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WHITE LUPINE SEEDS (*LUPINUS ALBUS,* L) FROM LOW-ALKALOID VARIETIES, A POTENTIAL SOURCE OF PROTEIN FOR POULTRY NUTRITION: A REVIEW

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Abstract

The ban of using animal flavours in pultry feeding and the high price of soy products and by-products due to the increasing demand for these feeds, enforce the requirements for finding out alternative protein sources to offset the protein balance in poultry farming. On this line, the white lupine beans can be a promising potential alternative in insuring the on-farm protein production for poultry feeding in our country. New lupine varieties are showing yields around 3500-3800 kg grains / ha, a very low alkaloids (below 0.02%), 31-48% protein and 6-10% fat content (depending on the climatic conditions). The lupine, like many other seeds of the legume *family, has a low limiting amino acids content (modest methionine, lysine, tryptophan and threonine content), compared to soybean meal.* ***The*** *high non-starch polysaccharides content is another limiting factor of using lupine in poultry feeding. The input of lupine up to 25% in broiler feeding, meaning about 30% of the protein requirements through to 21 days* of *age and 60% further to slaughtering, drives to similar outcomes as those acquired through soybean meal based diets. The lupine can be integrated in laying hen feeding up to 15% without interfering with egg production, eggs quality or feed efficiency level. Lupine beans showing a high content in essential fatty acids reveal a favorable outcome on the fatty acids of meat and egg yolk. Thus results in a decrease of the saturated fatty acids ratio having high androgenic potential (C14:0, C16:0, C18:0) and an increase of the polyunsaturated fatty acids ratio n-6 and n-3 (mainly, α-linolenic acid), and therefore enhance the nutritive value of the agro-food poultry products, in terms of the impact on human health.*

Key words: lupine, crude protein, nutrition and feeding, broilers, laying hens.

INTRODUCTION

Considering the banning of using animal flavours in poultry feeding and the high price of soy products and by-products, due to the increasing demand for these feeds, the necessity to start out studies and researches concerning the use of alternative protein sources to offset the protein balance in poultry farming become more and more stringent. This necessity is even greater for our country, since it is not showing suitable climate conditions for soybean production. On this line, the lupine beans may be a promising potential alternative in insuring the on-farm vegetable protein production for poultry feeding in our country.

In Europe, the cultivation of lupine species remain still far behind of those of other plants of the legume family, although it is the only one high productive on heavy or depleted soils (Sujak et al., 2006). Apart from the high protein content, the lupine is showing a higher nitrogen fixation capacity, organic phosphorus release and is improving soil value for the next crop (Kasprowicz-Potocka et al., 2016). Although in the last few decades more studies have been conducted on the sweet lupine, mainly for gathering species with a higher protein content and lower anti-nutritional compounds (especially alkaloids), in Romania the interest for cultivating such plants and mainly for using such valuable protein source in animal feeding is still down rated.

Old white lupine varieties, due to the high alkaloids content (2-4%), present a limited use in animal feeding, injuring their bio-productive performance (Gdala, 1998; Wasilewko and Buraczewska, 1999; Rutkowski et al., 2017). Lupine high productive varieties showing lower alkaloids content (below 0.02%) have been created lately, so these may be used as the main protein source even for monogastric feeding (pigs and poultry).

Scientific data describe new lupine varieties showing yields around 3500-3800 kg grains/ha, 31-48% protein and 6-10% fat content (depending on the climatic condictions). The lupine, like many other seeds of the legume family, has a low content of limiting amino acids (modest methionine, lysine, tryptophan and threonine content – Strakova et al., 2006), compared to soybean meal, which may restrict its use in poultry feeding, driving to the necessity of rise up the protein biological value by supplementing synthetic amino acids into the combined fodder. The high non-starch polysaccharides content is another limiting factor of using lupine in poultry feeding (Boch-Knudsen, 1997). The climatic conditions of our country stand for high lupine beans yields meeting the quality and quantity criteria (Mierlita si col., 2012).

The use of lupine in poultry feeding ensure in a certain manner an independence related soy products and by-products, along with a decrease in price / kg fodder, driving to a positive effect on the profit achievement. The start out of lupine cultivation in Romania should lead to plant production diversification, having a positive impact on the demand: supply ratio, all toghether in the context of a market mainly indicating a cereal prevalence. Moreover, lupine beans should not be exposed to heat treatment to destroy the anti-nutritive factors (e.g. trypsin inhibitors like in the case of soy beans), and also they are not genetic modified, turning out to be an important protein source suitable for ecological farming (Dora et al., 2002). The lupine beans in comparison with the soybeans, have lower levels of phytic acid and saponins, but also of lectins and protease inhibitors, improving the protein digestion (Sujak et al., 2006).

These legume beans are not only a valuable protein source, but at the same time an energy source, due to the high fat content (Petterson et al., 1997; Hickling 2003).

TAXONOMY AND CLASSIFICATION

The term ”lupine” is widely used to describe the seeds of various domesticated lupine species. The lupine is a member within genus *Lupinus* L., family of legumes (Fabaceae), order Fabales (Kurlovich, 2002). Among the 200 species of genus *Lupinus*, the white lupine (*L. albus* L.), the yellow lupine (*L. luteus* L.) and the narrowleaf lupine (*L. angustifolius* L.) are the most frequent cultivated, the latest one being the most commonly cultivated in Australia.

Among the cultivated species, the white lupine (*Lupinus albus* L.) is the most valuable for animal feeding, esspecially due to the high production potential, but also to the high protein and fat content [Erbas et al., 2005; Andrzejewska et al., 2016; Rybinski et al., 2017). The white lupine is an autogamous plant, with white or blue florwers, reaching the height of 0.75-1 m. The seeds are large, having a cream color, a circular flattened shape, and with a 1000-seed weight of 350-400 g.

AGRONOMIC PROPERTIES OF THE WHITE LUPINE CULTURE

The agronomic properties (pedoclimatic demands) of lupine for cultivation in our country, are more favourable (actually optimal), compared to those of soy. The lupine prefer the fields having a moderate fertility, an average content of organic matter and good water drain. The excess of organic matter and water results to specific disease advents affecting the root. Tap roots penetrate the soil into depth, facilitating nutrients absorbtion from deep soil layers.

Sowing shall be done in spring as soon as possible (April 15th – 20th) in order to avoid high temperatures during flowering when some of the flowers abort. Before sowing, lupin seed should be treated with *Rhizobium lupini* – bacterium which increases the nitrogen-fixing ability from atmosphere. During vegetation, throughout the symbiosis of lupin plants with these nitrogen figing bacteria, 160-200 kg atmosphere nitrogen / ha can be fixed in soil, wherefrom roughly ½ remains in the soil, thereby concurring to soil fertility increament. Consequently, only one fertilization shall be performed in lupine culture, ensuring 15 kg nitrogen/ha for sowing.

Harvesting is done at full of ripening (August 20th – 25th); harvest delays can cause significant production losses. As beans ripening is not homogeneous, artificial drying is required after harvesting to avoid production damage.

The climatic conditions of our country provide the prerequisites for reaching white lupin beans yields meeting the quantitaty and qualitaty criteria (2900-3100 kg/ha: Mierlita et al., 2012).

Nutritional characterization of white lupine seeds

Crude protein content in white lupine seeds, among the low alkaloids content varieties, rage between 32 si 41% (% DM), depending on the variety and pedoclimatic conditions (table 1). Even at the same lupine variety (Juno), protein content vary in the range of 39.8 to 48.2%, based on the year of harvest (Strakova et al., 2006).

Table 1

Nutrient composition of lupin seeds (*Lupinus albus*, L)

Cultivar	% of DM			Reference
	Crude protein	Ether extract	Crude fibre	
Amiga	34.1	9.9	-	Brenes et al., (2005)
	37.6	7.3	13.8	Roth-Maier et al., (1993)
	33.7	10.8	13.4	Zralý et al. (2007)
	36.4	10.2	12.9	Mierlita et al. (2017)
Hetman	37.0	10.4	10.7	Zdunczyk et al. (1996)
	31.9	10.4	12.2	Gdala et al. (1996)
Lublanc	38.4	7.9	14.7	Gdala et al. (1996)
	41.2	7.8	18.4	Mierlita, 2012
Energy	34.1	8.5	15.3	Mierlita et al., (2017)
Butan	38.5	7.9	15.3	Písaříková et al. (2008)
	35.5	10.2	11.7	Grela et al., (2017)
	37.6	10.4	13.7	Sujak et al., (2006)
Marta	37.4	11.3	-	Martinez-Villaluenga et al., (2006)

The white lupine proteins are rich in lysine and arginine (Sobotka et al., 2016). The lower level of sulfur amino acids (methionine and cysteine) and threonine of white lupine beans compared to soybean, next to the significantly higher content of arginine define its amino acid profile (Straková et al., 2006).

The white lupine beans fat composition vary between 5.7 and 12.1%, mainly represented by the oleic acid (C18:1 n-9) and the linoleic acid (C18:2 n-6) (Andrzejewska et al., 2016; Rybinski et al., 2017). Although lupine seeds fats are less approached, they may have an important nutritional role related to the influence on the fatty acids profile of fats included into animal agro-food products. Zduńczyk and Jankowski (2013) and Mierlita (2012, 2013, 2015) have carried out comprehensively approaches to improve fatty acids profile of egg yolk and poultry meat lipids, throughout partial replacement of the soybean meals with white lupine.

The non-starch polysaccharides (NSP) content of lupine seeds, compounds having an anti-nutritional effect is almost twice that of other protein-rich feeds (Gdala and Buraczewska, 1996; Knudsen, 2014). All the same, recent studies have proved that the lupine proteins are digested likewise those of soybean meal (Hughes and Kocher 1998; Hammershoj and Steenfeldt, 2005) or even better (Kaczmarek et al., 2014, 2015). The benefits of using enzymes in lupine based diets have been pointed out by many authors (Kocher et al., 2000; Hughes et al., 2000; Brenes et al., 2003; Mieczkowska et al., 2004).

The energy value of lupine beans varies between 1920 and 3570 kcal / kg DM depending on the variety, the pedoclimatic conditions and the alkaloids content (Brenes et al., 1993, Hughes et al., 1998; Kocher et al., 2000). Although the pupine has a high fat content, however it shows a low energy value due to the high NSP content (Kocker et al., 2000). The calculations performed are showing that for each percentage point of lupine in poultry diet, the energy value decreases with 0,288 MJ EM/kg (Sipsas and Glencross, 2005), and by adding specific enzymes into the feed, the apparent energy digestibility increases with 3.2 percentage points (Boguslaw et al., 2010) next to the aminoacids and protein intake (Wiryawan and Dingle, 1999; Kluge et al., 2002).

ANTI-NUTRITIONAL COMPUNDS CONTENT

The white lupine does not contain significant amounts of specific anti-nutritional factors (phytates, lectins, tannins, trypsin inhibitors), which can be found in other legumes. Alkaloids, the main inconvenient bygone of lupine, nowadays are no longer a problem since modern cultivated lupine varieties (also called sweet lupine) carry on only traces of these toxins. Currently, the non-starch polysaccharides (NSP) are the most important factor limiting the use of lupine in poultry feeding, which may stand up to 40% of DM (Petterson 2000, Kluge et al., 2002). NSP show a low digestibility in poultry. A higher NSP content in feed results in an increased viscosity of the intestinal contents (especially of the ileum) and moisture excretion, interfering with feed intake and efficiency (Kocher et al., 2000, Steenfeldt et al. 2003).

Bioproductive efficiency of lupine use in poultry feeding

Most of the studies performed have shown that the use of lupine up to 25% in broiler feeding conduct to similar results as those achieved throughout soybean meal based diets Centeno et al., 1990; Brenes et al., 1993; Lettner and Zollitsch 1995; Sitko and Cermac, 1998; Egorov et al., 2001; Nalle et al., 2010; Suchy et al., 2010; Mierlita et al., 2014). Froidmont et al. (2004) concluded that the feed may contain lupine flour up to a maxiumum ratio of 30%, in order to maintain the growth performance of broilers, but lupine cannot completly replace soybean meal in poultry diets. Moschini et al. (2004) and Nalle et al. (2010) claim that broilers, through to 21 days of age cannot tolerate lupine amounts higher than 200 g / kg combined fodder.

The use of lupine as a sole protein source for poultry farming is limited on the one hand by the biological value of the protein (modest content in methionine, lysine, threonine and tryptophan – Strakova et al., 2006), and on the other hand by the high NSP content (non-starch polysaccharides), which have a negative impact on the digestive processes and feed efficiency (Kocker et al., 2000; Brenes et al., 2002; Steenfeldt et al., 2003; Mieczkowska et al., 2004; Choct, 2006). Raising up the lupine efficiency in poultry feeding may be achieved throuhout the use of specific enzyme preparations or the shell of the beans, being able to replace up to 50% of the soybean meals comprised into the combined fodder composition, without changing broiler bioproductive performances (Suchy et al., 2006).

The input of lupine beans in ratios exceeding 35% in broiler diet reduce their production performances (Gilbert et al., 2000a; Roth-Maier and Paulics 2003; Steenfeld et al., 2003); the negative impact of lupine is due to the NSP high amounts (non-starch polysaccharides).

A resurvey carried out of Van Barneveld (1999) claims that high lupine levels in broiler feeding (300-400 g / kg) are associated with excessive moisture of livestock manure, which hampers the maintenance permanent litter and also may affect the health of poultry.

Mieczkowska and Smulikowska (2005) and Strakova et al., (2010) showed that the input of lupine in poultry diet leaded to an increased concentration of oleic acid and α-linolenic acid in the fat from the poultry meat. According to Zelenka et al., (2006, 2008) poultry dietary supplementation with essential fatty acids lead to a better meat quality and which can be defined a functional feed.

The results achieved by Mierlita si Popovici (2013) prove that the replacement of soybean meal protein with lupine flour in a ratio up to 30 % in the starter phase (1-21 days), 60 % in the growth phase (22-35 days) and finishing phase (36-42 days), has no negative impact on weight gain, feeding efficiency, carcass and meat quality, if the combined fodder are properly balanced in energy, protein and limiting amino acids. A significant decrease ($p < 0.05$) in performance was noted when the protein replacement level of soybean meal with lupine reached up 40% in the starter phase and 80% in the growth and finishing phase. Compared to the control lot, the final body live weight of the pullets registered lower values with 7.19%, all together with the feed intake ones lower with 5.47%, while the feed conversion ratio turned to be higher with 1.96 % and the proportion of the chest meat decreased with 2.18 percentage points. Biochemical blood tests indicate a lower biological value of the lupine proteins that those from soybean meal, highlighting the necessity of using synthetic amino acids to balance the lupine based diets.

Suchy et al. (2010) claim that the replacement of the soy protein with the one of the white lupine up to two-thirds rate has no impact on the protein and fat content of the chest muscles and haunch muscles, but an increment in the crude ash only at the chest level was noticed.

The lupine beans do not significantly influence the metabolism of proteins, but they show a positive influence on blood lipoprotein fractions (increase of HDL and decrease of LDL) (Mierlita and Popovici, 2013).

The outcomes achieved by Mierlita (2015) proved that the lupine flour, which contains high essential fatty acid values, has a favorable effect on the fatty acid composition of the intramuscular fat.

Lupine flour supplementation in pullets diets led to a decrement in the saturated fatty acids ratio with a high androgenic potential (C14:0, C16:0, C18:0) in chest intramuscular fat and also to an increment in the polyunsaturated fatty acids of n-3 ratio (mainly α-linolenic acid), which consequently drop down the ratio of n-3 / n-6 in chest/breast muscles, therefore enhancing the nutritional meat quality in poultry throughout its influence on human health.

The replacement of soybean proteins in broiler turkey throughout the input of white lupine beans free of alkaloids into the combined fodder composition, in a ratio up 30% (body weight %), has no negative impact on body weight gain , feed efficiency, slaughter and carcass quality index (Mierlita, 2014a, 2014b). A significant decline of the broiler turkey poults performances was noted, when the white lupine beans input reached a ratio of 40%, so the soybean meal proteins became substituted by lupine in a ratio of 78%, at the beginning of the growth period and completely after the age of 12 weeks. Compared to the control lot, the final body live weight of the turkey poults showed a lower value with 7.80%, also as the feed intake with 3.71%, meanwhile the feed conversion ratio was higher with 4.42%, and the proportion of chest in carcass structure showed a diminished value with 1.54 percentage points. The lupine beans in turkey poults resulted in a significant decrease in the saturated fatty acids (SFA) ratio and monounsaturated

(MUFA) of the fat content in chest muscles, along with an increase in the polyunsaturated fatty acids (PUFAs) ratio, and especially in those of the Omega 3 series, whose amount actually doubled. Among SFA, the most significant decrease was found in case of palmitic acid, whereas a significant increase was recorded for the linoleic acid (C18:2 n-6) and the α-linolenic (C18:3 n-3), in case of PUFA, that can be translated into a turkey meat enhanced nutritional value (Mierlita, 2014a, 2014b).

Referring to the studies carried out by Barneveld (1999), the input of white lupine in layer hens feeding may reach up values between 100 to 200 g/kg, without driving to bioproductive performances changes in poultry. The input of lupine beans in ratio of 15% into the laying hens feeding did influence neither eggs production, nor feeding efficiency (Hammershoj and Steenfeldt, 2005). Instead, a negative influence was pointed out related egg number production, egg size, feed intake and feeding efficiency (Watkins and Mirosh, 1987; Perez-Maldonado et al., 1999; Hammershoj nd Steenfeldt, 2005). Opposite to these results, Prinsloo et al. (1992) state that in hens feed intake rise up simultaneous with lupine ratio augmentation into the combined fodder composition. Laudadio et al. (2010) showed that shelled beans of white sweet lupine may completely replace soybean meals in laying hens feeding, along with a significant enhancement of egg number production (laying percentage) and a diminution of the average weight of eggs, but an increment of the of the combined fodder intake related to 1 kg of egg weight.

Other approaches showed that a lupine input of 250 g / kg combined fodder, without methionine supplementation, comes along with a significant decrease of egg laying percentage, egg weight, including feed intake and conversion.

The studies carried out by other researchers (Perez-Maldonado et al., 1999; Krawczyk et al., 2015) proved that blue lupine beans may be included into the laying hens feeding up to 300 g / kg, without interfering with egg production, feeding efficiency and physicochemical and sensory properties of the eggs for consumption.

The results achieved by Mierlita (2013), indicate that by substituing soybean meal protein with the lupine one in ratios of 40%, 60% si 80% in laying hens feeding and farming for egg production, no negative impact was registered related to egg production quantitative index, excepting the case when the soybean meal protein was replaced with the ones derived from white lupine beans in a ratio of 80% and the size of eggs significantly decreased ($p < 0.05$). The input of the wihte lupine flour into the laying hens feeding conclude to a negative impact on feed intake, the outcomes becoming more obvious when lupine replaced 80% of the proteins provided by the soybean meal proteins. The feed intake decrement in hens lots where the lupine flour was used, came along with a corresponding decrement in egg size, so that no changes in feed efficiency ocurred.

Lupine input along with an adequate decrease of soybean meal use in laying hens feeding shows a positive influence related to the feeding costs, which coclude in a net profit augumentation up to 36,11%, compared to the control lot (Mierlita, 2013).

The lupine beans showing high levels of limiting amino acids have a favorable impact on the fatty acid composition from the fat content in eggs intended for human consumption. Lupine flour supplementation in laying hens diets resulted in a decrement of the saturated acids ratio showing a high androgenic potential (C14:0, C16:0, C18:0) in egg yolk fat, but also in an augumentation of the polyunsaturated fatty acids 3 (mainly, α-linolenic acid), and therefore enhancing the nutritive value of the eggs intended for human consumption, in terms of the impact on human health.

CONCLUSIONS

The white lupine free of alkaloids may be a promising alternative in insuring the on-farm protein production for poultry feeding in our country. The use of lupine as the sole protein source in poultry farming is restricted on one hand to the protein biological value (modest methionine, lysine, tryptophan and threonine content), and on the other hand to the high NSP content (non-starch polysaccharides), interfering with the digestion processes and feed efficiency. Enhancing lupine efficiency in poultry feeding can be achieved throughout the use of specific enzyme preparations or beans shell, when they are able to replace up to 50% of the amount of the soy bean meals into the combined fodder composition, without changing their bioproductive performances.

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