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SUMMARY - Genetic variability is allowing to build *Vicia faba* genotypes with very diverse protein contents, starch contents and with zero levels in such antinutritional factors as tannins, vicine and convicine. Together with industrial processes, breeding will improve the quality of faba bean to meet the needs expressed by the different users.

RESUME - "Sélection pour qualité nutrionnelle chez la féverole". La variabilité génétique disponible chez Vicia faba *permet de disposer de génotypes à teneurs en protéines et teneurs en amidon très différentes et avec des niveaux zéro pour les facteurs antinutritionnels majeurs que sont les tanins et la vicine-convicine. En ajoutant les effets génétiques et ceux de la technologie industrielle, on est aujourd'hui en mesure de fournir les utilisateurs de graines de féverole en un produit de bonne qualité.*

Introduction

Many experiments have been conducted throughout the world on feeding farm animals with faba bean instead of soybean. The results have been confusing since the contribution of the following different factors in the results is not always clear:

- The specific reaction of animal species
- The rate of faba bean incorporation in the diet
- The absence or presence of sulphur amino-acid supplementation in the diet
- The form of preparation of the feed (thickness of grinding, dehulling, industrial processing)
- The genotype of faba bean.

In France, results of recent large scale feeding trials which used faba bean supplemented with sulphur amino-acids can be summarized as follows:

Incorporation of faba bean flour can be upto 10% in piglets' and fattening pigs' diets. It can be higher (25%) for fattening pigs when using dehulled faba bean seeds (Grosjean and Gatel, 1988). Digestible energy ranged from 3650 to 3900 kcal/kg in spring faba bean and 3450 to 3850 kcal/kg in winter faba bean (Bourdon and Perez, 1984). Faecal apparent digestibility of proteins was close to 74% in tannin-containing cultivars and to 80% in tannin-free cultivars (Bourdon and Perez, 1984).

In broilers' diet, incorporation of faba bean can reach upto 20-30%, but it cannot be higher than 5% for laying hens (Luckbert, 1988). Measurement of metabolisable energy on roosters gave values of 3092 kcal/kg in spring faba bean and 2887 kcal/kg in winter faba bean (Lacassagne, 1988). Starch digestibility can be improved by pelleting (Lacassagne *et al.*, 1988) or by thinner grinding (Carré, personal communication). Protein from tannin-free cultivars is more digestible (82.6%) than protein from tannin-containing cultivars (68.2%) (Lacassagne *et al.*, 1988).

In bull-calves' diet, 2 kg of faba bean seed flour can efficiently replace 1 kg of soybean meal in the feed (Weiss and Raymond, 1988) and it is a question to be answered if tannin-free cultivars can be used equivalently to tannin-containing ones.

The main antinutritional factors contained in the seed are tannins, vicine and convicine. These factors have been chemically characterised (Martin-Tanguy *et al.*, 1977; Marquardt, 1989b) and have proved to have deleterious effects, tannins on monogastric animals and vicine and convicine on laying hens (Marquardt, 1989a,b).

Plant breeders have, therefore, attempted to look into the genetic variability for various quality attributes including antinutritional factors and use it for improvement.

Protein content

According to previous results obtained by numerous workers, it has been shown that this character expresses large genetic variability in *Vicia faba* and has a high heritability. It means that it can be improved, but the demand of industrial users of faba bean is more for protein content stability. This last criterion must be considered by the breeder who should measure the level of environment and environment x genotype effects on seed protein content in his selections. Users must be aware that genetic variability for protein content is already higher among commercial cultivars of faba bean than it is for pea and consequently, this factor of variation will be added to the environmental factor. Preliminary measurements of variation coefficient due to environment for protein content of faba bean seeds, did not give us figures different from what are generally obtained in other legume crops or in cereals, but the consequence of such coefficients is higher when it concerns higher absolute values.

Protein quality

Faba bean seed, as many other legume seeds, is deficient in sulphur amino-acids. Improving their content by breeding seems difficult since a very strong correlation coefficient exists between protein content and the content of individual amino-acids (Sjödin *et al.*, 1981b). This fact can explain the failure of some breeding strategies to effect sulphur content improvement, or legumine/viciline ratio improvement (legumine contains twice as much sulphur aminoacids as viciline) (Sjödin *et al.*, 1981b).

Table 1. Antinutritional factors and the associated genetic variability in *Vicia faba*

Antinutritional factors	Measurement of genetic variability for total content	Measurement of genetic variability in composition
Hemagglutinins	Sjödin *et al.* (1981a)	
Trypsin inhibitors	Sjödin *et al.* (1981a)	
Tannins	Picard (1976) Martin-Tanguy *et al.* (1977) Sjödin *et al.* (1981a) Cabrera and Martin (1986)	Bjerg *et al.* (1988)
Glucosides	Pitz *et al.* (1981) Bjerg *et al.* (1985) Duc *et al.* (1989)	

Consequently, breeding for higher sulphur amino-acids does not appear at the moment cheaper than their industrial synthesis. It may be an objective for which the molecular genetics strategy may prove more efficient than classical breeding.

Carbohydrates

When compared to pea, the chemical nature of starch (Colonna and Carré, 1981) and cell wall constituents (Brillouet *et al.*, 1983) in faba bean is not much different. Within *Vicia faba*, genetic variability has been shown for starch and fibre contents (Bjerg *et al.*, 1988) which should have an effect on the energy value of the product. The possible benefit of a breeding programme aiming at improving the quality or availability of carbohydrates must be evaluated against the benefit of industrial processes such as thermomechanical treatments or thinner grinding (Carré, personal communication), which could make starch more digestible.

Antinutritional factors

Several antinutritional factors and the associated genetic variability, have been studied in *Vicia faba* (Table 1).

From feeding experiments conducted on laying hens (Marquardt, 1989a) and rats (Sjödin *et al.*, 1981a; Bjerg *et al.*, 1984), the main antinutritional factors seem to be tannins and two glucosides (vicine and convicine). These two glucosides are also believed to be responsible for causing favism in some genetically susceptible humans consuming faba bean.

Dehulling, which eliminates tannins, is an alternative technology to breeding. Vicine and convicine are thermostable products and removal or destruction of these causative agents by processing is difficult. Much breeding effort has been placed on these two types of antinutritional factors with success.

Tannins

Two recessive genes which code for absence of tannins in the seed coat have been found (Picard, 1976). These genes block synthesis of anthocyanin or anthocyanin's precursors and give rise to white-flowered plants. Consequently, the screening in F_2 of zero-tannin genotypes is easy. Some results (Loon *et al.*, 1989; Bond, 1987) justify the conclusion that the disease resistance of tannin-free faba bean depends on the genetic background and that tannin-free genotypes with adequate levels of disease resistance can be bred. Most seedling establish-

ment problems observed with some of these genotypes are alleviated by fungicidal seed dressing (Bond, 1987). Some white-flowered varieties are now available for national trials in different EEC countries or are already listed.

An alternative to the breeding of zero-tannin genotypes is the breeding for low tannin contents such as those reported by Cabrera and Martin (1986). M. Jay is presently investigating at the University of Lyon the genetic variability in the composition of tannins in a large collection of genotypes. A better knowledge of the relative antinutritional effect of different tannin fractions and of their thermosensitivity would be of importance in the breeding strategy.

Glucosides

Genetic variability for vicine and convicine content determined by using HPLC technique has been shown in previously mentioned works. On a collection of 919 genotypes, we measured a continuous variation for vicine + convicine content ranging from 0.41 to 1.50% of seed dry matter (Duc *et al.*, 1989). No significant correlation was found between the contents of the two glucosides. Beside this continuous variation, which has a strong genetic component, and thus opening possibilities for breeding, we detected a genotype with nearly zero-vicine/zero-convicine content in dry seeds (Duc *et al.*, 1989). The genetic studies have shown that this character is nuclear monogenic additive with maternal control. This gene gives nearly zero-vicine and convicine contents also in green pods. Among the broad genetic variability now available for vicine and convicine content, we have not yet detected any relationship of this character with other seed characteristics (seed size, protein content, tannin content) or other plant characteristics (growth vigor, earliness, disease susceptibility). The development of a breeding program necessitates a rapid screening technique to be used in F_2 generation. Near infrared reflectance technique, which has been evaluated in this respect, can only reduce by half the number of HPLC determinations required in F_2 progenies (Duc *et al.*, 1989). Some progress has to be made on this point.

Conclusion

Genetic variability for quality is very large in *Vicia faba* species.

The Zero-tannin and Zero-glucoside content genotypes can be developed with very diverse protein content. We arive at the optimistic conclusion that, together with industrial processes, breeding will fullfil the needs expressed by the different users of faba bean seeds in animal feed.

The requirements for faba bean quality in human food are limited by strong habits for seed size and seed colour. Cooking quality is an additional criterion. Progress made on low glucosides content faba bean for animal feeding will have positive effect in human nutrition as well.

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