe2+ (18) . This should also be taken into account when determining the maximum levels of rapeseed meal acceptable in diets.

Research has some decades ago mainly been focused on the negative effects of glucosinolate degradation products on productivity, growth and development of animals and to a minor degree on animal health. However, some glucosinolate degradation products, e.g. isothiocyanates 5-substituted oxazolidine-2-thiones, nitriles and the thiocyanate ion have also been tested for LD50 following mainly subcutaneous injection in mice or rats. From such studies typical LD50 values are in the range 0.5-10 µmol pr kg animal (19) and considering the effects from 1 µmol per g diet DM (Table 2; ref (19) and refs. cited therein) fed to 90 g young White rats per day (0.1 µmol/kg rat), this gives reasons to believe in the recommendations mentioned above as safe limits. The structurally different types of glucosinolates give a great number of transformation products (20) with correspondingly expected differences in physico-chemical-biochemical properties. For some of them, it has been shown that they exert positive effects on human health, e.g. antioxidant and anticancer activity (21, 22) . Further research should thus be targeted to ascertaining whether glucosinolate degradation products can also have positive effects on animals.

**CONCLUSION**

The native proteins, lipids and DF in *B. napus* and *B. rapa* rapeseeds are of high nutritive value. Limitations met with respect to obtaining the high quality rapeseed products for feed, food and non-food applications depend on obtaining acceptable levels of glucosinolates and glucosinolate-derived compounds – types and concentrations – in the products. The key factors in this respect are the level of the compounds in the seed, the storage, and the processing methods or treatments. The acceptable levels of glucosinolates depend upon their structural types – the effect being concentration dependent – and the type of animal – age, physical development and stress conditions. In low concentrations, glucosinolates and derived products are beneficial; at higher concentrations they can act as antinutrients and finally, toxic compounds. If the glucosinolate levels are acceptable, then the next limiting factors for obtaining high quality rapeseed products are DF and DF-associated compounds, and, especially, the effects caused by processing on proteins, lipids, DF, phenolics, antioxidants and other essential nutrients.

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