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ΕΥΦΡΟΣΥΝΗ ΜΑΛΙΤΣΙΔΟΥ

ΠΤΥΧΙΑΚΗ ΔΙΑΤΡΙΒΗ

ΘΕΜΑ: «ΤΟ ΚΤΗΝΟΤΡΟΦΙΚΟ ΜΠΙΖΕΛΙ ΣΤΗ ΔΙΑΤΡΟΦΗ ΤΩΝ ΑΓΡΟΤΙΚΩΝ ΖΩΩΝ»

ΕΠΙΒΛΕΠΩΝ ΚΑΘΗΓΗΤΗΣ: Δρ. ΒΑΣΙΛΕΙΟΣ ΜΠΑΜΠΙΔΗΣ
ΑΝΑΠΛΗΡΩΤΗΣ ΚΑΘΗΓΗΤΗΣ

ΘΕΣΣΑΛΟΝΙΚΗ 2014

Πίνακας Περιεχομένων

1. Πρόλογος

Η πτυχιακή διατριβή αυτή διενεργήθηκε στην Κατεύθυνση Ζωικής Παραγωγής του Τμήματος Τεχνολόγων Γεωπόνων της Σχολής Τεχνολογίας Γεωπονίας και Τεχνολογίας Τροφίμων και Διατροφής του Αλεξάνδρειου Τεχνολογικού Εκπαιδευτικού Ιδρύματος Θεσσαλονίκης.

Σκοπός της διατριβής αυτής είναι η αξιολόγηση του κτηνοτροφικού μπιζελιού (*Pisum sativum* L.) ως εναλλακτική πηγή πρωτεΐνης και η καταλληλότητα της χρήσης του για τη διατροφή των παραγωγικών ζώων. Αρχικά αναφέρονται η συστηματική ταξινόμηση, η χρήση και οι κυριότερες ποικιλίες του κτηνοτροφικού μπιζελιού, καθώς και τα αίτια που προκάλεσαν το αυξανόμενο ενδιαφέρον για την καλλιέργειά του. Στα επόμενα κεφάλαια παρουσιάζεται η χημική σύσταση του καρπού και του άχυρου του κτηνοτροφικού μπιζελιού, όπως προκύπτει από ανασκόπηση διαφόρων βιβλιογραφικών πηγών. Επίσης, αναφέρονται οι αντιδιαιτητικοί παράγοντες που υπάρχουν στο κτηνοτροφικό μπιζέλι και στο πως αυτοί επηρεάζουν τη διαιτητική του αξία, καθώς και διάφορες μέθοδοι βελτίωσης αυτής. Σε διάφορες ερευνητικές εργασίες μελετήθηκε η εισαγωγή κτηνοτροφικού μπιζελιού στη διατροφή των περισσότερων παραγωγικών ζώων και τα αποτελέσματα στις αποδόσεις τους. Τα αποτελέσματα αυτά, καθώς και αναλυτικοί πίνακες, παρουσιάζονται ξεχωριστά για κάθε είδος ζώου.

Με την ολοκλήρωση αυτής της διατριβής θα ήθελα να ευχαριστήσω τον Επιβλέποντα Καθηγητή μου κ. Βασίλειο Μπαμπίδη για την πολύτιμη βοήθειά του.

Ευφροσύνη Μαλιτσίδου
Ιούνιος 2014

2.1. Περίληψη

Μαλιτσίδου, Ε., 2014. Το κτηνοτροφικό μπιζέλι στη διατροφή των αγροτικών ζώων. Πτυχιακή Διατριβή, Κατεύθυνση Ζωικής Παραγωγής, Τμήμα Τεχνολόγων Γεωπόνων, Αλεξάνδρειο Τεχνολογικό Εκπαιδευτικό Ίδρυμα Θεσσαλονίκης. Θεσσαλονίκη, σελ. 1–34.

Τα τελευταία έτη παρατηρείται αυξανόμενο ενδιαφέρον προς τις εναλλακτικές πρωτεϊνικές πηγές για τη διατροφή των αγροτικών ζώων. Δύο σημαντικοί παράγοντες που συνέβαλαν στην αύξηση του ενδιαφέροντος αυτού, είναι η κρίση της σπογγώδους εγκεφαλοπάθειας των βοοειδών και τα υψηλά ποσοστά εισαγόμενης, γενετικά τροποποιημένης σόγιας, για τη διατροφή των αγροτικών ζώων. Το κτηνοτροφικό μπιζέλι είναι μια αξιόλογη εναλλακτική πηγή πρωτεΐνης αλλά και αμύλου και μπορεί να εισαχθεί με επιτυχία στη διατροφή μεγάλων και μικρών μηρυκαστικών, χοίρων, πτηνών, αλλά και ψαριών. Παρόλα αυτά, η χρήση του ως μοναδική πηγή πρωτεΐνης δε συνίσταται λόγω των εμπεριεχόμενων αντιδιαιτητικών παραγόντων, που σε μεγάλες ποσότητες, επηρεάζουν αρνητικά τη διατροφική αξία των ζωοτροφών.

2.2. Abstract

Malitsidou, E., 2014. Field peas in animal nutrition. Diploma Thesis, Department of Animal Production, School of Agricultural Technology, Food Technology and Nutrition, Alexander Technological Educational Institute of Thessaloniki. Thessaloniki, Greece, pp. 1–34.

In the recent years, there is an increasing interest towards alternative protein sources for animal nutrition. The main factors conducing to that increase are the Bovine Spongiform Encephalopathy crisis and the great amounts of imported, genetically modified soy for livestock feeding. Field pea is a valuable alternative source of protein and starch and it can be successfully included in ruminant, pig, poultry and fish diets. However, field pea use as a unique source of protein is not recommended, due to the contained anti-nutritional factors, adversely affecting its nutritional value, in high concentrations.

3. Introduction

Field peas belong to the family of *Fabaceae*, species: *Pisum sativum* L. Field peas and garden peas used to be classified as two different species, *Pisum arvense* and *Pisum hortense*, respectively, but they are now seen as subspecies or varieties of *Pisum sativum*. Therefore, one could come across various common and scientific alternative names, while browsing in bibliography, such as *Pisum arvense* L., *Pisum sativum* L. ssp. *arvense*, and more (Martin-Sanz et al., 2011).

Field pea (*Pisum sativum* L.) is one of the world's most important grain legumes (FAO, 1993), being a great source of energy, protein, amino acids and other nutrients. Field pea is primarily used for human consumption, commonly used in human cereal grain diets, as well as livestock feed (McKay et al., 2003). The major producing countries of field pea are Russia and China, followed by Canada, Europe, Australia and the United States (McKay et al., 2003).

Field pea varieties can differ in many characteristics such as flower colour, density of leaves and seed colour, shape and size. There are spring and winter varieties as well as early-maturing or late maturing varieties. Some winter varieties thrive even in low fertility soil and temperatures down to -16 ^{o}C, and yield up to 300 kg/1000 m^2 (Iliadis, 2001). Some typical cultivars used in Europe are Magnus, Setchey, Solara, Sponsor, Athos, Baccara, Nitoche, Rif and Gracia (FAO).

The growing interest in the cultivation of field peas arises from the need for an alternative source of non animal protein, other than soy. After the Bovine Spongiform Encephalopathy (BSE) crisis, research focusing on that aim gains increased financial interest (Christodoulou et al., 2006). The two main reasons are the big cost of importing soy seeds from countries outside Europe and the fact that most of those seeds are genetically modified.

4. Chemical composition of field pea grain and straw

The chemical composition of field pea grain is in Table 1. Field peas are a valuable source of protein for most livestock, with high concentrations of essential amino acids (Elzebroek and Wind, 2008). The protein content of field peas may range in different varieties, but there is no confirmed connection between the protein level and the color of the seeds (Igbasan et al., 1997). The content of starch can be up to 54% of dry matter (DM) and the 7.2% of the total protein content comes in the from of lysine, while the same percentage in soy is 6.8% (Sosulski and Holt, 1980; Igbasan et al., 1997). The content of neutral detergent fiber (NDF) is 14.8% DM and of acid detergent fiber (ADF) is 8.55% DM. The gross energy (GE) of field peas is 18.65 MJ/kg DM and the metabolizable energy (ME) is 10.55 MJ/kg DM (Abreu and Bruno-Soares, 1997; López et al., 2005; Mihas, 2008).

Legume straws have higher levels of crude protein (CP) and lower fiber, thus showing better nutritional quality than cereal straws. CP in field pea straw is 8.3% DM (Table 1), while NDF and ADF are 65% DM and 44.65% DM, respectively (Bruno-Soares et al., 1999; López et al., 2005; Mihas, 2008). Field pea straw is also rich in minerals, notably magnesium and calcium (Leclerc, 2003).

Table 1
Chemical composition (g/kg dry matter, unless otherwise stated) of field pea (FP) grain and straw summarized from several sources[a].

Components	Field pea grain	Field pea straw
DM[b] (g/kg)	860	890
Ash	29.0	101.0
CP	243.3	83.0
Crude fat	16.2	21.0
Crude fiber	109.3	363.0
NDF	148.0	65.0
ADF	85.5	446.5
TDN	880	500
Starch	453.0	
Total NSP	162.5	
GE (MJ/kg DM)	18.65	17.90
ME (MJ/kg DM)	10.55	7.70
Calcium (Ca)	0.5	6.0
Phosphorus (P)	4.8	1.5
Magnesium (Mg)	1.3	11.0
Potassium (K)	10.5	1.5
Micronutrients (trace elements, ppm)		
Copper (Cu)	8.15	
Iron (Fe)	82	
Manganese (Mn)	11.1	
Selenium (Se)	0.26	
Zinc (Zn)	44	
Amino-acids (% DM)		
Alanine	1.14	
Arginine	2.25	
Aspartic acid	2.99	
Cystine	0.37	
Glutamic acid	4.44	
Glycine	1.10	
Histidine	0.62	
Isoleucine	1.08	
Leucine	1.81	
Lysine	1.91	
Methionine	0.25	
Phenylalanine	1.21	
Serine	1.14	
Threonine	0.97	
Tryptophan	0.26	
Tyrosine	0.73	
Valine	1.81	

[a] References: Sosulski and Holt (1980), Reichert and MacKenzie (1982), AEC (1987), Würzner et al. (1988), Brenes et al. (1993), Abreu and Bruno-Soares (1997), Igbasan et al. (1997), Bruno-Soares et al. (1999), Pisulewska and Pisulewski (2000), López et al. (2005), Mihas (2008) and Nalle et al. (2011a).
[b] ADF, acid detergent fiber; CP, crude protein; DM, dry matter; GE, gross energy; ME, metabolized energy; NDF, neutral detergent fiber; NSP, non starch polysaccharides; TDN, total digestible nutrients.

5. Anti-nutritional factors (ANFs) in field peas

All legumes, field peas among them, contain anti-nutritional factors (ANFs) which interfere during digestion, causing reduction of the nutritional value of the feed. Furthermore, the improper absorption of nutrients has apparent adverse effects on animal growth and health. It has been reported that some ANFs can cause hypertrophies in monogastrics, affecting various organs such as liver and pancreas (Huisman et al., 1990; Bampidis and Christodoulou, 2011). The most important ANFs of field peas are succinctly presented below.

5.1. Trypsin and chymotrypsin inhibitors

Protease inhibitors are peptides that form complexes with the proteolytic enzymes of the pancreas (Huisman and Van der Poel, 1989). Their natural role is to protect the plant from proteolysis, diseases, animals and insects (Xavier-Filho and Campos, 1989). Most trypsin inhibitors act also on chymotrypsin and other proteases, while only a few present specialization. They are considered responsible for the reduction of protein digestibility in field peas (Pisulewski et al., 1983). Various researchers conclude that the level of trypsin and chymotrypsin inhibitors in field peas depends mostly to the variety of the plant and the environmental conditions (Valdebouze et al., 1980; Griffiths, 1984; Bacon et al., 1991).

5.2. Tannins

Tannins are large polyphenolic compounds with an aromatic ring and one or more hydroxyls. They can be divided into two groups, hydrolysable and non-hydrolysable or condensed tannins (Claden et al., 2001). Many plant species contain hydrolysable tannins while condensed tannins can be found in most legume seeds. Their natural role is to bind to the proteins in the hulls, making the seed resistant to decay and protecting it from predation and pests. Tannins also affect plant growth regulation (Bate-Smith and Swain, 1962).

Condensed tannins have a great impact in animal nutrition because of their ability to form complexes with many macromolecules, such as proteins, carbohydrates and various enzymes involved in digestion (Swain, 1965; Griffiths, 1980; Haslam, 1989). In ruminants, toxicity from condensed tannins could damage the epithelium of the gastrointestinal tract, while it could cause adverse effects in monogastrics' growth (Bernays et al., 1989; Reed, 1995). Field pea varieties with yellow and green seeds have fairly lower levels of tannins than the varieties with dark seeds, ranging from 0.1 g/kg and lower, for the varieties with yellow and green seeds, over to 11.5-41 g/kg for the varieties with dark seeds (Brenes et al., 1993; Igbasan et al., 1997).

5.3. Oligosaccharides

Oligosaccharides are formed by one molecule of sucrose linked with one or more molecules of galactose. Galactosides, a subcategory of oligosaccharides, contain a-lycosides, such as raffinose and stachyose, which could have adverse effects in animal digestion

(Larbier and Leclercq, 1994; Walstra et al., 2005). Dehulled seeds of field peas contain 44.2 to 56.1 grams of oligosaccharides per kilo of dry matter (Reichert and MacKenzie, 1982).

5.4. Lectins, saponins and phytic acid

Lectins are carbohydrate-binding proteins and they naturally take part in biological recognition phenomena. Lectins are possible to cause atrophies in small intestine but the ones contained in field peas present limited activity and have nontoxic effects (Rutishauser and Sachs, 1975; Grant et al., 1983).

Saponins are glycosides that naturally serve as anti-feedants in plants, because of their bitter taste. Besides the reduction of palatability in animal feeds, some saponins are known be toxic in particular concentrations, but there is no recent research to support that the amount of saponins in field pea can have harmful effects on livestock health (Liener, 1980; Hostettmann and Marston, 2005).

Phytic acid is a saturated cyclic acid that serves as the principal storage form of phosphorus in many plant tissues, especially seeds. It has the ability to bind with metal ions, thus making non-absorbable important nutrients such as iron, zinc, magnesium and calcium. Phytic acid also counteracts with some digestive enzymes in ruminants, while it is indigestible for monogastrics. Seeds of field pea contain 22 g of phytic acid per kg DM (Forbes et al., 1984; Blatny et al., 1995; Ali et al., 2010).

5.5. Vicine and convicine

Vicine and convicine are glycosides that can be found in most legume seeds. Their degradation products can cause hemolytic anemia in man. In birds, they can result in a decrease in egg weight and size, weaker egg shells, increased number of blood spots in the egg and a decrease in fertility and hatchability of eggs. In pigs, they have been known to reduce reproductive performance. Nevertheless, there is no direct effect on nutrient digestion and metabolism, due to vicine and convicine or their degradation products (Lattanzio et al., 1983; Marquardt et al., 1983).

6. Improving the nutritional value of field peas

There are many ways to improve the nutritional value of field peas. One commonly used is the improvement via selective plant breeding, which is quite easy for field peas (Duc and Lacassagne, 1990; Bond and Duc, 1993; Gatel, 1994). Caution is advised towards using some European varieties like “Maro” and “Progreta”. While most varieties contain small amounts of ANFs, the above show higher levels of trypsin inhibitors, thus making them potentially harmful especially to monogastrics (Monti, 1983; Bond and Smith, 1989).

Besides genetic choice, there are various processing techniques that affect the secondary compounds of field peas or their nutritional properties and sometimes both, improving their nutritional value (Gupta, 1987; Gatel, 1994; Larbier and Leclercq, 1994; Francis et al., 2001; Adamidou et al., 2009). These processing techniques can be divided in two main groups, physical and chemical treatments (Wiryawan and Dingle, 1999; Khattab et al, 2009).

Physical treatments include mechanical and heat treatments, while chemical treatments can be achieved with the application of enzymes in field pea diets (Longstaff and McNab, 1987; Charlton and Pugh, 1995; Choct et al., 1995; Jeroch et al., 1995; Wiryawan and Dingle, 1999).

6.1. Mechanical treatments

Decortication or dehulling is the most common mechanical treatment used for field peas, as it reduces the level of tannins and fiber in the feed (Gatel, 1994; Gouveia and Davies, 1998; Wiryawan and Dingle, 1999; Gouveia and Davies, 2000). There is also research reporting higher nitrogen digestibility for dehulled peas (Grosjean et al., 1991).

Grinding and pelleting is another effective method to improve field pea digestibility, especially for poultry (Carré et al., 1991; Conan et al., 1992). As Longstaff and McNab (1987) report, grinding significantly improves starch digestibility (88.1% instead of 75.6%) and metabolized energy content (11.38 KJ/g instead of 9.91 KJ/g) in feed.

Soaking is another method used commonly in combination with other treatments such as extrusion (Liener, 1983; Gupta, 1987; El-Hady and Habiba, 2003). As El-Hady and Habiba (2003) report, soaking for 16h in combination with extrusion improves the nutritional value of field peas, as well as other legumes. Nevertheless, it is the least effective method if used separately (Khattab et al, 2009).

6.2. Heat treatments

Heat treatment decreases the activity of trypsin and chymotrypsin inhibitors (TIA) as well as of lectins (Kalać and Míka, 1997; Francis et al., 2001; Habiba, 2002; Dvořák et al., 2005). There are various techniques that include heat treatment, from boiling water to infrared radiation and extrusion, in order to improve the nutritional value of field peas (Wiryawan and Dingle, 1999; Masoero et al., 2004). Heat treatments can improve starch digestibility by 5% to 20% according to Longstaff and McNab (1987).

Extrusion is a process that combines high pressure with steam heating (Alonso et al., 1998; Nalle et al., 2011a). It reduces the activity of TIA (Bertrand et al, 1982; Grosjean and Gatel, 1989; Bengala-Freire et al., 1991) and it is considered more efficient on lectins than dry heating (Gatel, 1994). There is research showing that extrusion improves starch and protein digestibility and reduces phytic acid (Goelema et al., 1999; Aufrere et al., 2001; Alonso et al., 2011). Masoero et al. (2004) report that starch enzymatic degradability increased from 11.8% to 39.7% for untreated and extruded peas respectively.

Infrared radiation can inactivate trypsin inhibitors (Van Zuilichem and Van der Poel, 1989). Research with broilers showed that infrared radiation on peas increased metabolizable energy as well as protein and starch digestibility (Igbasan and Guenter, 1996).

Autoclaving inactivates trypsin inhibitors, increases the total essential amino acid content and is considered by some the most efficient treatment to improve protein quality (Brenes et al., 1993; Khattab et al, 2009). Researchers conclude that autoclaving acts more by improving enzymatic digestion of nutrients than by inactivating ANFs (Carré et al., 1991).

There are other applied heat treatments such as boiling, toasting and microwave cooking (Gupta, 1987; Khattab et al., 2009). All heat treatments can be inefficient under suboptimal conditions. Excessive heat can result in a reduction of protein digestibility and destruction of certain amino acids (Van Barneveld et al., 1993; Wiryawan and Dingle, 1999), while specific temperature and duration is required for inactivation of different ANFs (Liener, 1983; Griffiths, 1984; Gatel, 1994).

6.3. Chemical treatments

Enzyme supplementation improves the nutritional value of wheat and grain legumes by increasing protein values and metabolizable energy (Choct and Annison, 1992; Choct et al., 1995; Hew et al., 1995). It is also reported to be equally effective with heat treatment in reducing ANFs (Wiryawan and Dingle, 1999). In research conducted about the effects of enzyme supplementation in ten different legumes, field pea among them, researchers report an increase of the true metabolizable energy for most legumes (Wiryawan et al., 1995). Other research reports that net protein ratio of field pea improved by 3.71% after supplementation of chicken diets with xylanase, a-amylase and protease (Wiryawan et al., 1997).

Effects of some mechanical and heat treatments on the chemical composition and ANFs of field peas are presented in Table 2 and Table 3, respectively.

Table 2
The effect of processing on the chemical composition (g/kg dry matter) of field pea grain summarized from several sources[a].

Components	Treatment					
	Raw/Whole	Dehulled	Boiled	Extruded	Expanded	Toasted
CP[b]	24.15	24.03	10.2	24.80	24.40	24.15
Fat	1.40	–	1.30	1.78	3.66	1.40
Fiber	55	24	10.80	41	–	–
Starch	49.61	–	–	45.2	47.92	49.61
Ash	3.70	3.50	0.43	4.60	3.93	3.70

[a] References: Castel et al. (1996), Hernandez-Infante et al. (1998), El-Hady and Habiba (2003), Masoero et al. (2005), Prandini et al. (2005), Diaz et al. (2006), Adamidou et al. (2009b) and Kalogeropoulos et al. (2010).
[b] CP, crude protein.

Table 3
The effect of processing on anti-nutritional factors (ANFs) of field pea grain summarized from several sources[a].

Treatment	ANFs			
	Lectins (units/mg)	Tannins (mg/g)	Trypsin Inh. (mg/g)	Polyphenols (mg/g)
Raw	200	7.6	17.70	11.19
Boiled	–	2.5	0.36	–
Oven heated	192	7.5	17.40	–
Toasted	–	0.39	0.92	2.27
Microwave cooked	196	7.4	17.90	–
Autoclaved	–	5.1	0.70	–
Extruded	–	0.12	0.24	8.08
Expanded	–	0.34	0.40	7.54
Infrared radiation	10	6.7	0.66	–

[a] El-Hady and Habiba (2003), Masoero et al. (2005), Prandini et al. (2005) and Adamidou et al. (2009b).

7. Use of field peas in animal nutrition

The increasing interest for alternative protein sources in animal nutrition resulted in extensive research about the nutritional value of field pea and its adequacy as a protein source. Researchers report its successful use in lactating and growing ruminants (Hoden et al., 1992; Corbett et al.,1995; Petit, 1997), in broilers and layers (Moschini et al., 2005; Dotas et al., 2014), turkeys (Palander et al., 2006; Juodka et al., 2010), pigs (Bonomi, 2005), rabbits (Maertens et al., 2002) and fish (Allan et al., 2000; Burel et al., 2000; Booth et al., 2001; Adamidou et al., 2009a,b), as well as in rats (Mitchell et al., 1989; Hernandez-Infante et al., 1998).

7.1. Field peas in cattle nutrition

Masoero et al. (2006) conducted research in order to evaluate the nutritional value of field peas in lactating dairy cows' feeding. Holstein cows were fed with diets in which field pea replaced soybean and barley in the total mixed ration (TMR), in proportions of 6.6:3.4:0 and 0:0:10.3 % DM (as fed) for barley, soybean and pea (raw, extruded or expanded), respectively. They reported that cows fed with the extruded pea diet presented a 3.2% increase of milk yield compared to those fed the control diet, but different treatments on peas did not have a significant effect on milk yield. There were no negative effects on milk composition and no health problems that could be related to the feed were presented. The inclusion of pea did not affect the dry matter intake (DMI) suggesting no effects on palatability.

In their research, Volpelli et al. (2009) present the results of two different experiments conducted to evaluate flaked peas as a soybean substitute. Lactating Reggiana dairy cows were fed in both experiments with diets in which flaked peas partially replaced soybean meal in the concentrate, in proportions of 8.3:0 and 5:15 % as fed, for soybean meal and flaked peas, respectively. They report no significant changes in milk yield, no effects on palatability, and no health problems that could be related to the feed. Although the protein content of milk was not affected by the inclusion of pea, milk urea increased by about 8%.

Table 4 presents the effects of field pea inclusion in the diet of dairy cows, as it occurs by Masoero et al. (2006) and Volpelli et al. (2009).

7.2. Field peas in sheep nutrition

Various researchers have studied the effects of field peas on sheep nutrition and performance (Purroy et al., 1992; Vasta et al., 2008). Although most research focuses on growing lambs for meat production, there are a few references about lactating ewes and the effect of field pea use on milk production and composition (Bernes et al., 2012). In trials done to evaluate the use of field peas in partial or total replacement of soybean meal, results were slightly better for lambs fed diets where soybean meal was only partially replaced (Purroy and Surra, 1990; Lanza et al., 2003; Lanza et al., 2007; Bonanno et al., 2012).

Lanza et al. (2003) used thirty Barbaresca male lambs fed a soybean meal diet and two different pea diets. Peas partially and totally replaced soybean meal in proportions: 16:0% for soybean meal diet (as control diet), 9:18% and 0:39% for diet in which peas totally replaced soybean meal and diet in which peas partially replaced soybean meal, respectively. No significant differences were found in the average daily gain, growth rate and in final weight among groups, however daily gain was higher for lambs fed diets in which peas partially replaced soybean meal. Average daily gain for animals fed soybean meal diet was 218 g/d, for animals fed diets where peas totally replaced soy was 219 g/d, and for animals fed diets where soybean was partially replaced by field peas was 250 g/d. Pea diets did not significantly altered meat quality, although there was an increase of drip loses compared to soybean meal diet.

Loe et al. (2004) studied the effect of pea inclusion in corn-based diets, with or without soybean meal. Pea replaced corn in 0, 150, 300 and 450 g/kg on DM basis. There was also a fifth experimental diet formed, containing the highest level of field pea (450 g/kg) and no soybean meal. Results showed that the daily DM intake decreased between the diets of 150 g/kg and 300 g/kg, however final BW and average daily gain were not affected by treatment. No significant change on meat quality was reported.

In other research, Lanza et al. (2011) studied the effect of using field pea concentrates in comparison with soybean meals, as main protein sources for growing lambs. Thirty Comisana x Valle Del Belice cross lambs were fed with diets containing 400 g/kg field peas, in total replacement of soybean meal. Growth performance and meat characteristics were not significantly affected by field pea inclusion. Average daily gain was 251 g/d.

Bonanno et al. (2012) in their experiments used 28 male Comisana lambs fed with barley concentrates mixed with a different source of protein. The amounts of soybean meal and field pea were 250 g/kg and 858 g/kg, respectively. The growth performance and final BW were not significantly affected by the different protein sources, neither was the quality of meat. Table 5 presents the effects of field pea inclusion in the diet of growing lambs as it occurs from several sources.

Table 4
The effects of field pea (FP) grain on performance of lactating dairy cows summarized from several sources.

Feedstuff	FP processing	FP level (g/kg DM[a] TMR)	Cattle	Feed intake (kg/day)	Milk yield (kg/day)	Fat (g/kg)	CP (g/kg)	Lactose (g/kg)	Reference
Control diet		0	Holstein	22.34 kg DM/d	34.37	36.7	34.0	51.3	Masoero
FP seeds	raw	103 g/kg DM	dairy cows	22.59 kg DM/d	34.20	36.4	33.6	51.5	et al. (2006)
	expanded	103 g/kg DM		34.36 kg DM/d	34.36	36.0	33.2	51.2	
	extruded	103 g/kg DM		22.54 kg DM/d	35.47	35.2	33.8	51.5	
Control diet		0	30 Reggiana	7.80 kg TMR/d	21.52	36.1	33.7	49.8	Volpelli
FP concentrate	flaked	150 g/kg DM	dairy cows	8.14 kg TMR/d	20.92	35.6	32.7	49.2	et al. (2009)
Control diet		0	22 Reggiana	8.65 kg TMR/d	24.37	37.1	34.9	49.2	
FP concentrate	flaked	150 g/kg DM	dairy cows	8.70 kg TMR/d	24.24	35.5	33.3	48.6	

[a] CP, crude protein; DM, dry matter; TMR, total mixed ration.

Table 5
The effects of field pea (FP; g/kg) grain on performance of growing lambs summarized from several sources.

Feedstuff	FP level	Sheep	Feed intake (g DM[a]/day)	BW gain (g/day)	FCR (g feed /g BW gain)	Carcass weight (kg)	Meat characteristics				Reference
							pH	Moisture	Protein	Fat	
Control diet	0	Barbaresca	1016	218	4.70	12.50	5.7	72.90 %	22.60%	3.50 %	Lanza et
FP seeds	180	male lambs	1025	250	4.10	13.30	5.6	72.30 %	23.00 %	3.60 %	al. (2003)
	390		1054	219	4.80	13.60	5.6	73.00 %	22.60 %	3.40 %	
Control diet	0	Columbia ×	1580	353	–	32.20	–	–	–	–	Loe et al.
FP dry	150	Hampshire	1660	367	–	32.90	–	–	–	–	(2004)
	300	crossbred	1570	366	–	31.40	–	–	–	–	
	450	lambs	1580	338	–	34.30	–	–	–	–	
FP dry + SBM	450		1560	368	–	–	–	–	–	–	
Control diet	0	growing	1470	278	5.28	18.11	5.86	74.05 %	23.34 %	1.20 %	Lanza et
FP concentrate	400	lambs	1370	251	5.45	17.45	5.78	74.05 %	23.34 %	1.26 %	al. (2011)
Control diet	0	Comisana	495	186	4.68	11.20	–	–	–	–	Bonanno
FP	858	lambs	546	184	5.45	11.60	–	–	–	–	et al. (2012)

[a] BW, body weight; DM, dry matter; FCR, feed conversion ratio; SBM, soybean meal.

7.3. Field peas in pig nutrition

There are many references about field peas in pig nutrition and their use for pigs of different ages and stage of growth (Savage and Deo, 1989; Castell, 1990; Gatel and Grosjean, 1990; Sauer et al., 1990; Castell and Cliplef, 1993; Canibe and O'Eggum, 1997; Stein et al., 2006; Htoo et al., 2008; Bauza et al., 2013).

Castell et al. (1996) reported that starter pigs fed raw field peas presented reduced feed intake and growth, although these effects were eliminated when extruded pea was used. In growing pigs, field pea inclusion reduced daily gain however, when supplementary amino acids were added, no adverse effects on growth rate were presented. Finishing pigs did not present any significant differences in growth rate and daily gain but some carcass characteristics were affected by extensive use of field pea at that stage. Concerning breeding stock feeding, field pea use did not cause any adverse affects on semen quality of boars. On the contrary, there was a reduced litter size at birth, when sows were fed pea diets.

O'Doherty and Keady (2001) studied the effects of expanded and extruded field peas in diets of growing and finishing pigs (Table 6). Four experimental diets were fed to Landrace × Large White growing and finishing male pigs: A control cereal diet with no field peas and three pea diets with 400 g/kg raw peas, 400 g/kg expanded peas, and 400 g/kg extruded peas, respectively. They report that the inclusion of raw peas adversely affected growth rate for both growing and finishing pigs, while the inclusion of expanded peas affected growth rate of finishing pigs only. On the contrary, the inclusion of extruded peas significantly improved growth rate and feed conversion ratio (FCR). No difference in average feed intake between cereal and pea diets was reported.

Table 6
The effect of field pea (FP; g/kg) grain on performance of pigs summarized from several sources.

Feedstuff	FP level	Pigs	DFC[a] (kg/day)	BW gain (kg/day)	FCR (kg DFC/kg BW gain)	Carcass weight (kg)	Reference
CD	0	Growing-	2.120	0.981	2.17	72.00	O'Doherty
FP raw	400	finishing	2.120	0.927	2.32	71.80	and Keady
FP expanded	400	male pigs	2.130	0.940	2.28	73.60	(2001)
FP extruded	400		2.210	1.016	2.18	72.70	
SBM (CD)	0	Weaned	0.811	0.383	2.09	–	Prandini et
FP raw	200	piglets	0.812	0.370	2.16	–	al. (2005)
FP extruded	200		0.840	0.354	2.35	–	
SBM (CD)	0	Growing-	–	0.740	–	–	Chrenková
FP raw	150	finishing	–	0.840	–	–	et al.
FP extruded	300	male pigs	–	0.900	–	–	(2011)

[a] BW, body weight; CD, control diet; DFC, daily feed consumption; FCR, feed conversion rate; SBM, soybean meal.

Trials conducted by Prandini et al. (2005) evaluated the suitability of raw and extruded peas as feed for weaned piglets, in comparison with soybean meal and lupin. The field pea level in the feed was 200 g/kg for both raw and extruded pea diets. According to their results, feed intake and average weight gain were not affected by different diets. Piglets of 22 to 42 days of age fed with raw peas presented the highest feed conversion rate of 2.35 in comparison with 2.16 and 2.09 for extruded pea and soybean meal diets, respectively.

In other research, Chrenková et al. (2011) studied the effects of field pea use in pig nutrition, meat production and quality. Thirty Slovak White Meaty x Pietrain pigs were fed with a control soybean meal diet and two pea diets, each containing 15% raw and 30% extruded pea respectively. They reported no adverse effects on average weight gain, chemical composition and quality of meat, although ω-3 and ω-6 fatty acids were significantly lower in pigs fed pea meals.

7.4. Field peas in poultry nutrition

Broiler chickens have high nutritional needs and require feeds with high contents of CP and essential amino acids. Pea inclusion in high rates satisfies these requirements but increases the concentration of ANFs in the feed (Ravindran et al., 2010). On the contrary, layer hens are not as easily affected by ANF content, require less protein and have lower energy needs (Castell et al., 1996). However, inclusion of 300 g/kg of field peas in layer diets tends to reduce feed utilization and egg production, while inclusion in levels up to 500 g/kg significantly reduce egg production (Moran et al., 1968; Davidson, 1980; Castenon and Perez-Lanzac, 1990). Igbasan and Guenter, (1996) studied the effects of field peas on broiler performance and nutrition. They reported that field peas, when included in levels higher than 200 g/kg tend to reduce body weight and feed conversion ratio (FCR) but these effects could be minimized by protein and essential amino acid supplementation.

McNeill et al., (2004) studied pea inclusion in broiler diets and their effect on growth rate and performance. Peas were included in levels of 100 and 200 g/kg as fed, but significant adverse effects in feed palatability were noted. Feed conversion was not affected by treatments, but feed intake and body weight were significantly reduced.

In recent research, Dotas et al. (2014) studied the effects of field pea supplementation on performance of broiler chickens. Five dietary treatments were formed, with raw field peas partially substituting soybean meal and corn. They report similar growth performance for all treatments and no adverse effects on carcass and meat quality induced by the use of field peas.

Field pea inclusion results to lower average daily gain but has no significant effects on breast and leg quarter weights (Quarantelli and Bonomi, 1991; Moschini et al., 2004; Nalle et al., 2010) or lipid and protein oxidation of meat (Laudadio and Tufarelli, 2010). Most researchers agree that the higher level of inclusion should be avoided during the first three weeks of growth where birds might be more sensitive to limiting amino acids. Tables 7 and 8 present the effects of field pea inclusion in diets of broiler and layer chickens, respectively.

Table 7
The effect of field pea (FP; g/kg) grain on performance of broilers summarized from several sources.

Feedstuff	FP level	Poultry	FI[a] (g)	BW gain (g/bird)	FCR (g FI /g BW gain)	Carcass yield (g/100 g BW)	Reference
Control diet	0	Broilers	560.4 g/d	403.1 g	1.38	–	Igbasan and
FPYC	150	(5–19 days of age)	563.4 g/d	397.2 g	1.41	–	Guenter (1996)
	300		560.7 g/d	377.9 g	1.48	–	
	450		523.5 g/d	345.5 g	1.51	–	
FPYC + methionine	300		584.1 g/d	419.9 g	1.39	–	
FPGC	150		556.9 g/d	390.4 g	1.42	–	
	300		532.9 g/d	362.9 g	1.47	–	
	450		492.2 g/d	306.6 g	1.61	–	
FPGC + methionine	300		596.3 g/d	421.8 g	1.41	–	
Control diet	0	Broilers	4528 g	2601 g	0.57	–	McNeill et al.
FP	100	(1–42 days of age)	4556 g	2588 g	0.57	–	(2004)
	200		4148 g	2431 g	0.58	–	
Control diet	0	Broilers	147.7 g/d	3019.8 g	2.10	–	Diaz et al.
FP raw	353	(1–42 days of age)	159.1 g/d	3217.2 g	2.08	–	(2006)
FP extruded	353		156.6 g/d	3217.2 g	2.05	–	
Control diet	0	Broilers	3718 g	2459 g	–	–	Nalle et al.
FP	200	(1–35 days of age)	3772 g	2548 g	–	–	(2010)
FP + meat meal	200		3694 g	2369 g	–	–	
Raw FP	0	Male broiler chickens	101.2 g/d	2460 g	1.73	73.3	Dotas et al.
	40-120[b]	(1–42 days of age)	105.7 g/d	2428 g	1.83	73.9	(2014)
	80-240[b]		100.9 g/d	2400 g	1.77	73.5	
	120-360[b]		102.9 g/d	2378 g	1.82	73.4	
	160-480[b]		105.5 g/d	2409 g	1.84	74.2	

[a] BW, body weight; DM, dry matter; FCR, feed conversion rate; FI, feed intake; FPGC, field pea green chips; FPYC, field pea yellow chips.
[b] Field pea level in feed differs according to growth period (starter, grower, finisher).

Table 8
The effect of field pea (FP; g/kg) grain on performance of layers (Moran et al., 1968).

Feedstuff	FP level	Poultry	AWG[a] (g)	DFC (g/day)	EP (eggs/hen/day)	EW (g)
CD-SBM	0	Laying hens	159	118	0.938	59.3
FP raw	150		218	118	0.908	58.6
FP raw	300		166	119	0.912	59.1
FP pelleted	150		174	114	0.907	59.1
FP pelleted	300		200	117	0.917	59.0

[a] AWG, average weight gain; CD, conrol diet; DFC, daily feed consumption; EP, egg production; EW, egg weight; SBM, soybean meal.

7.5. Field peas in fish nutrition

The use of legume crops in fish diets can sufficiently replace wheat as a starch source. At the same time the high protein content can partially replace fish meal and plant proteins in fish nutrition (Gouveia and Davies, 1998; Booth et al., 2001; Adamidou et al., 2009a,b).

Adamidou et al. (2009b) evaluated the nutritional value of field peas, chickpeas and faba beans in trials done with European sea bass (Table 9). Field peas were fed to fish in proportions of 0, 165, and 335 g/kg. No significant differences in final BW, feed intake or feed conversion rate were reported. Significantly better fillet yield was found for fish fed higher proportion of field pea, but no other differences were found in sea bass fillet organoleptic characteristics.

Table 9
The effect of field pea (FP; g/kg) grain on performance of growing fish.

Feedstuff	FP level	Fish	FI[a] (g/100 g BW)	Initial BW (g)	Final BW (g)	FCR (g FI/g BW gain)	Fillet yield (g/100 g BW)	Reference
Extruded FP	0	European	1.08	102.4	250.5	1.34	41.0	Adamidou et al.
	165	seabass	1.11	98.6	264.2	1.27	–	(2009b)
	335		1.17	96.5	256.0	1.35	44.2	

[a] BW, body weight; FCR, feed conversion ratio; FI, feed intake.

8. Conclusions

The ban of meat meals due to BSE and the rising public concern about GMOs, have increased attention towards the use of local protein sources to satisfy animal protein requirements. Field peas are adequate to European climate and many varieties can thrive in Mediterranean countries. Field pea is an appropriate protein and starch substitute and could safely replace soybean meals in the diets of animals. Inclusion of field pea in cow diets has no adverse effects on milk composition and dairy performance. Concerning small ruminants, the use of field peas is quite extensive in meat production animals and less common in milk production farming. Field pea can be a partial substitute for corn and soybean meal in growing lambs and pigs without detrimental effects on meat production. In poultry diets field pea should be sparingly used, in levels not higher than 200-300 g/kg. Research has yet to advance towards the use of field peas in fish and rabbit nutrition, although field pea can partially replace meat meals in fish nutrition without adverse effects on fish growth and performance. Better results are generally reported when field pea is used in combination with other protein sources or supplementary amino acids. Field pea is a notable alternative protein source and its use should be encouraged.

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