CHAPTER 1

GENERAL INTRODUCTION:

THE USE OF GRAIN LEGUMES AS A PROTEIN SOURCE IN PIG NUTRITION

D. Jezierny, R. Mosenthin, E. Bauer

Institute of Animal Nutrition, University of Hohenheim, 70593 Stuttgart, Germany

Submitted to Animal Feed Science and Technology

1 General Introduction: The Use of Grain Legumes as a Protein Source in Pig Nutrition

1.1 Summary

Grain legumes are valuable sources of protein and energy for monogastric animals. Grain legumes, such as faba beans, peas and lupins, can partially or even totally replace traditional protein sources of animal origin such as meat and bone meal or fish meal. Moreover, they represent an alternative protein-rich feed ingredient for soybean meal (SBM) and other oilseed meals. However, the presence of secondary plant metabolites, also referred to as antinutritional factors, such as protease inhibitors, saponins, pyrimidine glycosides, lectins, tannins, and alkaloids, has restricted the use of grain legumes in pig feeding. Furthermore, a high proportion of α-galactosides present in some grain legumes may lead to excessive fermentation and diarrhoea, while high levels of non-starch-polysaccharides (NSP) may have a negative impact on energy utilisation. Among different processing methods designed to further improve the nutritive value through reductions in content of secondary plant metabolites, recent progress in plant breeding has contributed to the commercial release of cultivars with improved feeding value in association with lower contents of secondary plant metabolites. This review focuses on the evaluation of the nutritional value of currently available cultivars of faba beans, peas and lupins, and their use in pig diets. Special interest is directed to nutritional composition, energy and amino acid (AA) digestibility of faba beans, peas and lupins, but also to their contents of secondary plant metabolites, including the threshold levels to be accounted for in diet formulation for pigs. Furthermore, feed processing technologies developed to improve the nutritive value of grain legumes are introduced.

1.2 Introduction

In 2001, the use of meat and bone meal and its by-products in diets for livestock was banned by the European Commission (EC directive 999/2001) to assure consumer safety on animal products. Soybean meal (SBM) is the most commonly used protein supplement of plant origin in pig diets, and is generally known as protein source with a high and consistent product quality. As SBM is the major by-product of oil extraction from soybeans, costs and availability of SBM are strongly correlated with the price development of

agricultural commodities on the world market. Factors which may influence world market prices include variations in population and economic growth, changes in consumer's product preferences, but world market prices are also dependent on weather conditions (Gill, 1997; Trostle, 2008). Therefore, price and availability of SBM on global markets may change rapidly, thereby stimulating swine producer's interest to maximise the use of locally produced feed ingredients including grain legumes. Furthermore, organic farming does not accept the use of processed oilseed products, when subjected to solvent extraction processes (e.g. hexane), or the use of genetically modified feed ingredients (e.g. soybeans), and in addition, the supplementation with crystalline amino acids (AA) to balance pigs' diet according to their AA requirement is prohibited (IFOAM, 2005). Therefore, it is crucial to develop suitable alternatives to meet the animals' protein and AA requirement in organic production systems according to IFOAM standards (2005). However, in the European Union, over 20 million tons of protein feeds are annually used in compound feeds for livestock, but only six million tons of protein feeds are produced within the European Union (Blair, 2007).

The search for alternative protein sources has led to an increasing interest in the use of grain legumes, as they supply an important source of plant protein. Moreover, grain legumes are grown as a nitrogen-fixation crop in rotation systems (López-Bellido et al., 2005). When grown in rotation with other crops, the use of nitrogen fertiliser can be reduced (Peoples et al., 1995) and soil fertility may be improved, whilst incidence of weeds, diseases and pests may be lowered (Peoples et al., 1995; Mwanamwenge et al., 1998). However, the use of grain legumes in animal nutrition has been hampered due to partially high concentrations of secondary plant metabolites, also referred to as antinutritional factors (ANF), including condensed tannins, protease inhibitors, alkaloids, lectins, pyrimidine glycosides and saponins. Possible negative effects of these secondary plant metabolites include, for example, feed refusals (tannins, alkaloids), reduced nutrient digestibilities (tannins, protease inhibitors, lectins) or even toxic effects (alkaloids) (e.g. Lallès and Jansman, 1998; Huisman and Tolman, 2001). Furthermore, a high proportion of α-galactosides as a part of the carbohydrate fraction in some grain legumes (Mul and Perry, 1994) may cause antinutritional effects in pigs, such as excessive fermentation, flatulence and diarrhoea (Benno et al., 1987; Fishbein et al., 1988). Moreover, considerable amounts of non-starch-polysaccharides (NSP) are present in several grain legumes such as lupins (Bach Knudsen, 1997), These NSP may exert negative effects in growing pigs, including reduced digesta passage rate which, in turn, may result in a

lowered feed intake and decreased growth performance (Dunshea at al., 2001; Ferguson et al., 2003). Due to considerable progress in plant breeding, the level of secondary plant metabolites present in grain legumes has been notably decreased, resulting e.g. in the development of zero-tannin faba bean cultivars (Duc et al., 1999) and sweet lupins (Petterson, 1998). Furthermore, progress in plant breeding offers possibilities for growing grain legumes with higher protein content but also better protein quality (Monti and Grillo, 1983; Clarke and Wiseman, 2000). On the other hand, it has to be emphasised that growing and harvesting conditions may also affect these characteristics (Mossé and Baudet, 1983; Simon and Köhn, 2004). Finally, several processing methods are available to lower the amount of secondary plant metabolites and NSP in grain legumes, thereby improving their feeding value. Thus, there is a need to re-evaluate the nutritional characteristics of currently available cultivars from faba beans, peas and lupins to optimise their utilisation as a locally produced feed component of high nutritional value in diets for pigs.

1.3 GRAIN LEGUMES

The botanical family of grain legumes is known as fabaceae, also referred to as leguminosae. Grain legumes are cultivated primarily for their seeds which are harvested at maturity, and which are rich in protein and energy. The mature dry seeds of grain legumes are used either as animal feed ingredient or for human consumption (Singh et al., 2007). Generally, legumes are characterised by their ability to use atmospheric nitrogen as a nutrient due to the symbiosis with nitrogen-fixing bacteria from the *Rhizobium* species (Sprent and Thomas, 1984; Zahran, 1999). Therefore, unlike other cultivated plants, legume crops need less nitrogen fertiliser for optimal growth, and the use of legumes in crop rotation systems reduces the need of nitrogen fertiliser in subsequent crops (Rochester et al., 1998). Nitrogen benefits in legume-cereal rotation systems have been attributed not only to the transfer of biologically fixed nitrogen (Chalk, 1998; Evans et al., 2001), but also to lower immobilisation of nitrate in the soil during the decomposition of legumes compared to cereal residues (Green and Blackmer, 1995), also termed as nitrogen-sparing effect. Thus, nitrogen benefits may result from a combination of legume nitrogen-sparing effects and the bacterial nitrogen fixation (e.g. Chalk et al., 1993; Herridge et al., 1995). In addition, crop rotation and intercropping with legumes may provide successful strategies for weed suppression (Liebman and Dyck, 1993; Bulson et al., 1997). Weed growth and development may be disrupted due to varying cultivation

conditions prevailing for the different crops used (e.g. fertiliser requirements, planting or maturation dates), thereby preventing domination of only a few weed species (Froud-Williams, 1988; Liebman and Janke, 1990). Due to these pioneer crop effects, cultivation of grain legumes is an important part of crop rotation, particularly in organic farming (Poetsch, 2006; Badgley et al., 2007). In animal nutrition, grain legumes are mainly used as protein supplements, but also as a valuable energy source, due to their partly high contents of starch (faba bean, peas) and lipids (lupins) (Gatel, 1994; Bach Knudsen, 1997; Salgado et al., 2002). In Europe, amongst others, the major grain legumes cultivated are peas (*Pisum sativum*), faba beans (*Vicia faba*) and lupins (*Lupinus* spp.), whereas in Argentina, Brazil, China, India, and the United States soybeans dominate (Karr-Lilienthal et al., 2004).

1.3.1 FABA BEANS (*VICIA FABA*)

Faba beans, also known as field beans, horse beans, broad beans or tick beans, represent an annual legume that is well adapted to cool climates, and thus is preferably cultivated in regions with mild winters and adequate summer rainfall (Blair, 2007). According to their seed size, *Vicia faba* can be classified in three subspecies: *Vicia faba minor* (small seeded), *Vicia faba major* (large seeded) and *Vicia faba equina* (intermediate seed size) (Hegi, 1964). For livestock, usually the small and intermediate seeded cultivars of *Vicia faba minor* and *Vicia faba equina* are grown, which have typical seed weights of up to 50 g/100 seeds and up to 100 g/100 seeds, respectively (Cubero and Suso, 1981; Duc, 1997). Furthermore, coloured flowered and white flowered cultivars are available, although the coloured flowered cultivars have been proven to be more disease-resistant than the white flowered ones, therefore the coloured flowered cultivars dominate (Duc, 1997). Faba beans represent a well established ingredient in diets for horses and ruminants (Blair, 2007). Recently, they have been receiving growing attention as protein supplement in diets for pigs, particularly in Europe, due to the low production of protein feed ingredients within the European Union (Blair, 2007).