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EVALUATION OF LUPINE, PEAS, AND CANOLA MEAL AS AN ALTERNATIVE PROTEIN SOURCE IN AQUACULTURE FEEDS

Mierliță Daniel[1], Boaru Anca[2], Ladoși Daniela[2*]

[1]University of Oradea, 26 Gen. Magheru St., 410048, Oradea, Romania;
[2]University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, 400372, Romania.
[*]*Corresponding author*: daniela.ladosi@usamvcluj.ro

Abstract

Fish meal, and soybean meal, are the most common sources of protein used in fish feed formulations around the world. These ingredients are widely use because of their high protein contents and well balanced amino acid profiles. The increase in the demand for traditional protein sources and thus the price makes it necessary for producers to find cheaper alternatives to ensure the cost efficient production while also not affecting performances. As a result, it has become necessary to evaluate alternative protein sources, which can fully or partially substitute conventional protein sources in in aquaculture feeds. Amongst the potential candidates, grain legumes such as white lupin (Lupinus albus, L), peas (Pisum sativum, L), and canola meal have the greatest potential for further evaluation in Romania. The is alternative source contain moderately high levels of protein and their amino acid profiles are generally comparable to that of soybean meal. However fish meal and plant protein sources are very different in the amount of proteins, structure of amino acids, energy availability and amount of mineral matter. The suitability of plant meals as dietary fishmeal substitutes in aquafeeds is highly dependent on the aquaculture species to be fed. Salmonids as highly carnivorous fish need a high-quality (e.g. well balanced and highly digestible) protein source for optimum health and growth performance. Among potential plant raw materials, white lupin, peas and canola meal with an elevated protein content to fish meal, has been described as a feasible ingredient for the partial replacement of fishmeal in salmonid feeds.

Key words: fish feed, vegetable proteins, health and growth performance.

INTRODUCTION

At present, aquaculture uses an important proportion of the world's fish meal and soybean meal offer (around 56% of the world's fish meal) because of their high protein contents and well balanced amino acid profiles (Nalle, 2009). The global availability of fish meal has reached static production levels and the price has increased considerably (Borquez et al., 2011). FAO data indicates the fact that 73% of the fish meal and 71% of the fish oil obtained worldwide is used in aquaculture production (FAO, 2014). The same source indicates that the effect of industrial fishing is the over exploitation of seas and oceans. This is revealed as well by the obvious decline in the fishmeal/oil production from about 30 mil. tonnes in the '90s to only 16 mil. tonnes in 2012.

Thus it gets factual that due to scarcity and increasing cost of the fish meal there is a clear need in finding new resources of protein - for total or partial substitution of the fish meal for further sustainability and development of aquaculture and animal farming.

The increase in the demand for traditional protein sources and thus the price makes it necessary for producers to find cheaper alternatives to ensure the cost efficient production while also not affecting performances. As a result, it has become necessary to evaluate alternative protein sources, which can fully or partially substitute conventional protein sources in in aquaculture feeds.

Amongst the potential candidates, grain legumes such as white lupin (*Lupinus albus*, L), peas (*Pisum sativum*, L), and canola meal have the greatest potential for further evaluation in Romania. The is alternative source contain moderately high levels of protein and their amino acid profiles are generally comparable to that of soybean meal.

The aim of many research works in aqua feeds is related to novel protein sources (Caruso, 2015) able to ensure digestibility, palatability while having a low fiber content or anti nutritional factors (Thiessen, 2001). All these would lead to maximizing growth and economic sustainability.

Producing feeds by replacing fish meal with vegetal proteins could be a cheaper and straight forward alternative (Ayadi et al., 2012). This is why so much aqua feed research efforts are channeled into this direction. However, usage of the vegetal protein in fish feeding – mainly in carnivorous ones – is impaired by their ability to use the starch, present in most of the harvested grains (Thiessen, 2001). Furthermore, the well known essential amino acid deficiencies (lysine, methionine and cystine) and the presence of carbohydrates decrease the efficiency of vegetal protein usage in aqua feeds (Francis et al., 2001; Stanković et al., 2011, Øverland et al., 2009). The partial or total substitution of the fish meal with vegetal proteins in aqua feeds has a further disadvantage: the presence of the so called anti-nutrients. These are substances interfering with nutrient usage, animal health and production performances (Caruso, 2015). Most of these are alkaloids decreasing palatability but oligosaccharides, phytate, saponin and protease inhibitors as well with negative impact on fish growth (Vikas et al., 2012). Antinutritional factors can be annihilated through several feed processing paths (Ayadi et al., 2012; Caruso, 2015). Thus, processing becomes essential for incorporating of plant protein sources into aqua feeds (Thiessen et al., 2003).

USE OF LUPIN MEAL IN AQUACULTURE DIETS

Lupinus is a large genus that has more than 200 species, only five species, however, are cultivated: *L. albus*, *L. angustifolius*, *L. luteus*, *L. mutabilis*, and *L. polyphilus*. Of the cultivated species, white lupine (*Lupinus albus* L.) is of the highest importance for animal nutrition, mainly due to high production potential but also to high protein and fat content (Erbas et al., 2005; Nalle, 2009, Andrzejewska et al., 2016; Rybinski et al., 2017).

Lupine has more favorable (even optimal) agronomic characteristics (requirements to pedoclimatic conditions) for cultivation in our country compared to soybeans. Lupine prefers moderately fertile land with medium organic matter content and good drainage. Excess of organic matter and water cause specific diseases that affect the root. During vegetation, by symbiosis of lupine plants with these nitrogen fixation bacteria, 160-200 kg of atmospheric nitrogen per hectare can be fixed in the soil, of which about 1/2 remain in the soil, thus contributing to the increase of soil fertility.

The climatic conditions of our country provide the premises for the production of white lupine grains correspondingly quantitative and qualitative (2900-3100 kg / ha: Mierlita, 2012).

Old varieties of white lupine, due to their high alkaloid content (2-4%), have limited use in animal feed, negatively affecting their bioproductive performance. In the last few years, productive lupine varieties with very low content of alkaloids (less than 0.02%) have been produced through breeding works, so that they can be used as the main source of protein even in the feed of monogastrics (Wasilewko and Buraczewska, 1999; Rutkowski et al., 2017).

The content of crude protein in white lupine grains of low alkaloid varieties varies between 32 and 41% (% of DM), depending on the variety and pedoclimatic conditions. Even in the same variety of lupine (Juno) the protein content varied between 39.8 and 48.2%, depending on the harvest year (Strakova et al., 2006).

Lupine, like many other legumes, has a low content of limiting amino acids (modest content in methionine, lysine, tryptophan and threonine - Strakova et al., 2006) compared to soybeans, which could limit its use in fish feed, resulting in the need to improve the biological value of the protein by adding synthetic amino acids to the compound feed structure.

Another restrictive factor in the use of lupine in fish feed is the high level in non-starch polysaccharides (Boch-Knudsen, 1997). The content of lupins in non-starch polyglucides (PNAs), considered as antinutrients, is almost twice as high as in other protein-rich feeds (Gdala and Buraczewska, 1996; Knudsen, 2014) (fig. 1). However, relatively recent research has shown that lupine proteins are digested as in the case of soybeans (Hughes and Kocher 1998; Hammershoj and Steenfeldt, 2005) or even better (Kaczmarek et al., 2014, 2015). The fat content of white lupine grains varies between 5.7 and 12.1%, mainly represented by oleic acid (C18: 1 n-9) and linoleic acid (C18: 2 n-6) (Andrzejewska et al , 2016; Rybinski et al., 2017). Lupine grains of fat, though less discussed, could have an important nutritional role in their influence on the fatty acid profile of fish meat.

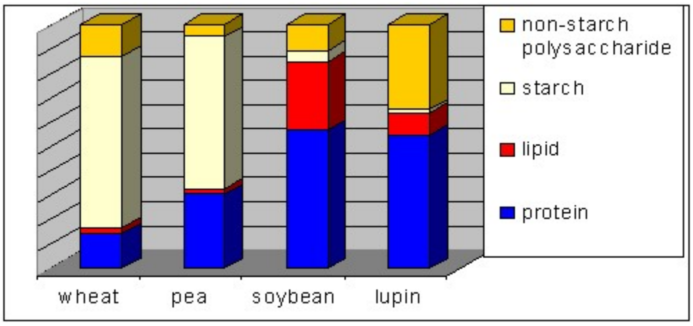

Fig. 1. Comparative whole grain content of the major nutrients (Nalle, 2009)

The energy value of lupine grains varies between 1920 and 3570 kcal EMAn / kg of DM depending on the variety, pedoclimatic conditions and alkaloid content (Brenes et al., 1993, Hughes et al., 1998; Kocher et al., 2000). Although lupine has a high fat content, it still has a low energy value due to its high content in PNAs (Kocker et al., 2000).

Compared to soybeans, lupine beans have a lower content of phytic acid and saponins but also in lectins and protease inhibitors, which improves protein digestion (Sujak et al., 2006). Alkaloids, the main disadvantage of lupine in the past, are no longer a problem nowadays because modern cultivars of lupine (also called sweet lupine) contain only traces of these toxins.

The suitability of plant meals as dietary fishmeal substitutes in aquafeeds is highly dependent on the aquaculture species to be fed (Glencross et al. 2003; Glencross 2007). Salmonids as highly carnivorous fish need a high-quality (e.g. well balanced and highly digestible) protein source for optimum health and growth performance. Among potential plant raw materials, white lupin, with an elevated protein content to fish meal, has been described as a feasible ingredient for the partial replacement of fishmeal in salmonid feeds (Glencross et al. 2004; Glencross 2005; Borquez et al., 2011).

The results obtained by Borquez et al., (2011) suggest that inclusion of whole lupin seed meal up to 20% in extruded diets for rainbow trout do not have any negative effect on growth, feed performance, or flesh quality.

Other studies on rainbow trout diets likewise reported that supplemented with lysine and methionine, lupine seed (*Lupinus albus*, L) at 44% inclusion level replaced fish meal, without detrimental effects on weight gain, protein efficiency or digestibility (Higuera et al., 1988). Burel et al., (1998) concluded that lupin seed (*Lupinus albus*, L) replacing >50 and 76% of the fish meal in diets for rainbow trout, without significant differences in growth performance. In diets for juvenile gilthead sea bream, lupin seed was included up to 30% without compromising weight gain, feed efficiency or protein (Robaina et al., 1995; Ranjan and Bavitha, 2015).

Lupine meal have great potential as a sustainable, locally produced replacement for fishmeal in diets for the rainbow trout with no negative effects on growth. Research done by Hoerterer et al., (2016) indicate that lupine can be successfully included at high levels the feed without negative effects on growth thereby replacing 75% of the fishmeal. A complete replacement of fishmeal by lupine led to a reduction of growth by half, which can be only partly explained by a lower feed intake. Dehulling of the lupine seeds seem to be sufficient to reduce anti-nutritive substances in lupine kernel meal (Hoerterer et al., 2016). Given the much lower cost of lupine kernel meal in comparison to fishmeal (ca. 30% of fishmeal cost by weight), significant economic savings can be made.

No histological changes were observed in the pyloric caeca or distal intestine of rainbow trout fed up to 50% yellow lupine kernel meal (of total diet), although hepatocytes appeared to have a lower level of lipid droplets in the fish fed the 50% inclusion level (Hoerterer et al., 2016).

Substitution of up to 25% of the soya protein concentrate by white lupin seed meal in diets for mirror carp did not have any significant negative effect on growth performance, feed utilization and carcass composition.

Smith (2002) conclude that when lupin was included up to 40% in P. monodon diets, weight gain was equal to and digestibility was higher than the diet using full fat soya as the primary protein source. Sudaryono et al., (1999) was found, that up to 75% protein of fish meal can be replaced with the protein of dehulled lupin seed meal in diets for juvenile P. monodon. The diet with total replacement of fish meal containing 40% lupin meal was utilized very poorly by the shrimp (Pereira et al., 2004).

The partial, but not total, replacement of soybean protein with lupin seed protein in juvenile tilapia diets (max. 67%) resulted in better, or at least equal, growth and feed performance. Dehulling further enhanced the growth and performance of lupin seed meal. Alkaloid removal improved feed performance but not the growth (Chien et al., 2003).

The lupin seed meal can replace up to 30% fish meal protein in diets for gilthead sea bream juveniles with no negative effects on growth performance. Furthermore, micronization of lupin seeds improves its dietary value for gilthead sea bream juveniles. At the same dietary lupin inclusion levels, diets including micronized lupin seeds promote significantly higher growth rates than raw lupin seeds (Pereira et al., 2004).

As lupin meals are included in aquaculture diets primarily as a protein source, however the essential fatty acids EPA (C20:5 n-3) and DHA (C22:6 n-3) are deficient. This means that formulated diets based on lupin meal usually have to be supplemented with some fish oil or fish meal which is critical in supplying the fatty acids EPA and DHA essentially required for freshwater species.

Compared to soy, the use of lupine in fish nutrition has a number of advantages (Ranjan and Bavitha, 2015): a cheaper protein source; increased digestibility of proteins; increasing the hardness and durability of the granules; high phosphate retention; do not produce enteritis in salmon compared to soy; proteins are not damaged by heat processing as in the case of soybeans, where the heat treatment is required to destroy antinutritive factors (trypsin inhibitors).

USE OF PEAS MEAL IN AQUACULTURE DIETS

Peas (Pisum sativum) represent one of the grains with high potential to be used as protein source in farm animals.

Chaemical composition of peas reveals a 22-25% crude protein level, 1-1,5% in crude fat, 4-7% crude fiber (Thiessen, 2001; Welsh, 2002). The relative low level of crude protein is the limiting factor of using peas in fish feeding, mainly in carnivorous species which do have high protein requirements (Oprea, 2000). Furthermore, starch – which is not necessarily an anti-nutritional factor – content of 50% in peas, has undesired effects on digestibility and lower usage efficiency of nutrients in carnivorous fish species (VKM, 2009). The peas proteins is a deficit of methionine and cystine. However, peas is well recognized as being a rich source of lysine (Cerioli et al., 1998; Thiessen, 2001). Peas also contain someanti nutritional factors such as: phytic acid, tannins, oligosaccharides, trypsin and chymotripsin inhibitors, lectinsand antigenic proteins (Thiessen, 2001; Thiessen et al., 2003; VKM, 2009).

Although peas has a low crude protein level and some anti nutritional factors it has proven to have high potential as a fish feed ingredient (Aslaksen et al., 2007; VKM, 2009; Øverland et al., 2009).

Replacing fish meal – at different ratios – with peas products was already tested in a wide variety of species: rainbow trout, Atlantic salmon, turbot, silver perch, European seabass and Nile tilapia (Carter and Hauler, 2000; Davis et al., 2002; Drew M.D., 2009; USA Dry Pea&Lentil Council, 2002; Thiessen et al., 2003; Welsh, 2002). This experiments indicates that growth performance, feed conversion and meat composition have not been influenced in a negative way where fish meal was replaced in proportion with 20-40% peas meal.

By processing peas meal a higher nutritional value is achieved (Bautista-Teruel, 2003) while increasing protein content (Øverland et al., 2009). The peas protein concentrate has the great advantage by its increasedprotein content up to 60% and starch decreased content. Moreover, in the protein isolate the protein content increases with 90% while the starch and anti-nutritional levels are negligible by comparison to unprocessed peas.

USE OF CANOLA MEAL IN AQUACULTURE DIETS

Canola is a traditional variety of rapeseed containing lower values of erucic acid and glucosinolates (Ayadi et al., 2012). Canola meal can be a valuable protein resource in animal nutrition (Enami, 2011; VKM, 2009).

With a crude protein content of 33-43%, depending on harvesting conditions, canola is one of the most utilized vegetal protein resource. The fact that canola protein has low lysine content is balanced by its high levels of methionine and cystine (Enami, 2011).

Canola has several anti-nutritional factors like:proteinase inhibitors, , phytic acid, tannins (VKM, 2009; Vikas et al., 2012). These factors are limiting usage of canola meal in aqua feeds to percentages which were set through experiments on different fish species and age groups.

Canola meal is a great proteine resource and it has been used for more than 20 years in feeding trout and salmon (Thiessen et al., 2003). However, studies revealed that this meal can be used as nutrient only after the fingerling period. In rainbow trout feeds added with canola meal did not had any detrimental effects on weight gain and feed conversion values, while feed cost was decreased. Furthermore, canola feed was found to be valuable in feed production for other aquatic species such as carp, perch, sea bream, turbot and shrimp (Hardy and Sullivan, 1983; Enami, 2011). Substituting fish meal with canola meal at levels of 25-50% was positive as well for species as such Oreochromis mossambicus and Pagrusauratus without any negative effects on growth rate and feed conversion performance (Bilgüven and Bariş, 2011).

CONCLUSIONS

Problems with fish meal in the world market led many manufacturers of fish feed to look for alternative sources of protein. This paper gives an overview of some alternative sources with their benefits and disadvantages.

Plant protein sources (lupine, peas and canola) are very different in the amount of proteins, structure of amino acids, energy availability and amount of mineral matter. The suitability of plant meals as dietary fishmeal substitutes in aquafeeds is highly dependent on the aquaculture species to be fed. Salmonids as highly carnivorous fish need a high-quality protein source for optimum health and growth performance. Plant raw materials is ingredient for the partial replacement of fishmeal in salmonid feeds; inclusion up to 20% in diets for rainbow trout do not have any negative effect on growth, feed performance, or flesh quality.

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