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Nutritional value of faba bean: effects on nutrient utilization, protein turnover and immunity

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SUMMARY - A reappraisal of the physiological, biochemical and immunological changes associated with feeding the growing animals on diets containing raw faba bean as source of protein from our experimental research is reported. The inclusion of this vegetable protein in animal diets brought about a number of unfavourable effects such as retardation of growth, reduced protein deposition, altered digestibility and absorption of nutrients and impairment of the immune response, which has been attributed to the occurrence of various antinutritional factors (lectins, protease inhibitors, etc.). The role of polyphenols and phytates in such alterations is discussed.

RESUME - "Valeur nutritionenelle des fèves: effets sur l'utilisation des nutriments, turnover des protéines et immunité". On présente une révision des changements physiologiques, biochimiques et immunologiques que l'on peut observer chez des animaux en croissance, nourris avec un régime dont la source de protéine est Vicia faba. *Cette protéine végétale dans les diètes régimes animaux produit plusieurs effects indésirables: retard de la croissance, diminution du dépôt de protéine, changement de la digestibilité et de l'absorption des nutriments et défaut dans le système immunitaire. On croit que tous ces effets sont dûs à la présence de différents facteurs antinutritionnels (lectines, inhibiteurs de protéase, etc.). On envisage le rôle des polyphénols et des phytates dans ces altérations.*

Introduction

Faba bean is widely used in the Mediterranean region as source of protein in both human and animal nutrition (Larralde, 1982). However, the occurrence of some antinutritional factors such as phytohemagglutinins, protease inhibitors, polyphenols, saponins, phytates, etc., has hampered a wider nutritional utilization of this legume (Liener, 1980; Gupta, 1987).

In this article we surveyed some aspects concerning *Vicia faba* composition and the effects of legume intake on nutrient utilization, growth, protein turnover and immunity response of animals, most of which were studied in this laboratory. The possible role of phytates and polyphenols on some undesirable physiological, metabolic and immunological changes is also discussed.

Chemical composition of Vicia faba

The nutritional value of field bean has been traditionally attributed to it high protein content, which ranges from 25 to 35%, despite the imbalance in sulphur aminoacids (Santidrián *et al.*, 1981a). Most of these proteins are globulins (60%), albumins (20%), glutelins (15%) and prolamins (Cubero and Moreno, 1982). It is also a good source of sugars, minerals and vitamins (Fig. 1). Thus, the chemical analysis of this legume reveals a 50-60% content of carbohydrate, which is mainly constituted by starch, while the proportion of lipids is relatively low at about 1-2.5% with oleic and linoleic acids representing about 75% of fats (Mataix and Salido, 1985).

The mineral content varies between 1-3.5%, being particularly rich in calcium and iron. Additionally the amount of thiamin, tocopherols, niacin and folic acid is

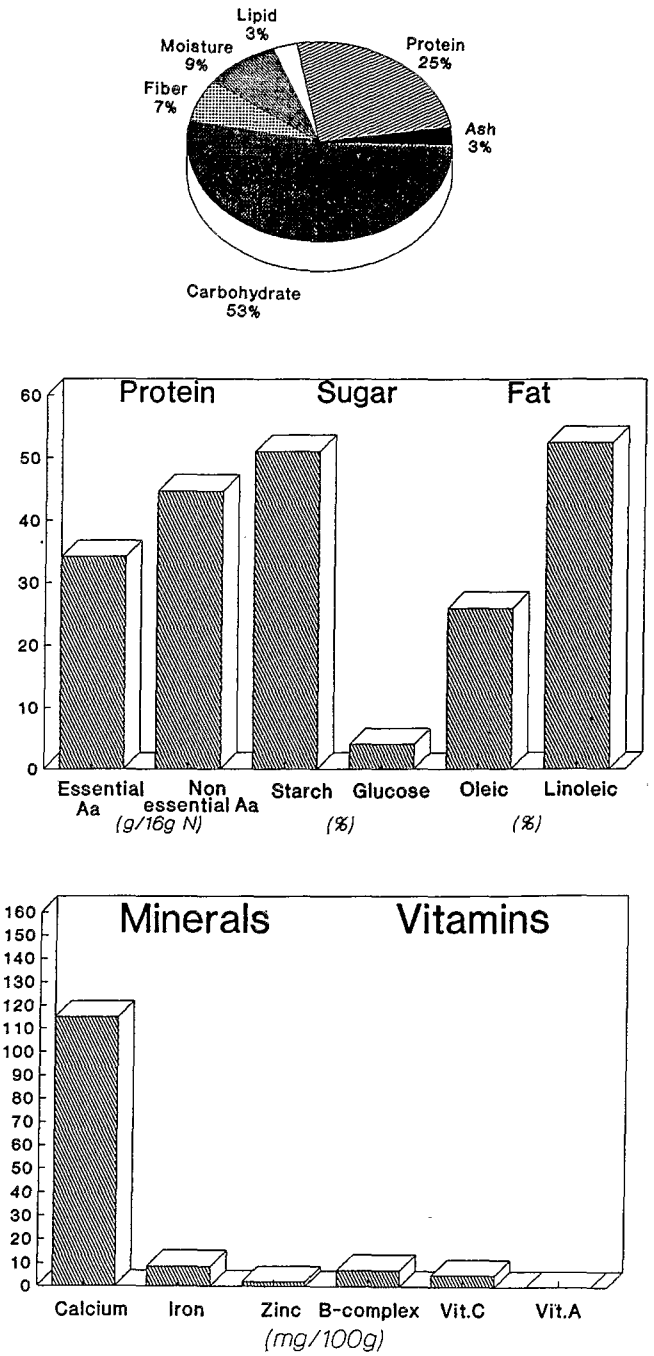

Fig. 1. Average elemental composition of faba bean.

high as compared with other grains, while vitamin C, riboflavin and other liposoluble vitamins are low. The presence of some antinutritional factors such as lectins, tannins, protease inhibitors, etc (Table 1), leads to some unfavourable effects on metabolism and nutritional utilization of this legumes in the food (Liener, 1980). Fortunately, some of these naturally occurring toxic constituents can be destroyed by heating, eliminated by soaking or removed by physico-chemical treatments or plant breeding.

Nutrient utilization as affected by faba bean intake

Digestibility and absorption of carbohydrates and proteins is adversely affected by the inclusion of faba bean in the diet (Sobrini *et al.*, 1983). The digestibility of food legumes is reduced by 15-30% (Gupta, 1987). The lower nutrient utilization has been mainly attributed to the occurrence of tannins, protease inhibitors and lectins as well as the deficiency of sulphur aminoacids in *Vicia faba* seeds. The biological indices of nutritional value (Fig. 2) ranged between 67 and 83% (Sobrini *et al.*, 1982), indicating poor digestibility and nitrogen retention (Martínez and Larralde, 1984a,b).

Table 1. Content of some antinutritional factors in faba bean.

ANF's	Amount	Units	Source
Saponins	3.5-5,7	g/kg	Bello *et al.* (1969)
Lectins	90-1000	Hemagglutinating activity(U/ml)	Bello *et al.* (1969)
Protease inhibitors	5-19	Trypsin inhibition (U/mg prot.)	Gupta (1987)
Tannins	4-5.5	mg/kg	Sobrini *et al.* (1982)
Phytates	1-3	g/kg	Martínez *et al.* (1985)

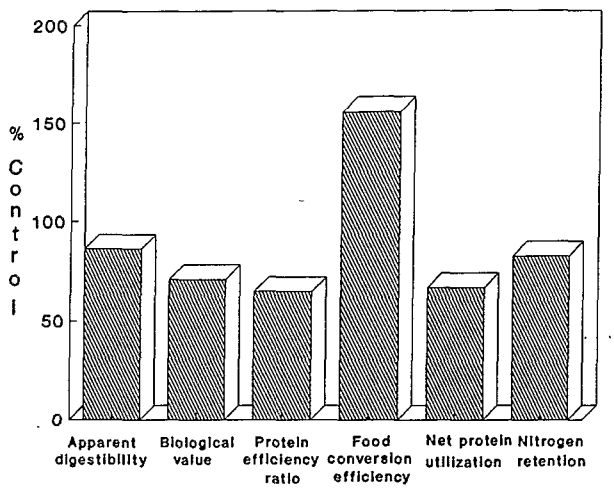

Fig. 2. Biological assays of the nutritional value of faba bean.

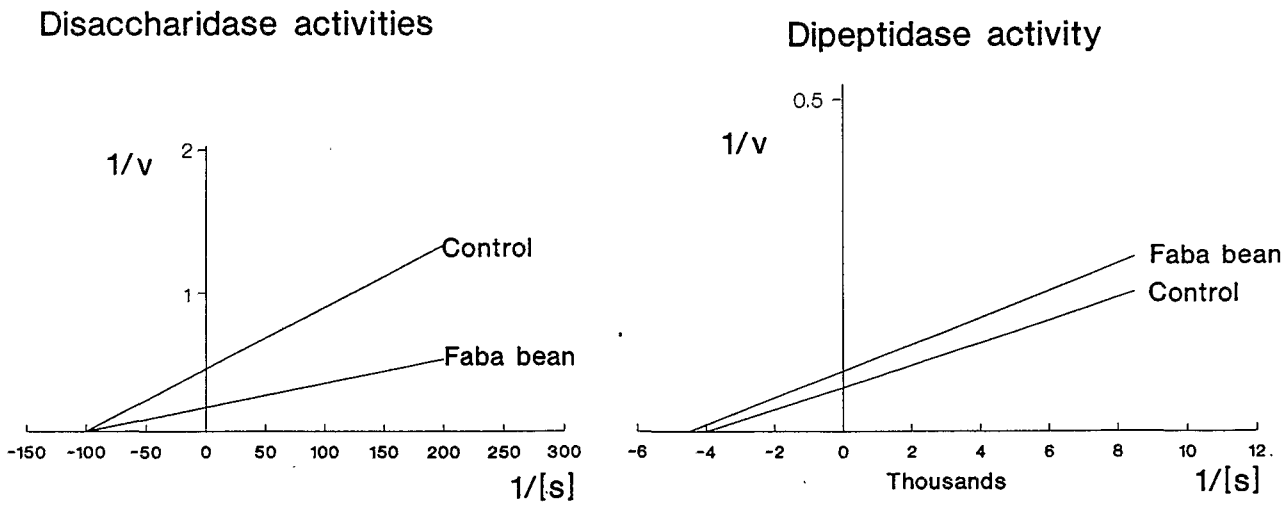

Fig. 3. Activities of intestinal mucosa enzymes from animals fed on faba bean.

The activity of some digestive enzymes, particularly of proteases and amylases is reduced in faba bean fed animals (Griffiths and Moseley, 1980). On the other hand, the response of intestinal disaccharidases and dipeptidases from animals fed on faba bean diets as source of protein is variable (Fig. 3). Maltase and sucrase activities were significantly decreased in rats (Villanueva *et al.*, 1987), while they remained relatively unaltered in chicks (Lasheras *et al.*, 1980). On the other hand, bean fed rats showed a slightly higher activity for the dipeptidase glycil-L-valine hydrolase (Villanueva *et al.*, 1987).

The intestinal absorption of sugars and aminoacids was reduced in animals fed on *Vicia faba* as source of protein (Fig. 4), the effects being more evident in mammals (Santidrián, 1981) than in birds (Santidrián *et al.*, 1981b).

Some of these undesirable influences are due to the high polyphenolic content of this crop, since alcoholic or aqueous extracts contaning *Vicia faba* tannins inhibited sugar transport (Motilva *et al.*, 1983). Pretreatment of those extracts with polyamide, in order to reduce their polyphenolic content, leads to a partial abolition of their capacity to inhibit glucose uptake (Fig. 4), further suggesting the presence of other possible anti-absorptive factors in these seeds (Barcina *et al.*, 1984).

The biochemical assessment of the nutritional status in rats and chickens fed on these seeds showed no significant changes in blood glucose, cholesterol and triglycerides as well as total plasma proteins (Fig. 5), while g-globulins and plasma zinc levels were reduced and urea excretion was markedly increased (Martínez *et al.*, 1986a; Rubio and Brenes, 1988).

Growth and protein turnover as affected by faba bean intake

Growth performance of different species is altered by legume intake in different ways (Fig. 6). Impairment of growth in animals fed on diets containing raw *Vicia faba* has been reported in rats (Martínez and Larralde, 1983a; Martínez *et al.*, 1987a), mice (Macarulla *et al.*, 1988) and chickens (Santidrián et al., 1980) as well as in monogastrics (Huisman *et al.*, 1987) and ruminant livestock (Bond, 1980). Also, egg production, milk yield and reproduction were reduced in legume fed animals (Bond,

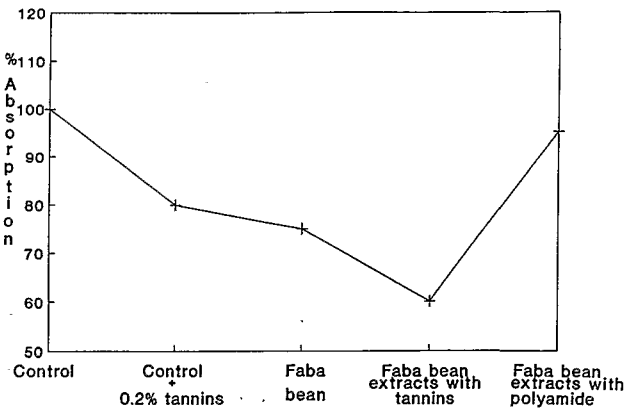

Fig. 4. Nutrient absorption in animals fed on faba bean under different experimental conditions.

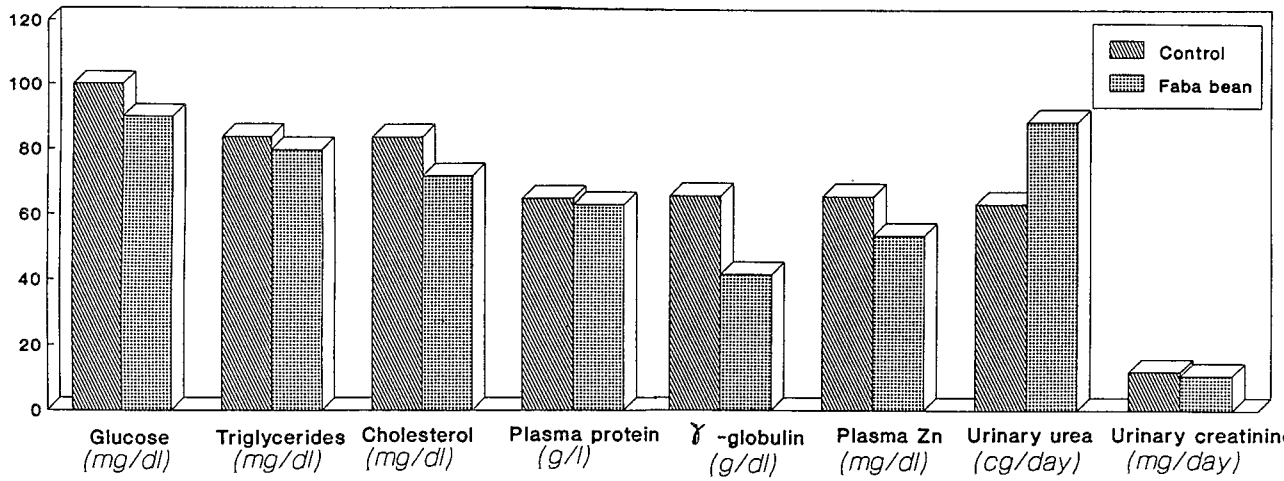

Fig. 5. Biochemical measurements in serum and urine from animals fed on faba bean.

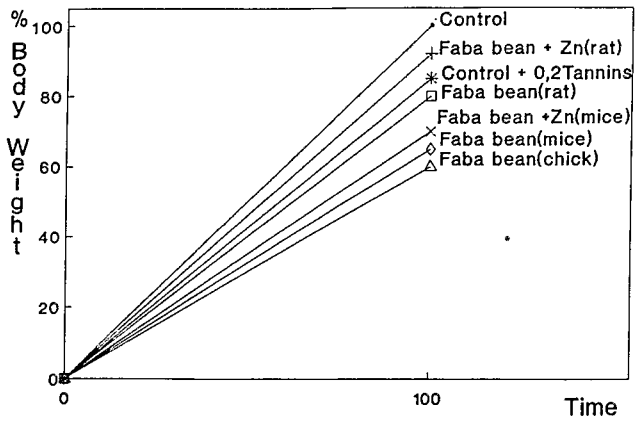

Fig. 6. Growth curves of animals fed on faba bean under different experimental conditions.

1980). Heat, soaking, methionine or zinc supplementation, and other physico-chemical treatments as well as varietal improvement through breeding have been used to improve the nutritional value of faba bean with only partial success (Gupta, 1987).

Organ proportions of animals fed on the raw legume remained unchanged except for pancreas (Huisman *et al.*, 1987), thymus and spleen, where a marked hypertrophy was found (Macarulla *et al.*, 1988). Muscle, liver and carcass relative weights and protein content, when expressed as percentage, were similar or slightly reduced in those animals on the raw pulse (Fig. 7), despite the lower growth rate (Martínez and Larralde, 1983a, 1984c).

Body composition in terms of protein, fat and water were unaltered by legume intake on a relative basis (%BW) as well as the myofibrillar fraction of muscle, while the sarcoplasmic fraction was decreased but com-

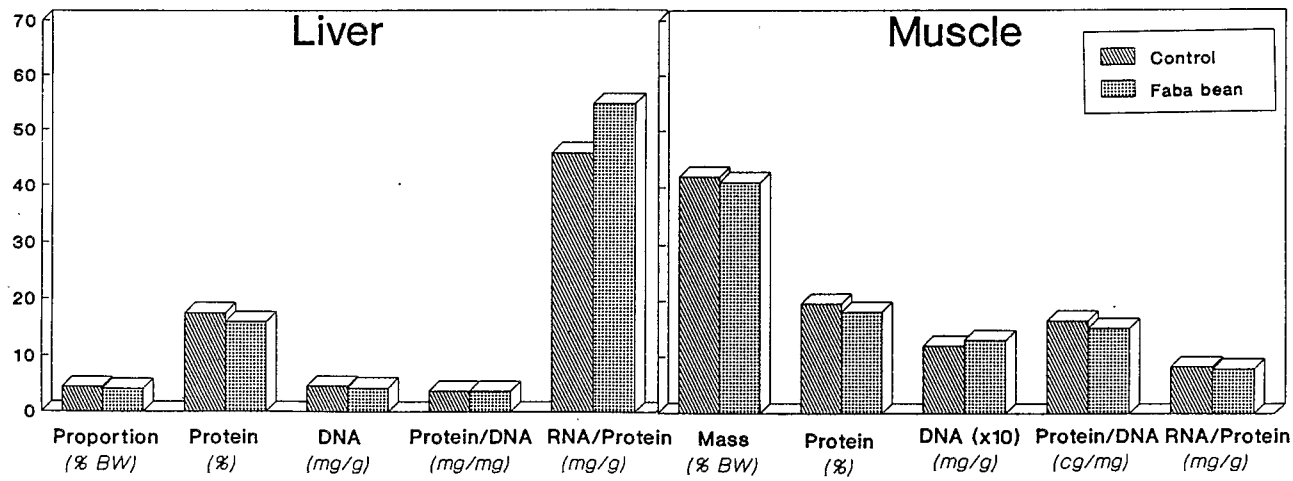

Fig. 7. Muscle and liver composition in animals fed on faba bean.

pensated by a parallel increase in the muscle non-protein fraction in rats (Bello *et al.*, 1972a,b; Martínez *et al.*, 1987b) and chickens (Santidrián *et al.*, 1980).

Muscle and liver DNA content, protein/DNA or RNA/protein ratios have been estimated as indirect indications of cell number, cell size and protein synthesis capacity, respectively. Our results (Fig. 7) apparently suggest that no significant changes occur in muscle fiber number and size while there is a fall in muscle protein anabolic capacity and an increase in liver protein biosynthesis (Barcina *et al.*, 1986).

In this context, when whole body, liver and muscle protein synthesis were assessed by using the technique of incorporation of a labelled aminoacid into protein (Martínez, 1987), similar conclusions were reached (Fig. 8), since whole and muscle protein turnover were reduced (Goena *et al.*, 1984a; Martínez *et al.*, 1987b) and liver fractional synthetic rate was enhanced (Goena *et al.*, 1984b).

Measurement of urinary 3-Methylhistidine (3-MeHis) excretion has been used as an index of myofibrillar breakdown (Martínez and Larralde, 1984a). No changes in 3-MeHis output were detected (Fig. 8), which seems to indicate that no variations in myofibrillar degradation are involved in the reduction of growth performance after the inclusion of legumes in the diet (Martínez and Larralde, 1983b, 1984b).

Assays concerning the activity of some enzymes in both rats and chicks (Fig. 8) have shown that liver and sarcoplasmic catepsin A and D are slightly increased (Santidrian, 1981; Santidrian *et al.*, 1982, 1987) as well as the activity of other aminoacid-degrading enzymes of the urea cycle (Cenarruzabeitia *et al.*, 1979), which is in agreement with previously published evidence concerning urea excretion (Martínez *et al.*, 1986a,b) and changes in the sarcoplasmic fraction (Bello *et al.*, 1972a,b).

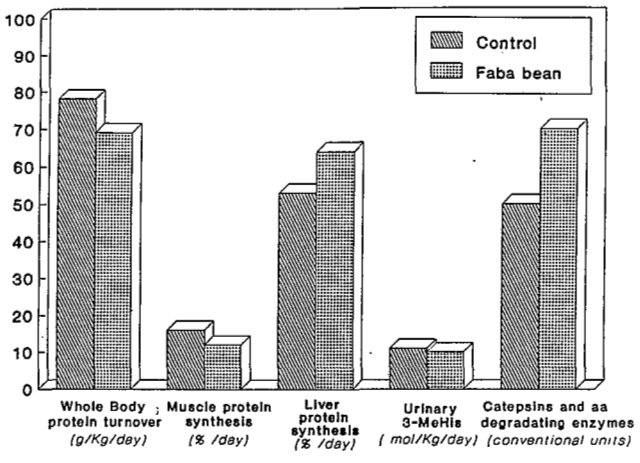

Fig. 8. Protein turnover evaluation in animals fed on faba bean.

The possible involvement of several antinutritional factors such as polyphenols, protease inhibitors and lectins in the proccesses of growth retardation has been reported (Bond, 1980; Gupta, 1987). However the nature of the main growth inhibitor remains still unclear (Marquardt *et al.*, 1977; Sobrini *et al.*, 1983; Pusztai, 1988).

It can be concluded, therefore that feeding growing animals with faba bean as source of protein leads to a significant impairment of growth, which must be mainly attributed to a decrease in muscle mass (representing about 40% of body weight in mammals) achieved by a fall in muscle protein synthesis rather than to changes in protein breakdown. The mechanism seems to involve a reduction in muscle RNA activity (grams of protein synthesized/grams RNA/day) associated with an increase in liver protein synthesis, which could be indirectly mediated by the flux of aminoacids coming from the skeletal muscle (Martínez *et al.*, 1987a,b; Goena *et al.*, 1988).

Immunity as affected by faba bean intake

Legume proteins contain considerable quantities of phytic acid, dietary fiber and other organic compounds (Fig. 1, Table 1), which may affect mineral bioavailability from the diet (Martínez *et al.*, 1985). On the other hand, the response of the immune system has been widely recognized as an adequate index for the evaluation of the nutritional value of a diet (Stinnett, 1987), because it is sensitive to legume feeding (Marzo *et al.*, 1983; Pusztai *et al.*, 1984; Sissons *et al.*, 1988).

A series of experiments were conducted in order to assess the influence of *Vicia faba* intake on immunocompetence, which studied separately the effect of legume consumption on humoral and cellular immune responses. Additionally, since zinc bioavailability is apparently reduced in animals fed on faba bean by the occurrence of phytates, as indicated by the reduction in plasma zinc concentration (Martínez *et al.*, 1986b) and zinc is apparently involved in some immune mechanisms, the effect of zinc supplementation of a *Vicia faba* diet on some immunoparameters was also investigated.

The functional competence of the immune system was reduced in mice fed on faba bean diets for both cellular and humoral-mediated responses (Table 2), when measured with specific assays: hemagglutination test, rossette forming cells, lymphocyte proliferation under specific mitogens, complement activation, etc. (Macarulla, 1989). Zinc supplementation improved significantly the humoral protection and the cellular mediated response, while the complement activation system was not recovered (Macarulla *et al.*, 1989).

These observations have clear implications in both human nutrition and animal production.

Table 2. Immunocompetence of mice fed on faba bean or zinc supplemented faba bean (Macarulla *et al.*, (1989).

Immunoparameter	Faba bean[a]	Faba bean+Zinc[a]
Immune organs		
Thymus and spleen (%BW)	+ +	+
Thymus and spleen cellularity (DNA)	– –	–
Humoral immunity		
B cell number	– –	– or =
B cell function	– –	– or =
Cellular immunity		
T cell number	– –	–
T cell function	– or =	– or =
Complement system activation	– –	– –

[a] +: increase, –: decrease, =: same

Acknowledgements

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