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Pea seeds (Pisum sativum), faba beans (Vicia faba var. minor) and lupin seeds (Lupinus albus var. multitalia) as protein sources in broiler diets: effect of extrusion on growth performance

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ABSTRACT

The effect of extrusion of pea seeds (Pisum sativum) (PS), faba bean (Vicia faba, variety minor) (FB) and lupin seeds (Lupinus albus, variety multitalia) (LS) on broiler performance were evaluated. Four hundred sixty two 1d-old Ross male chicks, Marek vaccinated, were randomly assigned to seven dietary treatments (3 pens per treatment/22 birds per pen). Chicks were floor housed, ad libitum fed isocaloric and isonitrogenous diets and had free access to water. Artificial light was provided 10 h/d. The bulk of the base diet (control diet) was corn (48.8%, 53.7% and 57%), solvent-extracted soy-bean meal (42.8%, 37.3% and 33.4%), corn oil (4.4%, 5.2% and 6.3%), plus synthetic amino acids, minerals, trace minerals and vitamins, respectively for the 1-10d-old, 11-28d-old and 29 to 42d-old growing periods. The amounts of PS, FB and LS used on an as fed basis were: PS and extruded PS (EPS): 353 (1-10d-old), 356 (11-28d-old) and 350 (29-42d-old) g/kg; FB and extruded FB (EFB): 479 (1-10d-old), 497 (11-28d-old) and 500 (29-42d old) g/kg; LS and extruded LS (ELS): 360 (1-10d-old) and 300 (11-42d-old) g/kg. High levels of pea (350 g/kg) and faba bean (500 g/kg) did not show negative effects on body weight gain (BWG) and bird feed intake compared to control. Lupin at the 300 g/kg level reduced (P < 0.05) the BWG during the finishing period (22 to 42 d), however the effect disappeared over the whole experimental period (1-42 d) compared to the control group. The ELS group had a lower (P < 0.01) feed intake compared to the control group and to the LS group. The feed conversion rate (FCR) was similar among groups for the whole experimental period; however during the grower period the FCR was higher (P < 0.05) for the PS, FB and EFB groups compared to the control group. Birds consuming the PS diet had a reduced (P < 0.05) eviscerated carcass yield compared to the control group. The breast meat percent yield was higher (P < 0.01) for birds consuming the FB and EFB diets compared to the control group. There were no statistical differences in percent yield of the leg quarters and in blood parameters.

Key Words: Broilers, Pea, Faba bean, Lupin, Extrusion.

RIASSUNTO

PISELLO, FAVA E LUPINO IN DIETE PER BROILERS: EFFETTI DELL’ESTRUSIONE SULLE PERFORMANCE DI CRESCITA

Lo studio ha valutato l’effetto dell’estruzione di Pisello (Pisum sativum) (PS), Fava (Vicia faba, varietà minor) (FB) e Lupino (Lupinus albus, varietà multitalia) (LS) sulle performance di crescita dei broilers. 462 pulcini maschi Ross di 1 un
Introduction

Research on vegetable-based protein sources has grown as a result of the European Union ban on the inclusion of meat and bone meal in diets of agricultural livestock. This together with recent concern over genetically modified soybeans, the agricultural livestock. This together with recent concern over genetically modified soybeans, the

Diaz et al.

antinutritional factors (protease inhibitors, lectins, phenolic compounds, saponins, etc.) in possible protein sources, like pea seeds (Pisum sativum) faba beans (Vicia faba var. minor) and lupin seeds (Lupinus albus var. multitalia), is minimal since genetic improvements of these ingredients make for products with minimal risk (Bond and Duc, 1993; Gatel, 1993; Castell et al., 1996; Rubio et al., 2003). The primary concern with these vegetable-based protein sources is related to their content of non-starch-polysaccharides (NSP). The α-galactoside linkages in these polysaccharides are not broken down for digestion in the gut of monogastric animals (Evans et al., 1993; Gdala and Buraczewska, 1996, 1997; Perez-Maldonado et al., 1999; Kocher et al., 2000).

These negative effects of high NSP containing protein sources can however be minimized by several methods. One of the most utilized and most studied is the utilization of specific enzymes (Gilbert et al., 1999; Kocher et al., 2000; Steenfeldt et al., 2003; Cowieson et al., 2003). Another effective method is by the optimization of their particle size with technological feed processing procedures (Lacassagne et al., 1991; Gatel, 1993; Daveby et al., 1998; Farrell et al., 1999; Alonso et al., 2001). For example, pelleting or extrusion has been shown to improve the starch and protein digestibility in faba bean, peas and lupin (Carré et al., 1987; Carré et al., 1991; Alonso et al., 1998; Farrell et al., 1999; Alonso et al., 2000a; Alonso et al., 2000b).

The objective of this study was to evaluate the effect of different levels of raw or extruded peas, faba beans or lupin seeds in partial substitution of soybean meal and other starch sources in broiler diets.

Material and methods

Four hundred sixty two 1d-old Marek vaccinated ROSS male chicks were obtained from a commercial hatchery (Dal Verme Camillo e Filippo, Torre degli Alberi, Pavia, Italy). Dietary treatments (seven treatments) were randomly assigned to twenty one pens (22 birds per pen with 3 pens/treatment). Chicks were floor housed (0.09 m2/bird) in two controlled environment rooms (24°C), ad libitum fed isocaloric and isonitrogenous diets and had free access to water. Artificial light was provided 10 h/d. Fluorescent lights with ultraviolet filters was provided 24 h/d for the first
EXTRUDED FEEDS IN BROILER DIETS

14d in the experiment. Birds were raised according to the European Union (European Commission, 1986) and Italian (Gazzetta Ufficiale, 1992) directives on animal welfare for experimental and other scientific purposes. Diets were formulated according to the ROSS breeder’s requirements for starter (1-10d-old), growing (11-28d-old) and finishing (29-42d-old) periods. The bulk of the base diet (control diet - CTR) was corn (48.8%, 53.7% and 57%), solvent-extracted soybean meal (42.8%, 37.3% and 33.4%), corn oil (4.4%, 5.2% and 6.3%), plus synthetic amino acids, minerals, trace minerals and vitamins, respectively for the 1-10d-old, 11-28d-old and 29 to 42d-old growing periods.

| Ingredients (g/kg as fed basis) and chemical composition of diets fed from 1 to 10 d-old. |
|------------------------------------------------------------------------------------------|
|                                                                                           |
|                                                                                           |
| Table 1.                                                                                   |
|                                                                                           |
| Pea seeds | Faba beans | Lupin seeds |
|-----------|------------|-------------|
| CTR | PS | EPS | FB | EFB | LS | ELS |
|                                                                                           |
| Ingredients:                                                                             |
|                                                                                           |
| Corn meal | 488 | 298 | 298 | 251 | 251 | 452 | 452 |
| Soybean meal | 428 | 258 | 258 | 180 | 180 | 88 | 88 |
| Pea seeds | - | 353 | 353 | - | - | - | - |
| Faba beans | - | - | - | 479 | 479 | - | - |
| Lupin seeds | - | - | - | - | - | 360 | 360 |
| Corn oil | 44 | 50 | 50 | 45 | 45 | 50 | 50 |
| L-Lysine hydrochloride | 1.1 | - | - | 1.3 | 1.3 | 5.0 | 5.0 |
| DL-Methionine | 1.8 | 2.8 | 2.8 | 3.5 | 3.5 | 3.5 | 3.5 |
| L-Threonine | - | 0.3 | 0.3 | 0.7 | 0.7 | 1.1 | 1.1 |
| L-Tryptophan | - | 0.5 | 0.5 | 0.8 | 0.8 | 1.3 | 1.3 |
| Calcium carbonate | 4.9 | 1.4 | 1.4 | 0.5 | 0.5 | - | - |
| Dicalcium phosphate | 23.3 | 27.1 | 27.1 | 28.7 | 28.7 | 30.1 | 30.1 |
| Sodium chloride | 2.8 | 3.0 | 3.0 | 2.3 | 2.3 | 1.4 | 1.4 |
| Sodium bicarbonate | 1.5 | 0.8 | 0.8 | 1.6 | 1.6 | 3.0 | 3.0 |
| Premix | 5 | 5 | 5 | 5 | 5 | 5 | 5 |

Composition by analysis:

| Crude protein | 230 | 225 | 209 | 221 | 228 | 217 | 217 |
| Ether extract | 75 | 70 | 74 | 76 | 68 | 76 | 74 |
| Crude fiber | 30 | 34 | 36 | 53 | 47 | 50 | 46 |
| Ash | 57 | 59 | 58 | 56 | 57 | 52 | 52 |
| Starch | 356 | 364 | 372 | 357 | 354 | 357 | 357 |
| Total sugars | 40 | 39 | 31 | 35 | 37 | 37 | 35 |

Composition by calculation:

| ME kcal/kg | 2975 | 3013 | 3022 | 2986 | 2987 | 3014 | 3017 |

1 Content for kg of premix: sodium lasalocid 16,000 mg; vitamin A 2,700,000 U; vitamin D3 950,000 U; vitamin E 13,000 mg; vitamin B1 480 mg; vitamin B2 1,575 mg; vitamin B6 1,380 mg; D-phantotenic acid 4,800 mg; vitamin H 60 mg; vitamin K3 910 mg; vitamin PP 14,800 mg; vitamin B12 5 mg; Folic acid 4,800 mg; Co 40 mg; Fe 9,800 mg; Cu 390 mg; Mn (oxide) 12,200 mg; Mn (sulphate) 12,200 mg; Cu 3,900 mg; Se 48 mg; Zn (sulphate) 9,800 mg; Zn (sulphate) 9,800 mg.

CTR: control; PS: raw pea seeds; EPS: extruded pea seeds; FB: raw faba beans; EFB: extruded faba beans; LS: raw lupin seeds; ELS: extruded lupin seeds.
Diaz et al.

Table 2. Ingredients (g/kg as fed basis) and chemical composition of diets fed from 11 to 28 d-old.

| Ingredients:                  | CTR | PS   | EPS  | FB   | EFB  | LS   | ELS  |
|-------------------------------|-----|------|------|------|------|------|------|
| Corn meal                     | 537 | 307  | 307  | 251  | 251  | 483  | 483  |
| Soybean meal                  | 373 | 230  | 230  | 146  | 146  | 111  | 111  |
| Pea                           | -   | 356  | 356  | -    | -    | -    | -    |
| Faba beans                    | -   | -    | -    | 497  | 497  | -    | -    |
| Lupin                         | -   | -    | -    | -    | 300  | 300  |      |
| Corn oil                      | 52  | 67   | 67   | 64   | 64   | 61   | 61   |
| L-Lysine hydrochloride        | 2.0 | 0.4  | 0.4  | 1.4  | 1.4  | 4.6  | 4.6  |
| DL-Methionine                 | 2.4 | 3.1  | 3.1  | 3.8  | 3.8  | 3.7  | 3.7  |
| L-Threonine                   | 0.4 | 0.6  | 0.6  | 0.9  | 0.9  | 1.2  | 1.2  |
| L-Tryptophan                  | -   | -    | -    | 0.3  | 0.3  | 0.9  | 0.9  |
| Calcium carbonate             | 9.1 | 10.0 | 10.0 | 8.0  | 8.0  | 8.0  | 8.0  |
| Dicalcium phosphate           | 14.7| 15.0 | 15.0 | 18.0 | 18.0 | 17.0 | 17.0 |
| Sodium chloride               | 2.5 | 2.0  | 2.0  | 2.0  | 2.0  | 1.0  | 1.0  |
| Sodium bicarbonate            | 1.9 | 3.0  | 3.0  | 3.0  | 3.0  | 4.0  | 4.0  |
| Premix^1                      | 5   | 5    | 5    | 5    | 5    | 5    | 5    |

Composition by analysis:

| Crude protein                 | 202 | 204  | 204  | 204  | 208  | 195  | 195  |
| Ether extract                  | 93  | 83   | 93   | 85   | 87   | 104  | 111  |
| Crude fiber                    | 32  | 38   | 41   | 57   | 51   | 39   | 37   |
| Ash                            | 56  | 59   | 57   | 57   | 57   | 49   | 51   |
| Starch                         | 337 | 408  | 391  | 398  | 392  | 375  | 358  |
| Total sugars                   | 40  | 39   | 31   | 38   | 37   | 37   | 35   |

Composition by calculation:

| ME kcal/kg                     | 3175| 3187 | 3172 | 3161 | 3159 | 3186 | 3163 |

^1 Content for kg of premix: sodium lasalocid 18,000 mg; vitamin A 2,700,000 U; vitamin D3 950,000 U; vitamin E 13,000 mg; vitamin B1 480 mg; vitamin B2 1575 mg; vitamin B6 1380 mg; D-phantotenic acid 4800 mg; vitamin H 60 mg; vitamin K3 510 mg; vitamin PP 14,800 mg; vitamin B12 5 mg; Folic acid 580 mg; Co 40 mg; Fe 9800 mg; I 390 mg; Mn (oxide) 12,200 mg; Mn (sulphate) 12,200 mg; Cu 3900 mg; Se 48 mg; Zn (oxide) 9800 mg; Zn (sulphate) 9800 mg.

CTR: control; PS: raw pea seeds; EPS: extruded pea seeds; FB: raw faba beans; EFB: extruded faba beans; LS: raw lupin seeds; ELS: extruded lupin seeds.

(Tables 1, 2 and 3). The pea seeds (PS), faba beans (FB) and Lupin seeds (LS), either raw or extruded (Anderson single-screw wet extruder with 300-350 kg h^-1 capacity, 120A power absorption; Cortal Extrasory, Vicenza, Italy), entered diets in substitution of the soybean meal and corn according to the cost optimization in diet formulation. The amount of PS, FB and LS used as fed basis were: PS and extruded PS (EPS): 353 (1-10d-old); 356 (11-28 d-old) and 350 (29-42-d old) g/kg; FB and extruded FB (EFB): 479 (1-28 d-old) and 500 (29-42-d old) g/kg; LS and extruded LS (ELS): 360 (1-10d-old) and 300 (11-42-d old) g/kg.

The PS, EPS, FB, EFB, LS and ELS and experimental diets were characterized for protein, crude lipids, total fiber, total sugar and ash contents.
(Table 4) (Martillotti et al., 1987), and for ADF and NDF (Van Soest et al., 1991). The starch content was measured by polarimetric method as described by Martillotti et al. (1987). Amino acids were measured (Table 5) with an amino acids analyser (Carlo Erba 3A29) according to published methods (Moore, 1963; Eggum, 1968; Moore et al., 1980). The methionine content was determined after oxidation with performic acid. Feeds were analyzed for total phenols and tannins, fractioned by adsorption chromatography according to Carmona et al. (1991), daidzein and genistein were determined by gas chromatography-mass spectrometry (Liggins et al., 1998) and by reverse-phase HPLC (Franke et al., 1994). The antitripsin activity was analyzed by the method described by Smith et al. (1980).
Diaz et al.

Table 4. Chemical composition (g/kg as fed basis) of the grain legumes.

| Parameter               | Soybean meal | Pea seeds | Faba beans | Lupin seeds |
|-------------------------|--------------|-----------|------------|-------------|
| Dry matter              | 885.9        | 880.1     | 861.8      | 883.1       | 872.6       | 911.2       | 912.3       |
| Crude protein           | 451          | 212.5     | 210.3      | 259          | 254.6       | 350.5       | 354.0       |
| Ether extract           | 13           | 12.3      | 31.5       | 16.1         | 17.5        | 77.4        | 99.8        |
| Crude fiber             | -            | 68.2      | 41         | 77.7         | 82.8        | 95.8        | 96.1        |
| Ash                     | 60.7         | 32.6      | 33.9       | 33.8         | 33.7        | 38.1        | 37.3        |
| Starch                  | -            | 436.6     | 413        | 327.2        | 333.7       | 114.1       | 81.5        |
| Total sugars            | 92.6         | 38.4      | 45.1       | 40.3         | 57.6        | 65.6        | 67.6        |
| Neutral Detergent Fiber| 179.3        | 162.8     | 105.7      | 276.4        | 200.4       | 183.7       | 192.4       |
| Acid Detergent Fiber    | 66.7         | 87.5      | 57.6       | 114.2        | 128.4       | 118         | 120.6       |

PS: raw pea seeds; EPS: extruded pea seeds; FB: raw faba beans; EFB: extruded faba beans; LS: raw lupin seeds; ELS: extruded lupin seeds.

* in vitro* alpha-amylase starch digestibility was determined using 1 mm screen flours (25 mg/mL of 0.2 M phosphate buffer, pH 6.9 at 37°C) after amylolysis with microbial alpha-amylase suspension at 37°C for 2 h according to the method of Mercier and Guilbot (1974). After 0, 30, 90 and 120 min. of incubation 3 mL of suspension were transferred in a 27 mL mixture of ethanol-acetone to block the enzyme activity. This mixture was then boiled for 8 min. with 2 mL of phenol and 5 mL of concentrated sulfuric acid. After cooling, the absorbance of the filtered solution was measured at 490 nm with glucose used as a standard.

*[in vitro]* amyloligosidase starch digestibility was determined in 1 mm screen flours (1 g in 2.5 mL distilled water, 2.5 mL of buffer - pH 4.8 and 5 mL amyloligosidase 1%) after suspension at 42°C for 1 h according to the method of Casper et al. (1990). Pens were weighted at days 1, 21 and 42 and feed intake was monitored. The weight gain, feed intake and feed efficiency were calculated.

Results and discussion

The antitrypsin activity, and the estrogenic molecules (genistein and daizein) were relatively low (Table 6) for peas, faba beans and lupin seeds. Extrusion tended to reduce polyphenol concentrations and antitrypsin activity in peas and fava
### Table 5. Amino acids content of the grain legumes (g/kg as fed basis).

| Amino acid   | Soybean meal | Pea seeds | Faba beans | Lupin seeds |
|--------------|--------------|-----------|------------|-------------|
| Alanine      | 19.8         | 8.9       | 10.6       | 11.6        |
| Arginine     | 34.6         | 14.2      | 23.1       | 35          |
| Aspartic Acid| 48.9         | 26.5      | 24.7       | 41.6        |
| Cystine      | 6.7          | 3         | 3.3        | 5           |
| Glutamic acid| 85.6         | 34.6      | 42.9       | 80.7        |
| Glycine      | 19.1         | 8.5       | 10.6       | 13.6        |
| Histidine    | 11.9         | 3.8       | 6.3        | 8.2         |
| Isoleucine   | 22.7         | 8.7       | 11.1       | 16.3        |
| Leucine      | 35.2         | 14.1      | 18.8       | 26.1        |
| Lysine       | 28.4         | 13        | 15.9       | 14.9        |
| Methionine   | 6.5          | 1.8       | 2.1        | 2.4         |
| Phenylalanine| 23.5         | 9.5       | 10.9       | 14.7        |
| Proline      | 24.5         | 8.5       | 11.8       | 15          |
| Serine       | 25.4         | 11.3      | 13.2       | 21.8        |
| Threonine    | 18           | 8.1       | 9          | 13          |
| Tyrosine     | 17.3         | 6.2       | 7.5        | 16          |
| Valine       | 22.8         | 9.1       | 12.2       | 13.8        |
| Tryptophan   | 6.1          | 1.8       | 2.3        | 2.1         |

### Table 6. Antinutritional content in protein sources.

| Analysis       | Soybean meal | PS | EPS | FB | EFB | LS  | ELS  |
|----------------|--------------|----|-----|----|-----|-----|------|
| Tannins, mg/g  | 0.39         | 0.14 | 0.34 | 0.47 | 0.42 | 0.61 | 0.81 |
| Polyphenols, " | 2.09         | 11.19 | 7.54 | 2.49 | 1.07 | 6.39 | 2.68 |
| Genisteine, ppm| 0.7          | 0   | 0   | 0   | 0   | 0   | 0.1  |
| Daidzeine, "   | 1.6          | 0.1 | 0.1 | 0.1 | 0.2 | 0   | 0.2  |
| Trypsin inhibiting activity | 1.3 | 0.89 | 0.4 | 0.78 | 0.3 | 0.72 | 1.4  |

PS: raw pea seeds; EPS: extruded pea seeds; FB: raw fava beans; EFB: extruded fava beans; LS: raw lupin seeds; ELS: extruded lupin seeds
Table 7. *In vitro* starch digestibility (%) for raw and extruded grain legumes.

|                  | PS  | EPS | FB  | EFB | LS  | ELS  | SEM | P  |
|------------------|-----|-----|-----|-----|-----|------|-----|----|
| Alpha-amylase    |     |     |     |     |     |      |     |    |
| digestibility:  |     |     |     |     |     |      |     |    |
| 0 min.           |  13.88 | 9.2 | 18.38 | 17.83 | 100 | 100  |     |    |
| 30 min.          |  5.94  | 66.98 | 4.70 | 53.72 | 23.32 | 79.83 |     |    |
| 90 min.          | 11.89 | 82.56 | 8.94 | 96.80 | 41.98 | 93.28 |     |    |
| 120 min.         | 11.96 | 86.85 | 10.42 | 91.50 | 48.51 | 100  |     |    |
| Amyloglucosidase|    |     |     |     |     |      |     |    |
| digestibility    |    |     |     |     |     |      |     |    |
|                  |  11.8 | 85.37 | 11.39 | 85.05 | 54.48 | 100  |     |    |

PS: raw pea seeds; EPS: extruded pea seeds; FB: raw faba beans; EFB: extruded faba beans; LS: raw lupin seeds; ELS: extruded lupin seeds.

Table 8. Influence of alternative protein sources on the average feed intake (FI), average body weight gain (BWG) and feed conversion rate (FCR) of broiler chickens.

| Parameter      | CTR | PS   | EPS  | FB  | EFB | LS  | ELS  | SEM | P  |
|----------------|-----|------|------|-----|-----|-----|------|-----|----|
| FI, 1-21d      | g/d | 50.7 | 48.2 | 51.1 | 51.4 | 51.1 | 50.4 | 48.2 | 1.04 | 0.204 |
| FI, 1-42d      | "   | 147.7<sup>a</sup> | 159.1<sup>c</sup> | 156.6<sup>c</sup> | 154.0<sup>c</sup> | 152.0<sup>c</sup> | 144.3<sup>c</sup> | 132.0<sup>c</sup> | 2.66 | 0.005 |
| FI, 22-42d     | "   | 98.9<sup>a</sup> | 103.5<sup>c</sup> | 103.5<sup>c</sup> | 102.4<sup>c</sup> | 100.1<sup>c</sup> | 97.4<sup>c</sup> | 90.1<sup>c</sup> | 1.43 | 0.007 |
| BWG, 1-21d     | "   | 38.4 | 34.6 | 38.4 | 36.5 | 37.1 | 36.9 | 36.6 | 0.87 | 0.179 |
| BWG, 1-42d     | "   | 71.9<sup>e</sup> | 76.6<sup>c</sup> | 76.6<sup>c</sup> | 69.8<sup>c</sup> | 74.3<sup>c</sup> | 66.9<sup>c</sup> | 62.9<sup>c</sup> | 1.63 | 0.006 |
| BWG, 22-42d    | "   | 55.1<sup>e</sup> | 55.6<sup>e</sup> | 57.5<sup>e</sup> | 53.1<sup'e</sup> | 55.7<sup'e</sup> | 51.9<sup'e</sup> | 49.7<sup'>e</sup> | 1.08 | 0.033 |
| FCR, 1-21d     | 1.32<sup>a</sup> | 1.40<sup>a</sup> | 1.34<sup>c</sup> | 1.42<sup>b</sup> | 1.41<sup>b</sup> | 1.37<sup>b</sup> | 1.32<sup>b</sup> | 0.02 | 0.028 |
| FCR, 1-42d     | 2.10<sup>a</sup> | 2.08<sup>a</sup> | 2.05<sup>b</sup> | 2.22<sup>a</sup> | 2.08<sup>a</sup> | 2.16<sup>a</sup> | 2.10<sup>a</sup> | 0.03 | 0.043 |
| FCR, 22-42d    | 1.81 | 1.87 | 1.81 | 1.94 | 1.84 | 1.88 | 1.81 | 0.03 | 0.13  |

<sup>1</sup> P of the model.

Within a row, means without a common superscript letter differ (P < 0.05).

PS: raw pea seeds; EPS: extruded pea seeds; FB: raw faba beans; EFB: extruded faba beans; LS: raw lupin seeds; ELS: extruded lupin seeds.

CTR: control.
Table 9. Influence of alternative protein sources on eviscerated carcass, breast muscle and leg quarter percentages of broiler chickens.

| Parameter          | CTR  | PS   | EPS  | FB   | EFB  | LS   | ELS  | SEM  | P  |
|--------------------|------|------|------|------|------|------|------|------|----|
| Eviscerated carcass| 82.7 | 73.8 | 76.6 | 82.5 | 85.0 | 79.3 | 80.0 | 1.42 | 0.043 |
| Breast             | 18.3 | 18.7 | 18.7 | 19.4 | 19.6 | 17.6 | 18.1 | 0.32 | 0.001 |
| Leg quarter        | 28.8 | 29.7 | 29.1 | 28.3 | 29.4 | 28.9 | 26.5 | 1.85 | 0.95  |

1 P of the model.
Within a row, means without a common superscript letter differ (P < 0.05).
PS: raw pea seeds; EPS: extruded pea seeds; FB: raw faba beans; EFB: extruded faba beans; LS: raw lupin seeds; ELS: extruded lupin seeds.
CTR: control.

Table 10. Influence of alternative protein sources on blood parameters of broilers chickens.

| Parameter                    | CTR  | PS   | EPS  | FB   | EFB  | LS   | ELS  | SEM  | P  |
|------------------------------|------|------|------|------|------|------|------|------|----|
| Urea mmol/L                  | 0.64 | 0.79 | 0.7  | 0.66 | 0.76 | 0.86 | 0.85 | 0.07 | 0.37 |
| Total protein g/L            | 30   | 29.25| 29   | 30.63| 29.63| 30.5 | 27.4 | 1.02 | 0.08 |
| Bilirubin mmol/L             | 5.29 | 5.49 | 5.64 | 7.86 | 6.01 | 7.33 | 4.83 | 1.46 | 0.75 |
| Albumin g/L                  | 14.38| 14.5 | 14.38| 14   | 14.38| 15.13| 14.13| 0.47 | 0.6  |
| Aspartate amino transferase U/L | 292.3| 478.9| 411  | 307.5| 257.8| 436.4| 326.9| 85.3 | 0.53 |
| Alanine aminotransferase     | 4.38 | 6.38 | 6.25 | 5.38 | 4.75 | 6.13 | 5.13 | 0.88 | 0.77 |
| Gamma-Glutamyltransferase    | 38.13| 44.38| 41   | 44.25| 38.5 | 43.13| 43.88| 2.88 | 0.6  |

1 P of the model.
PS: raw pea seeds; EPS: extruded pea seeds; FB: raw faba beans; EFB: extruded faba beans; LS: raw lupin seeds; ELS: extruded lupin seeds.
CTR: control.

bean (Table 6). Alonso et al. (2000a) reported that extrusion was effective in reducing trypsin, chymotrypsin, alpha-amilase inhibitors and haemagglutinating activity in peas (Pisum sativum L.) and kidney beans (Phaseolus vulgaris L.). In our study, both peas and faba beans in vitro alpha-amylase digestibility (after 120 min. of incubation) (Table 7) increased almost 100% after extrusion. Amyloglucosidase digestibility was similarly increased for peas and faba beans after extrusion. Alonso et al. (2000a, 2000b) found a similar effect of extrusion when they reported that extrusion was more effective in improving faba and pea protein and starch digestibility than dehulling, soaking or germination.

The mortality during the entire experiment was very low (3.6 %), and was not related to the experimental diets. The effects of experimental diets on weight gain, feed intake and the feed conversion rate (FCR) are showed in Table 8. High levels of peas (350 g/kg) and faba (500 g/kg) did not show negative effects on bird weight gain. Lupin at the 300 g/kg level reduced (P < 0.05) the weight gain during the finishing (22 to 42 d) and grower periods (1 to 21 d) but did not affect weight gain when the entire experimental period (1-42 d) was analyzed. Similarly, high levels of faba beans or peas did not affect feed intake. Extrusion of the lupin seeds reduced feed intake (P < 0.01) in comparison to the control group and to the non-extruded lupin diet. Feed conversion rate was not significantly affected by any of the experimental treatments for the full experimental period. During the grower period the FCR was higher (P < 0.05) for faba bean diets independent of extrusion. Although the feed analysis showed better quality in the extruded feeds (i.e. less antinutritional factors) and a better in vitro starch and protein
digestibility, as compared to raw products, no mayor effects on bird performance were observed over the entire experimental period between extruded and raw protein source treatment. Indeed, Moschini et al. (2005) showed that 350 g/kg of raw peas and 500 g/kg of raw faba beans did not have any negative effects on body weight gain and FCR during the grower period (1-21). Our results help support the concept that utilization of level higher than 150 g/kg of lupin pea has a negative effect on broiler performance (Olver and Jonker, 1997; Farrell et al., 1999). To the best of our knowledge there are no previous reports on the effects of extrusion of these legumes on broiler performance. There are however several studies that evaluate the effects of pelleting. Carré et al. (1987) saw an increase of 1.8-4.6% in apparent metabolisable energy for peas and of 3.5 and 5.4% respectively for protein and starch digestibility. Similarly, Lacassagne et al. (1991) saw the same effect of pelleting on protein and starch digestibility of faba beans. Carcass measurements are shown in Table 9. Birds consuming non-extruded peas had lower dressing percentage than the control group \((P < 0.05)\). Breast meat percent yield was higher \((P < 0.01)\) for birds consuming the faba bean diets independent of processing. There were no statistical differences in percent yield of the leg quarters. These values are in accordance to Quarantelli and Bonomi (1991). Serum chemical values are presented in Table 10. No statistical significance was observed for any of the parameters measured as was expected.

Conclusions

Data obtained in this experiment is supportive of the utilization of peas \((Pisum sativum)\), faba beans \((Vicia faba \text{ var. minor})\) and lupin seeds \((Lupinus albus \text{ var. multitalia})\) in partial substitution of soybean as an effective protein source. Lupin seeds in general were not as effective as the other two protein sources. Partial improvement was seen with extrusion of the faba beans and peas. This improvement attributed to the extrusion process however, was not seen for the lupin seeds based diets.

The utilization of these alternative proteins sources in broilers diets, without any negative effects in general performance, offers a viable protein option to help counteract the current constraints of soybean meal.

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